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Benefits Analysis for the Final Section 316(b) Existing Facilities Rule

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1 Introduction

EPA is issuing the final rule implementing section 316(b) of the Clean Water Act (CWA) to address the environmental impacts of cooling water intake structures (CWIS). The withdrawal of cooling water from streams, rivers, estuaries and coastal marine waters by CWIS causes adverse environmental impacts (AEI) to aquatic biota and communities in these waterbodies. These impacts are caused through several means, including impingement mortality (where fish and other aquatic life are trapped on equipment at the entrance to the CWIS and entrainment (where aquatic organisms, including eggs and larvae, are pulled into the cooling system, passed through the heat exchanger, then discharged back into the source body). Additional adverse effects are often associated with CWIS operation, including nonlethal effects of impingement, thermal discharges, chemical effluents, flow modifications caused by these facilities, and other impacts of variable and unknown magnitudes.

The final rule would establish national performance requirements for the location, design, construction, and capacity of CWIS. It is designed to minimize the AEI caused by CWIS through reduction of volume, frequency, and/or seasonality of water withdrawals. The final rule will significantly reduce impingement mortality and entrainment (IM&E), as well as reduce the magnitude of other impacts (i.e., thermal, chemical, and flow alteration) on aquatic ecosystems. Thus, changes in CWIS design or operation resulting from the final rule are likely to result in enhanced ecosystem function and increased ecological services provided by affected waterbodies.

The two broad categories of regulated facilities include: (1) electric generators and (2) manufacturers. These facilities include existing electric generators and manufacturers with a design intake flow (DIF) of at least 2 million gallons per day (mgd) that use at least 25 percent of the water (measured on an average annual basis for each calendar year) exclusively for cooling purposes.

EPA is required to conduct a benefit-cost analysis under Executive Orders 12866 and 13563 for economically significant rules. This report presents the methods EPA used for the environmental assessment and benefits analysis of the regulatory options. EPA had three main objectives: (1) to develop a national estimate of the baseline magnitude of IM&E at regulated facilities; (2) to estimate changes in IM&E of fish and invertebrates as a result of the rule; and (3) to estimate the national economic benefits of reduced IM&E.

This report describes the regulatory options that EPA considered, and identifies the types of economic benefits that are likely to be generated by improved ecosystem functioning under different regulatory options. The report also presents the basic concepts involved in analyzing these economic benefits—including benefit categories and benefit taxonomies associated with market and nonmarket goods and changes in ecological services likely to result from reduced IM&E. Specific chapters of the report detail the methods used to estimate values for reductions in IM&E. The organization of this analysis is described in Section 1.3.

The analysis conducted in support of the final rule and discussed in this report is based on data generated or obtained in accordance with EPA's Quality Policy and Information Quality Guidelines. EPA's quality assurance (QA) and quality control (QC) activities for this rulemaking include the development, approval and implementation of Quality Assurance Project Plans for the use of environmental data generated or collected from all sampling and analyses, existing databases and literature searches, and for the development of any models which used environmental data. Unless otherwise stated within this document, the data used and associated data analyses were evaluated as described in these quality assurance documents to ensure they are of known and documented quality, meet EPA's requirements for objectivity, integrity and utility, and are appropriate for the intended use.

1.1 Summary of the Final Rule and Other Options Considered

EPA considered regulatory options for existing units and new units at existing facilities. The options apply only to existing facilities with a DIF for cooling water of 2 mgd or greater. EPA considered three options for the existing units based on two technologies:

- **Proposal Option 4: IM for Facilities > 50 mgd.** Establish impingement mortality controls at all existing facilities that withdraw over 50 mgd; determine entrainment controls for facilities greater than 2 mgd DIF on a site-specific basis.
- **Final Rule – Existing Units: IM Everywhere.** Establish impingement mortality controls at all existing facilities that withdraw over 2 mgd; determine entrainment controls for facilities greater than 2 mgd DIF on a site-specific basis.
- **Proposal Option 2: IM Everywhere and E for Facilities > 125 mgd.** Establish impingement mortality controls at all existing facilities that withdraw over 2 mgd DIF; require flow reduction commensurate with closed-cycle recirculating systems for entrainment control by facilities greater than 125 mgd DIF.

Proposal Options 4 and Proposal Option 2 above correspond to Options 4 and 2 from EPA's analysis for the proposed rule (USEPA 2011) with some modifications. The final rule is Option 1 from the proposed rule with the same modifications. The final rule will establish entrainment controls for facility greater than 2 mgd DIF on a site-specific basis, as would Proposal Option 4. Findings presented in this document assume that facilities with impoundments will qualify as having closed-cycle recirculating systems in the baseline. As a result, EPA estimated zero IM&E reductions for these facilities under the final rule and other options considered; however, these facilities remain subject to today's rule and are assigned administrative costs. To the extent that some of these facilities do not qualify as having closed-cycle recirculating systems in the baseline, the monetized benefits reported in this document may be underestimates.[1]

EPA considered four regulatory options for new units at existing facilities. Stand-alone new units are newly built units adjacent to existing units and repowered units are existing units that have been wholly or partially demolished and rebuilt or upgraded on the same site.

- **Option A:** Entrainment performance requirements for all standalone new units and all types of repowered units.
- **Option B:** Entrainment performance requirements for all stand-alone new units, and replaced or repowered units in which turbine or condenser are newly built or replaced.
- **Option C:** Entrainment performance requirements for all stand-alone new units, and repowered new units where the turbine and condenser are newly built or replaced, but excluding high efficiency systems.
- **Final Rule – Option D:** Entrainment performance requirements for all stand-alone new units only.

[1] EPA notes that the vast majority of these facilities occur in the Inland benefits region. Any underestimation in monetized benefits due to the treatment of facilities with impoundments is likely to be minor because commercial fishing benefits and nonuse benefits are not estimated for the Inland region.

Refer to Section VI of the preamble for a more complete description of the final rule and other options considered for existing and new units.

This report presents EPA's analysis of environmental and economic benefits for the final rule and the other options considered described above. EPA also presents monetized values for baseline IM&E losses at existing facilities. The associated benefits estimates equivalent to benefits if all baseline IM&E losses were to be eliminated. EPA emphasizes that this not a regulatory option and that it presents baseline values for illustration purposes only.

EPA discounted and annualized benefits for the final rule and other options considered following three steps. First, EPA developed a time profile of benefits to show when benefits occur. Second, the Agency calculated the total discounted present value of the benefits as of the year 2013. Finally, EPA annualized the benefits of the final rule and other options considered, over a 51-year time span. Refer to Appendix D for additional detail regarding discounting and annualization.

1.2 Study Design

EPA's analysis of the regulatory options examined CWIS impacts and regulatory benefits in seven study regions. EPA defined the study regions on the basis of ecological similarities within regions (e.g., freshwater versus marine, similar communities of aquatic species), and on characteristics of commercial and recreational fishing activities. The seven study regions are: California[2], North Atlantic, Mid Atlantic, South Atlantic, Gulf of Mexico, Great Lakes, and Inland. The Great Lakes region includes all facilities located on the Great Lakes, the Inland region includes all other freshwater facilities, and the remaining five regions include coastal and estuarine facilities. Sections 1.2.1, 1.2.2, and 1.2.3 provide additional detail regarding the definition of each region. National estimates are the sum of regional estimates. Table 1-1 presents the number of regulated facilities that participated in the Section 316(b) Industry Surveys and their total actual intake flow by study region. EPA excluded facilities that it classifies as baseline closures from all totals and figures presented throughout this document, including Table 1-1. Baselines closures are also excluded from all totals and figures presented throughout this document. EPA classifies an electric generating facility as a baseline closure if it has retired all steam operations since the 316(b) survey was conducted or if EPA expects that it will retire its steam capacity by 2021, according the 2011 EIA-860 Database published by the Energy Information Administration (EIA) and U.S. Department of Energy (DOE). For manufacturers, baseline closures are facilities showing materially inadequate financial performance in the baseline. Refer to Appendix H of the Economic Analysis (EA) for additional detail regarding baseline closures.

The facility universe includes facilities that are subject to state regulations for CWIS in California and New York. The California state regulation requires closed-cycle recirculating systems for coastal electric generating facilities while the New York state regulation requires closed-cycle recirculating systems for all in-state facilities with DIF greater than or equal to 20 mgd. Fourteen surveyed facilities fall within the scope of the California state regulation and 32 surveyed facilities fall within the scope of the New York state regulation.[3] EPA determined that the state regulations are at least as stringent as the final rule and other options considered. Facilities within the scope of the state regulations would be subject to the requirements of the final rule, but they may not be required to install additional technologies to reduce IM&E under the final rule. Within the benefits analysis for the 316(b) rule, EPA assigns these facilities baseline levels of IM&E that are commensurate with compliance with the state regulations. These

2 Includes four regulated facilities in Hawaii.

3 These counts exclude 6 California facilities and 5 New York facilities which EPA classifies as baseline closures.

facilities do not influence the occurrence and magnitude of benefits under the final rule, similar to other facilities which already meet the requirements of the final rule.

EPA has determined that 280 surveyed facilities currently satisfy the IM performance standard established by the final rule or use one of several compliant technologies to achieve this goal, including all facilities that are subject to the California and New York state regulations described above. Although these 280 facilities are subject to the requirements of the final rule, they may not be required to install technologies in order to comply with the final rule. Thus, these facilities have not been factored into the benefits analysis for the final rule.

Table 1-1: Number of Facilities and Total Mean Operational Flow, by Region[a,b]

Region	Number of Surveyed Facilities	Flow (billions of gallons per day)		
		Non-Recirculating Facilities[c]	Recirculating Facilities	Total Flow
California[d]	21	10.65	0.00	10.65
Great Lakes	50	16.24	0.24	16.47
Inland[e]	566	107.56	18.06	125.62
Mid-Atlantic	46	24.69	0.07	24.76
Gulf of Mexico	22	10.14	0.05	10.18
North Atlantic	21	5.93	0.00	5.93
South Atlantic	12	5.91	0.05	5.96
All Regions	738	181.12	18.46	199.58

[a] This table presents counts of unweighted facility counts and flow for surveyed facilities (excluding baseline closures). The regional study design for the benefits analysis weights based on flow rather than facility counts. EPA did not developed weighted facility counts by benefits region. The "All Regions" total of 738 surveyed facilities includes 532 electric generating facilities and 206 manufacturing facilities, excluding baseline closures. The total (weighted) estimated universe of facilities, excluding baseline closures, is 1,065 facilities.
[b] The facility counts and flow presented in this table include facilities which are subject to state regulations for CWIS in California and New York. Within the benefits analysis for the 316(b) rule, EPA assigns these facilities baseline levels of IM&E that are commensurate with compliance with the state regulations.
[c] Recirculating facilities are facilities with closed-cycle recirculating systems or impoundments that qualify as closed-cycle recirculating systems. Non-recirculating facilities includes facilities with CWIS classified as once-through.
[d] The California region includes four facilities in Hawaii. There are no coastal facilities in Oregon and one costal facility in Washington is classified as a baseline closure.
[e] A facility in Texas has intakes located in both the Inland and Gulf of Mexico regions. It is included within the Inland region within in the table to prevent the double counting of facilities.
Source: U.S. EPA analysis for this report.

1.2.1 Coastal Regions

The five coastal regions (California, North Atlantic, Mid-Atlantic, South Atlantic, and Gulf of Mexico) correspond to regions defined by the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS). These regions include facilities that withdraw cooling water from estuaries, tidal rivers and ocean facilities within the NMFS regions.

Coastal regions are defined as follows. The California region includes all coastal, estuarine or tidal facilities in the state of California, plus four facilities in Hawaii. The North Atlantic region encompasses coastal, estuarine, or tidal facilities in Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut. The Mid-Atlantic region includes all coastal, estuarine or tidal facilities in New York, New Jersey, Pennsylvania, Delaware, Maryland, the District of Columbia, and Virginia. The South Atlantic region includes all coastal, estuarine or tidal facilities in North Carolina, South Carolina, Georgia, and the east coast of Florida. Finally, the Gulf of Mexico region includes coastal, estuarine or tidal facilities in Texas, Louisiana, Mississippi, Alabama, and the west coast of Florida. Coastal regions include a total of 123 facilities.

1.2.2 Great Lakes Region

The Great Lakes region is defined in accordance with the CWA to include facilities withdrawing cooling water from Lake Superior, Lake Michigan, Lake Huron (including Lake St. Clair), Lake Erie and Lake Ontario, and the connecting channels (Saint Mary's River, Saint Clair River, Detroit River, Niagara River, and Saint Lawrence River to the Canadian border) (Great Lakes 1990). The Great Lakes region is comprised of 50 facilities.

1.2.3 Inland Region

The Inland region includes all regulated facilities that withdraw water from all inland waterbodies such as freshwater streams and rivers, lakes, reservoirs (excluding those included within the Great Lakes Region) regardless of geographical location. There are 566 such facilities in 39 states (including states with both coastal and inland facilities).

1.3 Organization of the Document

Chapter 2 provides information on the baseline conditions of the water bodies affected by regulated facilities. To obtain regional IM&E estimates, EPA extrapolated loss rates from facilities for which IM&E data are available (hereafter, model facilities), to all regulated facilities within the same region. EPA's extrapolation methods for, and results from, regional IM&E models are described in Chapter 3.

EPA provides an overview of all benefits (Chapter 4) and investigates several benefit categories in detail, including: benefits from improved protection of threatened and endangered (T&E) species (Chapter 5), commercial fishing benefits (Chapter 6), recreational fishing benefits (Chapter 7), and nonuse benefit transfer (Chapter 8). Chapter 9 presents benefits estimates based on the social cost of carbon. Chapter 10 summarizes benefits for existing units estimated using the methodologies described in Chapters 5 through 9. EPA also used the preliminary results of a its 316(b) stated preference study to illustrate potential willingness to pay (WTP) for aquatic ecosystem improvements (Chapter 11). Chapter 12 presents benefit estimates for new units at existing facilities based on benefits methodologies described in Chapter 5 through 9. Chapter 13 summarizes total national benefits for existing and new units at regulated facilities.

Additional details regarding EPA's benefits analysis are presented in Appendix A through Appendix I. Appendix A presents the extrapolation methods used by EPA to analyze the benefits from reducing IM&E at regulated facilities; Appendix B describes potential ecological effects due to thermal discharges; Appendix C presents detailed output from IM&E models; Appendix D discusses economic discounting and the expected timing of benefits; Appendix E presents a list of T&E species likely impacted by IM&E; Appendix F provides details on the methodologies used to estimate the effects of IM&E on T&E species, and the benefits from the section 316(b) rule; Appendix G presents EPA's analysis of the potential for IM&E reductions to impact the market price of commercially fished species; Appendix H presents details of the benefits of IM&E on commercial fishing by region; and Appendix I presents detailed regional results of the effects of IM&E on recreational fishing benefits.

2 Baseline Impacts

2.1 Introduction

This chapter provides a brief summary of adverse environmental impacts from the IM&E of fish and invertebrates in CWIS used by electric power and manufacturing facilities subject to the final rule under section 316(b) of the CWA.

CWIS impacts do not occur in isolation from other ongoing physical, chemical, and biological stressors on aquatic habitats and biota in the receiving waterbody. Additional anthropogenic stressors may include, but are not limited to: degraded water and sediment quality, low dissolved oxygen (DO), eutrophication, fishing pressure, channel or shoreline (habitat) modification, hydrologic regime changes, and invasive species. For example, many aquatic organisms subject to the effects of cooling water withdrawals reside in impaired (i.e., CWA 303(d) listed) waterbodies. Accordingly, they are potentially more vulnerable to cumulative impacts from other anthropogenic stressors (USEPA 2006a). The effect of these anthropogenic stressors on local biota may contribute to or compound the local impact of IM&E, depending on the influence of location-specific factors. In addition to multiple stressors acting on biota near a single CWIS, multiple facilities and CWIS located in close proximity along the same waterbody may have additive or cumulative effects on aquatic communities (USEPA 2006a).

Although it is difficult to measure, an aquatic population's compensatory ability—the capacity for a species to increase survival, growth, or reproduction rates in response to decreased population —is likely compromised by IM&E and the cumulative impact of other stressors in the environment over extended periods of time (USEPA 2006a). These cumulative impacts may lead to subtle, less-easily observed changes in aquatic communities and ecosystem function. These secondary impacts are difficult to isolate from background variability, partly because of the limited scope and inherent limitations of the data available to characterize IM&E.

Since the aquatic habitat quality and health of the biotic community are shaped by the cumulative effect of many factors, it is important to characterize the environmental context of baseline impacts. This will permit comparisons between the relative influences of CWIS-related stressors and other factors, and result in a more accurate estimate of the environmental impact of the final rule.

This chapter provides a qualitative description of baseline IM&E impacts and anthropogenic stressors found in aquatic environments affected by CWIS.

2.2 Major Anthropogenic Stressors in Aquatic Ecosystems

All ecosystems and biota are subject to natural variability in environmental conditions (e.g., seasonal perturbations), as well as periodic large-scale disturbances in environmental settings (e.g., drought, flood, fire, disease). Indigenous aquatic species and communities are adapted to this natural variability, such that large-scale events elicit a predictable loss, response and recovery cycle. Conversely, anthropogenic stressors tend to be more chronic in nature and often do not lead to recognizable recovery phases. Instead these stressors often lead to long-term environmental degradation associated with lowered biodiversity, reduced primary and secondary production, and a lowered capacity or resiliency of the ecosystem to recover to its original state in response to natural perturbations (Rapport and Whitford 1999).

Anthropogenic stressors are present to some degree in all major waterbodies of the United States, and are the result of many different impacts (Table 2-1). Four of the more important stressors include: (i) habitat loss; (ii) degraded water quality and sediment contamination; (iii) extractive uses of aquatic resources; and (iv) invasion by non-indigenous species (Rapport and Whitford 1999). CWIS-related impacts are listed here as a separate, fifth category of anthropogenic stress, one with many apparent similarities to overharvesting. Other large-scale stressors, such as change in watershed land use and engineering diversions, may be present. Thus, the true impact of CWIS on an aquatic community may be partly masked, or difficult to detect, due to the influence of other stressors on the receiving water.

The remainder of this section summarizes effects of these four anthropogenic stressors on the waterbodies affected by regulated facilities. CWIS impacts on the aquatic ecosystems are summarized in Section 2.3.

Table 2-1: Anthropogenic Stressors Impacting Aquatic Ecosystems Potentially Affected, Both Directly and Indirectly, by the Final Rule and Options Considered

Anthropogenic Stressor	Impacted by the Rule			Scale of Stressor
	Proposal Option 4	Final Rule	Proposal Option 2	
CWIS	Yes: Direct	Yes: Direct	Yes: Direct	Local/Regional/National
Habitat loss				
Development	No	No	No	Local
Eutrophication	Yes: Indirect	Yes: Indirect	Yes: Indirect	Local/Regional
Climate change	No	No	No	Regional/National/Global
Engineering diversions				
Re-routing	No	No	No	Local/Regional
Flow adjustments/removals/ modifications	No	No	Yes: Direct	Local/Regional
Water impoundments/damming	No	No	No	Local/Regional
Water quality				
Eutrophication	Yes: Indirect	Yes: Indirect	Yes: Indirect	Local/Regional
Loss of riparian buffer zones	No	No	No	Local/Regional
Sedimentation	No	No	Yes: Direct	Local/Regional
Chemical pollution (organics, heavy metals, etc.)	No	No	Yes: Direct	Local/Regional
Non-native / invasive species	Yes: Indirect	Yes: Indirect	Yes: Indirect	Local/Regional
Extractive uses (e.g. fishing)	Yes: Indirect	Yes: Indirect	Yes: Indirect	Local/Regional

Source: U.S. EPA analysis for this report

2.2.1 Habitat Loss

Structural aquatic habitat is generally recognized as the most significant determinant of the nature and composition of aquatic communities. Human occupation and restructuring of shorelines; construction and maintenance of harbors; installation of dams, canals, and other navigational infrastructure; draining of wetlands for agriculture and residential uses; and degradation of critical fish habitats have all taken a heavy toll on the numbers and composition of local fish and shellfisheries. Most regulated facilities have been built on shoreline locations where power-generation buildings, roadways, CWIS, canals, impoundments, and other water storage or conveyance structures have often been constructed at the cost of natural habitat, including terrestrial, aquatic, and wetlands.

The loss of coastal and estuarine wetlands that serve as important fishery spawning and nursery areas is particularly severe, with an estimated historical loss of 100 million acres of wetlands since the late 1700s (Bromberg and Bertness 2005; USEPA 2010c). Critical fishery habitat loss is not restricted to nearshore environments. Decades of fishing activities have degraded offshore bottom habitats (Auster and Langton 1999; Turner et al. 1999).

The main impact of aquatic habitat loss is a reduction in the number of fish in the environment, a reduction in fish spawning and nursery areas, shifts in species dominance based on available habitat, and local extirpation of historical fish species. Habitat loss in adjacent shoreline areas exacerbates the effect of CWIS losses, since many fish species affected by IM&E (e.g., bay anchovy, winter flounder) rely on coastal wetlands as nursery areas.

In riverine environments, the effects of channelization and navigation can also lead to habitat loss. For example, Tondreau et al. (1982) conducted a 10-year study of the aquatic ecosystem of the Missouri River near the Neal Generating facility in Sioux City, IA. The investigators found that the combined effects of channelization, heavy barge traffic, and high river flow rates had resulted in a significant loss of fish habitat. As a result, reported IM&E is relatively minor, because local fish populations were already greatly diminished.

2.2.2 Water Quality

Water quality is a major stressor of aquatic biota and habitats. Degraded surface water and sediment contaminants reflect current and historical industrial, agricultural and residential land use as well as discharges from wastewater treatment facilities. Poor water quality can limit the numbers, composition, and distribution of fish and invertebrates; reduce spawning effort and growth rates; select for pollution-tolerant species; cause periodic fish kills; or result in adverse effects to piscivorous wildlife.

CWA section 303(d) listings inventory, on a state-by-state basis, the locations of impaired waters not meeting designated uses and the known or suspected source(s) of impairment. Figure 2-1 identifies regulated facilities, those within two miles of a 303(d)-listed waterbody, and those impaired for temperature, using a database of 303(d) waterbodies assembled in October, 2010. The map clearly shows that facilities along the coasts, Great Lakes, and major waterways such as the Mississippi, Missouri, and Ohio rivers are located in the vicinity of impaired waterbodies.

EPA's analysis of regulated facilities demonstrated that the majority of facilities (74 percent) are within two miles of a 303(d)-listed waterbody. Table 2-2 summarizes the number of regulated facilities on waterbodies impaired by any cause, by region. These include impairment due to chemical, physical, and biological factors, categorized into biological stressors, nutrients, organic enrichment/loading, bioaccumulation, toxics, unknown causes, and general water quality impairment.

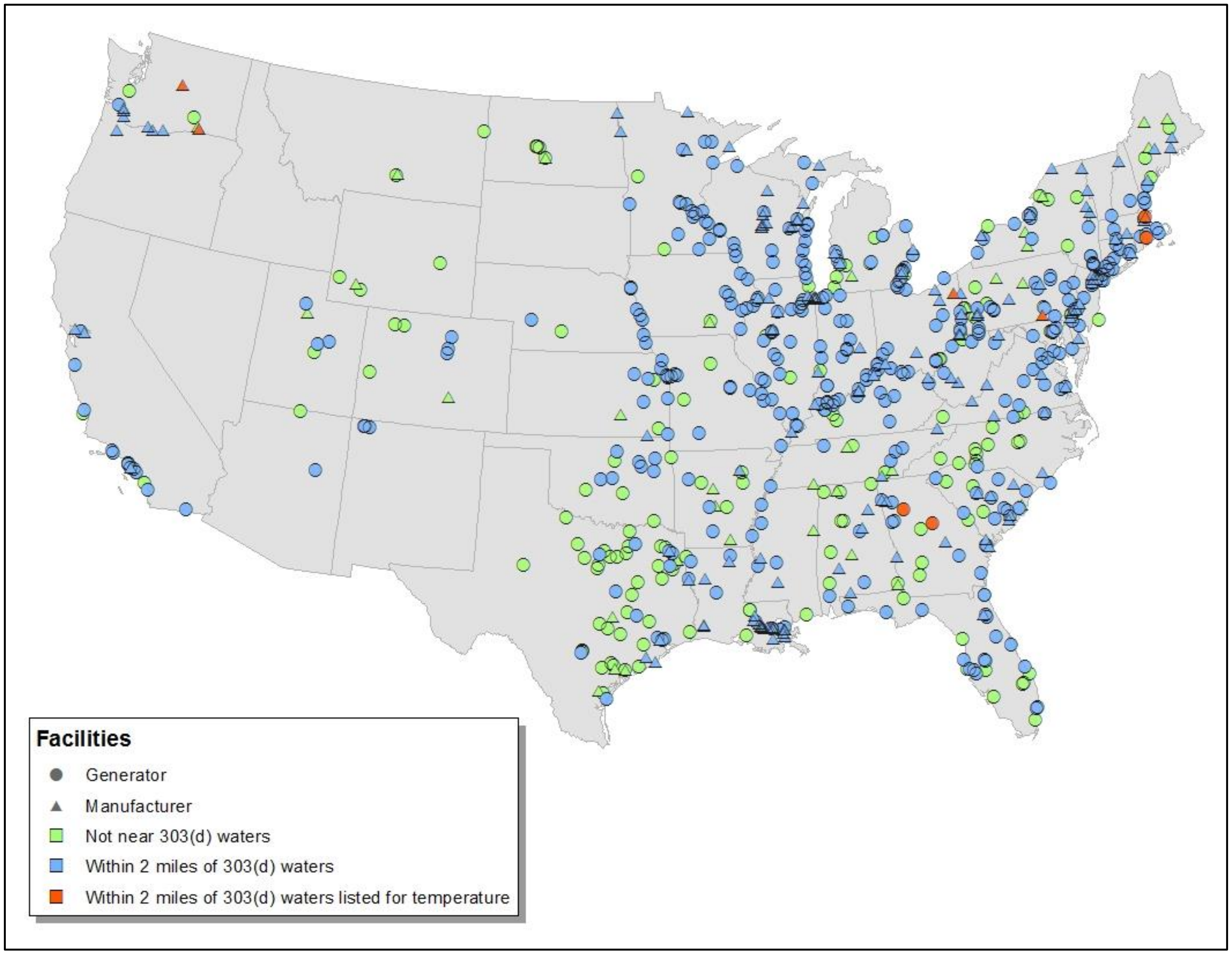

Figure 2-1: Map of Facilities Located on 303(d) Waters and Those 303(d) Waters Listed for Temperature in 2010

The most common causes of impairment for waterbodies serving as 316(b) source waters are polychlorinated biphenyls (PCBs), pathogens, mercury, as well as organic enrichment/oxygen depletion and nutrients. The entire universe of all 303(d) water quality impairment causes is much too diverse to cover fully in this section. However, below is a discussion of some of the more common and important physico-chemical impairments in aquatic environment where regulated facilities draw cooling water from, and discharge to, 303(d) listed waters.

- An oversupply of nutrients can result in excessive algal production, reduced light clarity, more frequent outbreaks of harmful algal blooms (HABs), high internal loads of biochemical oxygen demand (BOD), and spatial and temporally variable DO levels. In addition, eutrophication can reduce or eliminate habitat-formers such as coral reefs and submerged aquatic vegetation (SAV), and create other adverse ecological effects. Thermal discharges from regulated facilities can increase receiving water temperature, which may favor formation of blue-green algal blooms.
- Low levels of dissolved oxygen (hypoxia) may be present in many estuaries and coastal waters (IWG 2010), in the hypolimnia of eutrophic lakes, and in areas of high organic loading (e.g., below wastewater treatment plant outfalls). DO concentrations may be further decreased in or downstream of thermal plumes arising from cooling water return discharges from regulated facilities. Low DO can limit the distribution of fish and macroinvertebrates, reduce growth rates, and alter nutrient and carbon recycling.
- Persistent, bioaccumulative and toxic substances (PBTs) such as mercury or PCBs may be present in waterbodies near regulated facilities, due to atmospheric deposition of local air emissions or from historical uses of PCBs in electrical transformer units, in addition to other urban or industrial sources. These PBTs can impair water uses by regulatory restrictions or advisories regarding acceptable ingestion of fish consumption (see below), as well as affecting higher trophic level predators in the food chain.
- Toxic pollutants, such as metals, polycyclic aromatic hydrocarbons (PAHs), pesticides, biofouling chemicals, or chlorine may be present in the discharge of regulated facilities. This could lead to local extirpation of sensitive species, or to greatly altered biological communities due to chronic impacts on viability, growth, reproduction, and resistance to other stressors.

In addition to the 303(d) listings, many of the waterbodies in which the CWIS are located are subject to fish advisories. Fish advisories are issued by States to protect their citizens from the risk of eating contaminated fish or wildlife (USEPA 2009a). Fish advisories are recommendations and do not carry regulatory authority, but they indicate the presence of bioaccumulative chemicals which may pose risk for humans and piscivorous wildlife, and which may also interfere with the reproduction and survival of taxa in lower trophic levels.[4]

[4] Although fish advisories do not themselves carry regulatory authority, waterbodies may be included on 303(d) lists because of persistent fish advisories resulting from the bioaccumulation of specified and unspecified toxics.

Table 2-2: Number of Regulated Facilities on 303(d)-listed Waterbodies, by Impairment and Region[a]

Impairment	California	Great Lakes	Inland	Mid-Atlantic	Gulf of Mexico	North Atlantic	South Atlantic	Total
Regulated Facilities	21	50	566	46	22	21	12	738
Biological Stressors								
Noxious Aquatic Plants			1					1
Nuisance Exotic Species	3	3						6
Pathogens	6	9	85	5	1	9	4	119
Nutrients								
Algal Growth			1					1
Nutrients		9	37	3	1	2	6	58
Organic Enrichment / Loading								
Organic Enrichment, Oxygen Depletion	2	6	43	1	5	3	6	66
Sediment	2	3	15	2				22
Persistent, Bioaccumulative, Toxic (PBTs)								
Dioxins	2	13	12			2		29
Fish Consumption Advisory, Pollutant Unspecified	3		7				1	11
Mercury	3	24	85		3	2	2	119
PCBs	9	45	122	10		2	1	189
Pesticides	10	11	15					36
Physical Alterations								
Flow Alteration			4					4
Habitat Alteration		1	7					8
Temperature			6			3		9
Turbidity			21		1		2	24
Toxics								
Ammonia	1					1		2
Chlorine			1					1
Metals (Other Than Mercury)	5	4	37	6		1		53
Total Toxicity	7		4	2		1		14
Toxic Inorganics			1			1		2
Toxic Organics		3	8			2		13
Unknown / Other Causes								
Cause Unknown			8					8
Cause Unknown - Fish Kills			1					1
Cause Unknown - Impaired Biota	2	2	12	2				18
Other Cause	3		1					4
Water Quality Use Impairments (General)								
Oil And Grease			4			3		7
pH		3	7					10
Salinity, TDS, Sulfates, Chlorides	1	1	6					8
Taste, Color And Odor			3			1		4
All Impairment Categories								
One or More Impairments	18	46	398	38	12	20	11	543

[a] Waterbodies may be listed for multiple impairments and facilities may be counted in more than one row.

Source: U.S. EPA analysis for this report

EPA's 2008 National Listing of Fish Advisories (NLFA) database indicates that 97 percent of the advisories are due (in order of importance) to: mercury, PCBs, chlordane, dioxins, and DDT (USEPA 2009a). Fish advisories have been issued for 39 percent of the total river miles (approximately 1.4 million river miles) and 100 percent of the Great Lakes and connecting waterways (USEPA 2009a). Fish advisories have been steadily increasing over the NLFA period of record (1993-2008), but these increases are interpreted to reflect the increase in the number of waterbodies being monitored by States and advances in analytical methods rather than increasing levels of these problematic chemicals.

The water quality impacts arising from the combination of operations and/or discharges of regulated facilities and other anthropogenic sources (as indicted by the presence of widespread fish advisories) could result in highly degraded or altered aquatic communities that may be further reduced by IM&E.

2.2.3 Overharvesting

Overharvesting is a general term which describes the exploitation of an aquatic population (e.g., fish, shellfish, and kelp) in an unsustainable fashion to the point of reducing or even eliminating much of the population. Stocks of commercial and recreationally important species are reduced as a result of fishing, but such fish catches may be sustainable if sufficient recruitment of juveniles into the fishery can replace population losses from fishing and other stressors.[5] Unfortunately for many aquatic species, overharvesting has a long history and in many instances has preceded impacts by other competing anthropogenic stressors by several centuries (Jackson et al. 2001).

Many species (and fishery stocks) subject to IM&E are also subject to overharvesting. For example, the 2011 NMFS stock status report indicated that 14 percent of federally monitored fish stocks were being fished at rates above the maximum sustainable yield ("overfishing"), while 21 percent of species are considered over-exploited ("overfished") (NMFS 2012c); many of these fish stocks are also subject to IM&E. Table 2-3 lists 10 groups of species subject to IM&E that are overfished or subject to overfishing. Additional detail regarding the status of stocks is provided in Chapter 6 on commercial fishing benefits. Notably, this assessment does not include many important fishery species not subject to federal regulation that may be subject to high IM&E, nor does this assessment consider threatened and endangered (T&E) species.

Severe overfishing can drive species to ecological insignificance, where the overfished populations no longer interact meaningfully in the food web with other species in the community, or even to extinction (Jackson et al. 2001). The collapse of the Great Lakes whitefish fisheries has been shown to be principally due to overfishing, although habitat alteration and introduction of a non-indigenous (exotic) invader (sea lamprey) were also contributory (Rapport and Whitford 1999).

[5] Recruitment is the number of young fish that enter into a population.

Table 2-3: Depleted Commercial Fish Stocks Subject to IM&E

Stock or Stock Complex	Status of Stock[a]	Stock Region
Surfperches	Overfished but not subject to overfishing[b]	California
Atlantic Cod	Overfished or subject to overfishing	North Atlantic
Windowpane	Overfished but not subject to overfishing	North Atlantic
Winter Flounder	Overfished but not subject to overfishing	North Atlantic
Flounders	Overfished or subject to overfishing	North Atlantic
Atlantic Menhaden	Subject to overfishing but not overfished	North Atlantic/South Atlantic
American Shad	Overfished	North Atlantic/Mid-Atlantic
Weakfish	Overfished but not subject to overfishing	North Atlantic/Mid-Atlantic/South Atlantic
Alewife	Overfished	Mid-Atlantic
Tautog	Overfished and subject to overfishing	Mid-Atlantic

[a] Species group may consist of many individual component species with conflicting stock statuses. The most common stock status among the component species was designated the Status of Stock for the species group.
[b] "Perch" species were used as a proxy for Surfperch.
Source: NMFS 2012c and U.S. EPA analysis for this report

2.2.4 Invasive Species

Non-indigenous, invasive species (NIS) are a significant and increasingly prevalent stressor in both freshwater and marine environments (Cohen and Carlton 1998; Ruiz et al. 1999). Approximately 300 NIS are established in marine and estuarine habitats of the continental United States, and that rate of invasion is rapidly increasing (Ruiz et al. 2000). Aquatic NIS are taxonomically diverse and include plants, fish, crabs, snails, clams, mussels, bryozoans, and nudibranchs. Analysis of freshwater NIS indicated that between 10 to 15 percent are nuisance species with undesirable effects (Ruiz et al. 1999). The adverse implications of marine and coastal NIS are generally not as well-characterized as those in freshwater settings.

Interactions between NIS and other anthropogenic stressors are likely to affect the colonization and distribution of native species subject to CWIS impacts. Thermal discharges from regulated facilities may extend the seasonal duration of non-resident organisms, allowing transient summer species to become permanently established in geographic areas beyond their historical range. For example, in Mount Hope Bay, increased water temperature due to the Brayton Point Station facility led to an increase in abundance of the predacious ctenophore *Mneimiopsis leidyi* as well as increased overwintering in the Bay for this formerly seasonal resident (USEPA 2002b).

2.3 CWIS Impacts on Aquatic Ecosystems

EPA has determined that multiple types of adverse environmental impacts may be associated with CWIS operations at regulated facilities, depending on site-specific conditions at an individual facility. Many of these facilities employ once-through cooling water systems that impinge fish and other aquatic organisms on intake screens if the intake velocity exceeds these organisms' locomotive ability to move away. Impinged organisms may be killed, injured or weakened, depending on the nature and capacity of the plant's filter screen configuration, cleaning and backwashing operations, and fish return system used to return organisms to the source water. In addition, early life stage fish or planktonic organisms can be entrained by the CWIS and subjected to death or injury due to high velocity and pressure, increased temperature, and chemical anti-biofouling agents in the system. This IM&E can act in concert with the other stressors identified above.

The magnitude and regional importance of IM&E is generally a function of the operational intake volumes and the characteristics of the aquatic community in the region (see Chapter 3 for details). IM&E can contribute to: impacts to T&E species (Chapter 4); reductions in ecologically critical aquatic organisms, including important elements of an ecosystem's food chain; diminishment of organism populations' compensatory reserves; population declines, including reductions of indigenous species population levels, commercial fisheries (Chapter 6), and recreational fisheries (Chapter 7); and stresses to overall communities and ecosystems, as evidenced by reductions in diversity or other changes in ecosystem structure or function. In addition, fish and other species affected directly and indirectly by CWIS can provide other valuable ecosystem goods and services, including nutrient cycling and ecosystem stability.

The impacts of IM&E occur at many levels of ecological organization and across a wide range of environmental scales. Table 2-4 presents a summary of direct and indirect impacts of CWIS and IM&E. The effects are identified as direct, indirect, or a combination. This table also indicates the relative scale (local, regional, national) of the particular effect. In most cases, EPA was unable to estimate the magnitude of these effects due to a lack of data. This section discusses a subset of these effects.

2.3.1 Losses of Fish from IM&E

The most visible direct impact of IM&E is the loss of large numbers of aquatic organisms, distributed non-uniformly among fish, benthic invertebrates, phytoplankton, zooplankton, and other susceptible aquatic taxa (e.g., sea turtles). This has immediate and direct effects on the population size and age distribution of affected species, and may cascade through food webs.

Populations of aquatic organisms decline when recruitment rates are lower than mortality rates. Natural sources of mortality for fish species include predation, food availability, injury, climatic factors and disease. Anthropogenic sources of fish mortality, both proximate and ultimate, include fishing, habitat modification, pollution, and IM&E at CWIS. Reducing IM&E will contribute to the health and sustainability of fish populations by lowering the total mortality rate for these populations.

In some cases, IM&E has been shown to be a significant source of anthropogenic mortality to depleted stocks of commercially targeted species. For example, IM&E [expressed as age-one equivalents (A1E)] equal approximately 10 percent of the average annual recruitment to the Southern New England/Massachusetts stock of winter flounder (*Pseudopleuronectes americanus*) (IM&E values from Chapter 3; recruitment data from Terceiro (2008)).

Table 2-4: CWIS Effects on Ecosystem Functions/Cumulative Impacts Potentially Affected, Both Directly and Indirectly, by the 316(b) Rule

Category	Direct/Indirect	Local/Regional/National
A. Impingement and Entrainment (direct and indirect effects)		
Effects on Individuals		
Loss of individuals (direct effects)	Direct	Local/Regional/National
Phytoplankton	Direct	Local/Regional/National
Zooplankton (excluding fish larvae/eggs)	Direct	Local/Regional/National
Invertebrates	Direct	Local/Regional/National
Fish	Direct	Local/Regional/National
Non-fish vertebrates	Direct	Local/Regional/National
Species and Population-Level Effects		
Alteration of phenology of system (function of % water reduction in stream)	Direct	Local/Regional/National
Altered distribution of populations	Direct	Local
Altered niche space	Direct	Local/Regional
Altered stable age distributions of populations	Direct	Regional
Loss of keystone species	Direct	Local
Loss of T&E species	Direct	Regional
Novel selection pressure (e.g., negatively buoyant or stationary eggs)	Direct & Indirect	Local
Reduced/altered genetic diversity	Direct & Indirect	Regional/National
Reduced lifetime ecological function of individuals	Direct	Local/Regional
Community and Trophic Relationships		
Altered competitive interactions	Direct & Indirect	Local
Disrupted trophic relationships	Direct & Indirect	Local
Disrupted control of disease-harboring insects (e.g., mosquito larvae, etc.)	Indirect & Direct	Local/Regional
Increased quantity of detritivores	Indirect	Local
Loss of ecosystem engineers (due to trophic interactions)	Indirect & Direct	Local
Reduced potential for energy flows (e.g. trophic transfers)	Indirect	Local/Regional
Species diversity and richness	Direct & Indirect	Local/Regional/National
Trophic cascades	Indirect & Direct	Local/Regional
Ecosystem Function		
Altered ecosystem succession	Indirect & Direct	Local/Regional
Decreased ability of ecosystem to control nuisance species (algae, macrophytes)	Indirect	Local
Disrupted cross-ecosystem nutrient exchange (e.g., up/downstream, aquatic/terrestrial)	Indirect	Regional
Disrupted nutrient cycling	Indirect & Direct	Local/Regional
Reduced compensatory ability to deal with environmental stress (resilience)	Direct & Indirect	Regional
Reduced ecosystem resistance	Indirect	Local/Regional
Reduced ecosystem stability (alternate states)	Indirect	Local/Regional
Sediment regulation	Indirect	Local/Regional
Substrate regulation	Indirect	Local
B. Thermal Effects (direct and indirect)		
Novel selection pressure (e.g., thermal optima, location of breeding, etc.)	Direct & Indirect	Regional/National
Altered phenology	Direct	Local/Regional
Links between temperature and metabolism		
Dissolved oxygen (physical)	Direct	Local
Dissolved oxygen (bacterial, respiratory rates)	Indirect	Local

Table 2-4: CWIS Effects on Ecosystem Functions/Cumulative Impacts Potentially Affected, Both Directly and Indirectly, by the 316(b) Rule		
Category	**Direct/Indirect**	**Local/Regional/ National**
Ecological energetic demands	Indirect	Local/Regional
Ecological nutrient demands	Indirect	Local/Regional
Altered algal productivity	Direct & Indirect	Local/Regional
Shifted nutrient cycling	Indirect & Direct	Local/Regional
C. Chemical Effects (anti-foulants, etc.)		
Altered survival/growth/production	Indirect & Direct	Local
Altered food web dynamics	Indirect	Local
D. Altered Flow Regimes (local and system-wide)		
Altered flow velocity	Direct & Indirect	Local/Regional
Altered turbulence regime	Direct & Indirect	Local/Regional
E. Cumulative Impacts (as a concentrated number of facilities)		
May push systems over the edge of nonlinearities in the system	Direct/Indirect	Local/Regional
Intensified CWIS effects (as above, Section B.)	Direct/Indirect	Local/Regional
Intensified thermal effects (as above, Section B.)	Direct/Indirect	Local/Regional
Source: U.S. EPA analysis for this report		

In addition to its impact on stocks of marine commercial fish species, IM&E increases the pressure on native freshwater species, such as lake whitefish (*Coregonus clupeaformi*) and yellow perch (*Perca flavescens*), whose populations have seen dramatic declines in recent years (USDOI 2008; Wisconsin DNR 2003). Although recovery of these species is greatly affected by fisheries policy (e.g., NEFSC 2008), IM&E represent an additional source of mortality to fish populations being harvested at unsustainable levels.

Overall, IM&E is likely to contribute to reduction in the population sizes of species targeted by commercial and recreational fishers, particularly for stocks that are undergoing rebuilding. Although these reductions may be small in magnitude compared to fishing pressure (Lorda et al. 2000), and often difficult to measure due to the low statistical power of fisheries surveys, a reduction in mortality rates on overfished populations is likely to increase the rate of stock recovery. Although researchers know less about the population biology of forage fish not targeted by fishers, similar benefits are likely to accrue for these species. Overall, reducing IM&E may lead to more-rapid stock recovery, a long-term increase in commercial fish catches, increased population stability following periods of poor recruitment and, as a consequence of increased resource utilization, an increased ability to minimize the invasion of exotic species (Shea and Chesson 2002; Stachowicz and Byrnes 2006).

For many fish species, IM&E may not lead to measurable reductions in adult populations. These losses, however, are likely to reduce the compensatory ability of populations to respond to environmental variability, including temperature extremes, heavy predation, disease, or years with low recruitment. Additionally, because predation rates are often directly related to the concentration of available prey, IM&E may lead to indirect population effects, whereby reductions in a prey fish may indirectly result in reductions to predator species or increases to species in apparent competition (Holt 1977).

Moreover, IM&E represents a novel selective pressure for fish populations. Consequently, populations may be selected for resistance to IM&E (through behavioral or physiological changes) at the expense of other, more “natural” evolutionary pressures. Although this may help sustain populations in the short term, it may reduce genetic diversity and population stability in the long-term.

2.3.2 IM&E Effects on T&E species

T&E species are species vulnerable to future extinction or at risk of extinction in the near future, respectively. Due to low population sizes, IM&E from CWIS may represent a substantial portion of the annual reproduction of T&E species. Consequently, IM&E may either lengthen population recovery time, or hasten the demise of these species. For these reasons, the population-level and social values of T&E losses are likely to be more important than the absolute number of losses that occur.

Adverse effects on T&E species due to water withdrawals by CWIS may occur in several ways:

- Populations of T&E species may suffer increased mortality as a consequence of IM&E.
- T&E species may suffer indirect harm if the CWIS substantially alters the food web in which these species interact.
- T&E species may suffer indirect harm if the CWIS substantially alters habitat that is critical to their long-term survival.

Chapter 5 provides detail on CWIS impacts on T&E species.

2.3.3 Thermal Effects

Once-through cooling water systems release heated effluent as a byproduct. Concerns about the impacts of heated effluents are addressed by provisions of CWA section 316(a) rule. Most of the facilities subject to 316(b) IM&E concerns have also been required to address the impact of thermal pollution in the discharge-receiving waters (Abt Associates 2010b).

Thermal pollution has long been recognized as having effects upon the structure and function of ecosystems (Abt Associates 2009). Numerous studies have shown that thermal discharges may substantially alter the structure of the aquatic community by modifying photosynthetic (Bulthuis 1987; Chuang et al. 2009; Martinez-Arroyo et al. 2000; Poornima et al. 2005), metabolic, and growth rates (Leffler 1972), and reducing levels of DO. Thermal pollution may also alter the location and timing of fish behavior including spawning (Bartholow et al. 2004), aggregation, and migration (USEPA 2002b), and may result in thermal shock-induced mortality for some species (Ash et al. 1974; Deacutis 1978; Smythe and Sawyko 2000). Thus, thermal pollution is likely to alter the ecological services provided by ecosystems surrounding facilities returning heated cooling water into nearby waterbodies.

Adverse temperature effects may also be more pronounced in aquatic ecosystems that are already subject to other environmental stressors such as high biochemical oxygen demand (BOD) levels, sediment contamination, or pathogens. Thermal discharges may have indirect effects on fish and other vertebrate populations through increasing pathogen growth and infection rates. Langford (1990) reviewed several studies on disease incidence and temperature, and while he found no simple, causal relationship between the two, he did note that it was clear that warmer water enhances the growth rates and survival of pathogens, and that infection rates tended to be lower in cooler waters.

The magnitude of thermal effects on ecosystem services is related to facility-specific factors, including the volume of the waterbody from which cooling water is withdrawn and returned, other heat loads, the rate of water exchange, the presence of nearby refugia, and the assemblage of nearby fish species. In addition to reducing total IM&E, cooling towers reduce thermal pollution. Consequently, the installation of closed-system cooling towers could have geographically variable effects on ecosystems, ranging from comprehensive changes in community structure and habitat type (Schiel et al. 2004), to localized changes in the relative proportion of species adapted to warm and cold water (Millstone Environmental Laboratory 2009). Further information on thermal discharges is provided in Appendix B.

2.3.4 Chemical Effects

One of the environmental impacts associated with operation of electric generators is the release of chemicals in the discharge of once-through cooling water. These chemicals include metals from internal corrosion of pipes, valves and pumps (e.g., chromium, copper, iron, nickel, and zinc), additives (anti-fouling, anti-corrosion, and anti-scaling agents) and their byproducts, and materials from boiler blowdown and cleaning cycles.

EPA used the Discharge Monitoring Report Pollutant Loading Tool (DMR-PLT)[6] to obtain estimated annual pollutant loadings for regulated facilities. EPA extracted data for all regulated facilities (excluding those designated as baseline closures) by querying on a facility's NPDES permit identification number. Of the 739 regulated facilities (excluding baseline closures), 569 have annual loading estimates in DMR-PLT; of these, nearly 75 percent are electric power generators. Table 2-5 lists the top 20 pollutants discharged by regulated facilities in 2011, sorted by mass. These chemicals represent pollutants generated by the operation and maintenance of the facility and other location-specific activities. The most common pollutants include: total dissolved solids, calcium carbonate, sulfate, chloride and fecal coliform.

In addition to these pollutants, facilities also discharge anti-fouling agents. Biofouling is a serious operational concern for facilities. Microbial biofouling on surfaces in cooling water systems can accelerate metal corrosion, increase resistance to heat transfer energy, and increase fluid frictional resistance (Cloete et al. 1998). Sessile macrofouling-organisms such as algae, insects, hydroids, polychaetes, barnacles, mussels and tunicates can colonize intake pipes, bulkheads, and filter screens, and may clog pipes and reduce intake flows or filter-screen effectiveness. Further, some of these infestations produce larvae, which can colonize downstream equipment including pipelines, valves, and heat exchangers. Severe macrofouling-associated problems can include intake flow reduction, increased pressure drop across heat exchangers, and equipment breakdown.

6 The Discharge Monitoring Report (DMR) Pollutant Loading Tool calculates pollutant loadings from EPA's Permit Compliance System (PCS) and Integrated Compliance Information System for the National Pollutant Discharge Elimination System (ICIS-NPDES) as well as wastewater pollutant discharge data from EPA's Toxics Release Inventory (TRI). Data is currently available for the years 2007 through 2011.

Table 2-5: Top 20 Pollutants Discharged by Regulated Facilities, by Total Annual Loadings (2011)

	Parameter	Number of facilities	Total Loading (million lbs/yr)
1	Solids, total dissolved	42	18,508.3
2	Hardness, total (as $CaCO_3$)	31	1,548.5
3	Solids, total suspended	487	651.0
4	Coliform, fecal general	82	535.3
5	Residue, total filterable (dried at 105 C)	8	524.3
6	Sulfate, total (as SO_4)	52	485.1
7	Chloride (as Cl)	53	440.3
8	Nickel, total recoverable	41	395.4
9	Selenium, total recoverable	51	262.6
10	Lead, total recoverable	47	251.2
11	Chromium, total recoverable	27	224.7
12	Chromium, trivalent total recoverable	4	217.7
13	Sulfate	11	178.6
14	Cadmium, total recoverable	32	165.6
15	Solids, total dissolved- 180 deg. C	7	127.7
16	Calcium Chloride	1	106.9
17	Chemical Oxygen Demand (COD)	35	105.9
18	Solids, total dissolved (TDS)	3	102.1
19	Chromium, hexavalent dissolved (as Cr)	14	97.4
20	Antimony, total (as Sb)	12	81.9

Source: Discharge Monitoring Report Pollutant Loading Tool (DMR-PLT)

These anti-fouling and cleaning chemicals potentially pose a risk to organisms downstream of the CWIS discharge. Adverse effects to aquatic organisms may include acute and residual effects of biocides used as anti-fouling agents in condenser tubes, or from chemicals resulting from corrosion or use in cleaning of either stream or cooling cycles (Kelso and Milburn 1979). A typical biofouling procedure is continuous low-level chlorination at chronic toxicity levels with an occasional high ("shock") dose. The use of oxidants (chlorine, bromide) can give rise to residuals and/or disinfection byproducts (DBPs) such as trihalomethanes, haloacetic acid, bromoform, and others (Taylor 2006). Concentrations of released chemicals are variable among facilities, and are a function of treatment dose, CWIS design, rates of degradation, and the volume and flushing rate of the receiving water.

With the exception of chlorination impacts (Taylor 2006), the potential effects of chemicals in facilities' cooling water discharges on local aquatic ecosystems are not well-characterized. In most cases, chemical effects are considered, along with thermal and mechanical effects, as a component of the cumulative stress of entrainment on organisms. Little information is available on the chronic or low-level effects of these discharge chemicals on local ecosystems or in concert with other anthropogenic stressors.

Review of the effects of chemical treatment and discharge into the environment suggests that direct ecotoxicity in discharge plumes is relatively rare beyond the point of discharge or mixing zone near the pipe outlet (Poornima et al. 2005; Taylor 2006). However, concentrations of these chemicals may be additive to low-level chronic adverse effect with other anthropogenic stressors identified above.

2.3.5 Effects of Flow Alteration

The operation of CWIS and discharge returns significantly alter patterns of flow within receiving waters both in the immediate area of the CWIS intake and discharge pipe, and in mainstream waterbodies, particularly in inland riverine settings. In ecosystems with strongly delineated boundaries (i.e., rivers, lakes, enclosed bays, etc.), CWIS may withdraw and subsequently return a substantial proportion of water available to the ecosystem. For example, of the 435 facilities that are located on freshwater streams or rivers, 30 percent (132) of these facilities have average actual intake flow that is greater than 5 percent of the mean annual flow of the source waters.[7] Even in situations where the volume of water downstream of regulated facilities changes relatively little, the flow characteristics of the waterbody, including turbulence and water velocity, may be significantly altered. This is particularly true in locations with multiple CWIS located close to each other.

Altered flow velocities and turbulence may lead to several changes in the physical environment, including sediment deposition (Hoyal et al. 1995), sediment transport (Bennett and Best 1995), and turbidity (Sumer et al. 1996), each of which play a role in the physical structuring of ecosystems. Biologically, flow velocity is a dominant controlling factor in aquatic ecosystems. Flow has been shown to alter feeding rates, settlement and recruitment rates (Abelson and Denny 1997), bioturbation activity (Biles et al. 2003), growth rates (Eckman and Duggins 1993), and population dynamics (Sanford et al. 1994).

In addition to flow rates, turbulence plays an important role in the ecology of small organisms, including fish eggs and larvae, phytoplankton, and zooplankton. In many cases, the turbulence of a waterbody directly affects the behavior of aquatic organisms, including fish, with respect to swimming speed (Lupandin 2005), location preference with a waterbody (Liao 2007), predator-prey interactions (Caparroy et al. 1998; MacKenzie and Kiorboe 2000), recruitment rates (MacKenzie 2000; Mullineaux and Garland 1993), and the metabolic costs of locomotion (Enders et al. 2003). The sum of these effects may result in changes to the food web or the location of used habitat, and thereby substantially alter the aquatic environment.

Climate change is predicted to have variable effects on future river discharge in different regions of the United States, with some rivers expected to have large increases in flood flows while other basins will experience water stress. For example, Palmer et al. (2008) predict that mean annual river discharge is expected to increase by about 20 percent in the Potomac and Hudson River basins but to decrease by about 20 percent in Oregon's Klamath River and California's Sacramento River. Thus, the adverse effects of flow alteration may increase or decrease over longer periods for larger rivers, depending on their geographic location.

2.4 Community-level or Indirect Effects of CWIS

In addition to the direct effects of CWIS, IM&E may alter a wide range of aquatic ecosystem functions and services at the community-level (Table 2-4). Most of these impacts on aquatic community function and service are poorly characterized, given the limited scope of IM&E studies and an incomplete knowledge of baseline or pre-operational conditions within affected waters.

[7] Facility counts exclude baseline closures.

For example, fish are essential for energy transfer in aquatic food webs (Summers 1989), and for the regulation of food web structure. Fish play important roles in nutrient cycling (Wilson et al. 2009) and sediment processes, and are known to play key roles in the maintenance of aquatic biodiversity (Holmlund and Hammer 1999; Peterson and Lubchenco 1997; Postel and Carpenter 1997; Wilson and Carpenter 1999).

While IM&E of commercially or recreationally important fish species can be quantified and monetized (Chapters 6 and 7), the accompanying loss of other aquatic organisms may be poorly characterized (e.g., lumped into broad taxa such as “forage fish” or “other”) or simply not reported. In addition, IM&E on species of lower concern may create unrealized ripples of ecological effect within the aquatic community. Species may respond to altered ecological circumstances such as reduced predation, altered food concentrations, or slower nutrient recycling, etc. Therefore, the removal of selected fish species or considerable biomass by IM&E may substantially affect these processes.

Several examples of ecological services indirectly affected by IM&E are described below, although others listed in Table 2-4 may be of equal importance for individual ecosystems.

2.4.1 Altered Community Structure and Patchy Distribution of Species

The role of some aquatic species may be more critical in shaping the structure and composition of the community than that of others. These keystone species are species that have an effect on community structure disproportionate to their population (Paine 1966; Paine 1969). Consequently, the loss or reduction of keystone species may lead to substantial changes in aquatic food webs, and decrease overall ecosystem stability. Thus, the potential for ecosystem impacts resulting from, for example, the loss of an important predator fish due to IM&E may not be strictly proportional to the number or biomass of lost fish or foregone fish production.

The operation of CWIS by generating facilities can lead to localized areas of depressed fish and shellfish abundance. Facilities (and the intake volume they represent) are distributed in a non-uniform manner along coastlines and rivers, and may be clustered (Section 2.5), such that IM&E and the populations they affect are geographically heterogeneous. This can result in a highly localized and patchy distribution of aquatic organisms in regional areas. A secondary effect is increased probability of colonization and establishment by NIS due to niche space availability caused by a local reduction in the density of native organisms (Byrnes et al. 2007; Ovaskainen and Cornell 2006).

2.4.2 Altered Food Webs

Sources of mortality, including IM&E, may disrupt established predator-prey relationships and the niche space available to species through direct pathways (i.e., mortality of the organism) or indirectly (i.e., alterations to the food web). The loss of young-of-year (YOY) predators (e.g., striped bass) or important forage fish (e.g., menhaden and bay anchovy) is likely to affect trophic relationships and alter food webs. These changes may alter the realized species niche and life history traits due to alterations in inter- and intra-specific interactions (e.g., predator-prey, competition, mate selection, etc.) (Fortier and Harris 1989; Hixon and Jones 2005; Jirotkul 1999). These alterations in trophic interactions and food webs, combined with other CWIS-related impacts such as thermal pollution (Section 2.2.3) or flow alteration (Section 2.3.5), may lead to rapid changes in life history strategies as a consequence of facultative (Ball and Baker 1996) or evolutionary changes (Hairston et al. 2005; Reznick and Endler 1982).

2.4.3 Reduced Taxa and Genetic Diversity

IM&E may lead to reductions in local community biodiversity (due to destruction of selected species) or in a loss of genetic diversity in individual fish populations. IM&E represents a novel selective pressure on early life stages that may reduce the genetic diversity of resident fish and prevent the recovery of depleted stocks (Stockwell et al. 2003; Swain et al. 2007; Walsh et al. 2006). Because many populations stocks are differentiated by oceanic region and/or timing of migratory movements, IM&E could alter the seasonal timing and movement (i.e., phenology) of overall fish populations, which could have ramifications for predator species.

2.4.4 Nutrient Cycling Effects

IM&E impacts may alter the pace of nutrient cycling, and energy transfer through food webs. Fish species have been shown to have substantial effects on nitrogen, phosphorous, and carbon cycling due to storage effects (i.e., large quantities of nutrients are found within fish biomass) and translocation effects (i.e., fish migrate, moving large quantities of nutrients to new ecosystems) (Kitchell et al. 1979; Vanni et al. 1997). These alterations in nutrient cycling could lead to redirection of nutrient flows to other components of the ecosystem including water column phytoplankton, benthic macroalgae and attached epiphytes, with subsequent changes to the condition of critical ecosystem habitats, such as submerged aquatic vegetation. Juvenile Atlantic menhaden (*Brevoortia tyrannus*) are capable of significantly grazing down plankton concentrations in Chesapeake Bay, leading to more-rapid regeneration of nutrients and enhanced primary production. Removal of juvenile menhaden by IM&E would lead to reduced grazing and turnover of nutrients and increased algal density in the water column (Gottlieb 1998). The amount of nitrogen and phosphorus regenerated in facility discharge water due to nutrient recycling of IM&E biota might also lead to areas of localized nutrient enrichment near outfalls (Abt Associates 2010a). Additionally, the preferential removal of upper water column species by IM&E could increase energy flow to benthic organisms, and thereby increase the relative importance of detritivores in bottom communities.

2.4.5 Reduced Ecological Resistance

The effect of long-term or chronic IM&E may lead to a decrease in ecosystem resistance and resilience (i.e., ability to resist and recover from disturbance including invasive species) (Folke et al. 2004; Gunderson 2000). That is, IM&E is likely to reduce the ability of ecosystems to withstand and recover from adverse environmental impacts, whether those impacts are due to anthropogenic effects or natural variability.

2.5 Cumulative Impacts of Multiple Facilities

Cumulative effects of CWIS are likely to occur if multiple facilities are located in close proximity such that they impinge or entrain aquatic organisms within the same source waterbody, watershed system, or along a migratory pathway of a specific species (e.g., striped bass in the Hudson River) (USEPA 2004a). The cumulative impacts of CWIS may be exacerbated by the presence of other anthropogenic stressors discussed above (Section 2.2).

EPA analyses suggest that approximately 20 percent of all regulated facilities are located on waterbodies with multiple CWIS (USEPA 2004a). Inspection of geographic locations of regulated facilities (approximated by CWIS latitude and longitude) indicates that facilities in inland settings are clustered around rivers to a greater extent than marine and estuarine facilities (see Figure 2-1).

2.5.1 Clustering of Facilities and CWIS on Major Rivers

To illustrate the potential for cumulative impacts, EPA reviewed data from five major U.S. rivers with clustered concentrations of facilities. Table 2-6 summarizes average annual river flow and facility DIF and actual intake flow (AIF). Based on the non-uniform distribution of facilities, locations were noted where the potential for cumulative impacts is high (Abt Associates 2010b).

Table 2-6: U.S. Rivers with Largest Withdrawals by Regulated Facilities

River	Avg. Annual[a] Flow (mgd)	Facilities	Cumulative DIF (mgd)	DIF as % Avg. Annual Flow	Cumulative AIF (mgd)	AIF as % Avg. Annual Flow
Mississippi	383,266	57	22,436	5.9	13,170	3.4
Ohio	181,615	47	19,315	10.6	13,384	7.4
Missouri	49,249	23	10,718	21.8	6,598	13.4
Illinois	8,079	11	6,259	77.5	1,605	19.9
Delaware	7,562	11	3,585	47.4	1,485	19.6
Sources: USGS 1990 and U.S. EPA analysis for this report						

For example, the Mississippi River provides source water for cooling water for 57 facilities along its length,[8] with 27 facilities located in Louisiana upstream of the Mississippi River delta. Using facility intake coordinates as location markers, the relative distances between facilities were estimated (Abt Associates 2010b). In upper Louisiana, facilities are typically separated by tens of miles; inter-facility distance decreases downstream of Baton Rouge, LA. Several locations along the Mississippi River have clusters of facilities:

- Between Ascension and St. James Parishes, a 13-mile span of the river hosts six manufacturing facilities, three of which have intakes located within the same mile. These facilities have a combined DIF of nearly 270 mgd.
- Fifteen miles downstream, near Garyville, LA, there is a cluster of three facilities within six miles of the river stretch.
- Seven miles further downstream near Laplace, LA, six facilities are located on a six-mile stretch of the river. Four of these facilities, with a combined DIF exceeding 5 billion gallons per day (bgd) (three generators and one manufacturer), are located within a 1.7 mile section of river.
- Further downstream in Chalmette, LA (just east of New Orleans), three manufacturers, capable of withdrawing up to 457 mgd, are clustered within four river miles.

Therefore, the potential for cumulative impacts is high, and investigating ecosystem effects by extrapolating results on a per facility basis is likely to underestimate the true effects.

[8] This total excludes one facility that EPA projects as baseline closure.

2.5.2 Implications of Clustered Facilities for Cumulative Impacts

The cumulative impact of clustered facilities may be significant, due to the concentrated IM&E, combined intake flows, and the potential for other impacts such as thermal discharges. It should also be noted that power generation demand and cooling intake water volume are typically at their annual maximum during mid-late summer, which is also a period of seasonal low flows and highest in-stream temperatures. The effect of cumulative impacts may be greater in inland or Great Lakes waters due to the following factors:

- The majority of national AIF is associated with freshwater CWIS.
- Freshwater facilities use a greater relative volume of available fish habitat than marine or estuarine counterparts.
- Seasonal variation in power demand and river flow may increase entrainment potential during low-flow periods of the year (NETL 2009). Although low flows are traditionally in late summer to early fall, drought conditions and manipulations of water levels may lead to low flow during other periods. This may be locally significant if periods of low flow overlap with seasonal concentrations of eggs, developing YOY, and migrating juveniles.
- Freshwater facilities are more likely to be clustered along a waterbody, and pose a greater risk of cumulative impacts. This is exacerbated by the presence of numerous impoundments associated with navigational lock and dam structures located on larger rivers (e.g., Mississippi, Missouri, Ohio, etc). These impoundments result in slow or slack water conditions with a lower effective volume than free-flowing reaches or periods of higher flow.

2.6 Case Studies of Facility IM&E Impacts

While the information provided in this chapter provides a broad overview of potential impacts associated with CWIS, it is highly informative to evaluate these impacts in the context of actual facilities to see how and to what extent these impacts and IM&E are realized, how site-specific factors come into play, the effects of cumulative impacts, and what has been learned with regard to community-level effects. Case studies provide useful, detailed information for evaluating IM&E and major stressors in the context of a specific waterbody or region.

As part of the Phase II regulations, review and analyses of IM&E data and environmental information were presented in comprehensive case studies in EPA’s 2002 Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule (USEPA 2002a). The document provided detailed analyses of CWIS impacts in major regional waterbodies throughout the United States. These cases studies included:

- Delaware Estuary Watershed: a regional assessment of the impacts of 7 generating and 6 manufacturing facilities in the transition zone of the Delaware River Estuary. The estuary’s transition zone was chosen due to its biological, recreational, and economic importance, and because of the high concentration of CWIS.
- Ohio River Watershed: a detailed assessment of the impacts of 9 (of 29) facilities in a 500-mile stretch of the Ohio River between the McAlpine and New Cumberland pools, this case study is representative of a large industrial river.

- Tampa Bay Watershed: highlighted as a representative of the Southeast Atlantic and Gulf coasts, this case study included four of eight facilities in watersheds draining into Tampa Bay.
- San Francisco Bay/Delta Estuary: included as representative of an urban estuary, and a waterbody containing several T&E species, this case study highlighted the effects of two large generating facilities.
- Brayton Point Facility: a case study of a single facility and its impacts on a confined waterbody.
- Seabrook and Pilgrim Facilities: with a pair of facilities located in the same ecological region, but with very different CWIS placements, this case study highlights the potential effects of CWIS location of IM&E impacts.
- J.R. Whiting Facility: an assessment of the before and after effects of the installation of a deterrent net on IM&E for a representative facility on the Great Lakes.
- Monroe Facility: located nearby the J.R. Whiting facility (above), the Monroe facility case study provides an estimate of the effects of IM&E on Great Lakes facilities.

These regional case studies provide a set of information describing the variety of CWIS impacts under marine, coastal, and riverine environmental settings. The following sections present three additional case studies to provide examples of facility-specific CWIS impacts in settings including freshwater coastal (Bay Shore, Oregon, OH), estuarine (Indian Point, Buchanan, NY), and estuarine-coastal (Indian River, Sussex County, DE) environments. These brief case studies also illustrate the quantitative levels of IM&E, the indirect effects of IM&E on local aquatic ecosystems, and the cumulative effects of combined effects (IM&E and thermal).

2.6.1 Bay Shore Power Station

The Bay Shore power station is a 631 megawatt (MW) facility located on the south shore of Lake Erie near the confluence of the Maumee River and Maumee Bay, OH. Cooling water for the four coal-fired steam-electric units is withdrawn from Maumee River/Maumee Bay via an open intake channel of approximately 3,700 ft in length, and enters the facility via a shoreline surface CWIS. Approximately 749 million gallons per day (mgd) are withdrawn, including once-through cooling water and sluice water used for transporting bottom ash from the boilers to ash settling ponds (OEPA 2010). Major environmental concerns for the facility include IM&E and thermal impacts.

Bay Shore Power Station IM&E: Medium-sized Plant with Large-Scale Impacts:

A comprehensive demonstration study, conducted in 2005-2006, estimated annual impingement at greater than 46 million fish per year, the majority of which were forage fish species—emerald shiner and gizzard shad. Annual estimates for entrainment were equally impressive—209 million fish eggs, 2,247 million fish larvae, and 14 million juvenile fish (OEPA 2010). As noted on the NDPES fact sheet, “It is likely that Bay Shore Station impinges and entrains more fish than all other power stations in Ohio combined.” Notably, the facility does not currently employ technologies to reduce IM&E (OEPA 2010).

In addition to IM&E effects, concerns have also been raised regarding the size and impact of the thermal discharge plume—a focus of concern for local residents and commercial fishermen. Depending on wind patterns and hydrological factors, the thermal plume extends to the south shore of Maumee Bay (over 1 mile from the facility). The Ohio Environmental Protection Agency (OEPA) assessed the results from a 2002 thermal mixing zone study, and concluded that the thermal discharge exceeded Ohio water quality standards for temperature within the thermal plume (>85°F in Maumee Bay), but that the impacts on aquatic life and designated uses in Maumee River/Bay did not justify reduction of the thermal mixing zone. However, it did find that the thermal activity could restrict recreational activities in certain areas of the facility and required the facility owners to conduct a two-year study of the benthic community within the mixing zone (OEPA 2010).

2.6.2 Indian Point Nuclear Power Plant

The Indian Point nuclear power plant is a 2,045 MW facility located in Buchanan, Westchester County, New York, on the east shoreline of the Hudson River. Cooling water (up to 2,500 mgd) for the two nuclear-fired steam-electric units (Units 2 and 3) is withdrawn from the estuarine portion of the Hudson River through three intake structures on the shoreline (NYSDEC 2003a). The heated non-contact cooling water is discharged through sub-surface diffuser ports in a discharge canal located downstream of the intake structures.

Concerns regarding impact to fish, particularly anadromous striped bass populations, as well as a high level of involvement and litigation from local stakeholder groups, have made the Indian Point power generation plant (along with other Hudson River facilities) particularly well-characterized in terms of IM&E impacts. Accordingly, the Hudson River aquatic community has been sampled and studied over many decades, with detailed investigation starting in the 1970s.

Results suggest that IM&E impacts to the local and transient anadramous fish species are substantial. For example, studies of fish entrainment in 1980 predicted fish class reductions ranging from 6 to 79 percent, depending on fish species (Boreman and Goodyear 1988). Subsequent sampling work predicted year-class reductions due to IM&E of 20 percent for striped bass, 25 percent for bay anchovy, and 43 percent for Atlantic tomcod. The Final Environmental Impact Statement (FEIS) prepared by the New York State Department of Environmental Conservation (NYSDEC) concluded these levels of mortality “could seriously deplete any resilience or compensatory capacity of the species needed to survive unfavorable environmental conditions” (USEPA 2006a).

Indian Point Final Environmental Impact Statement (FEIS) details cumulative effects:

The FEIS estimated, from samples collected between 1981 and 1987 for three facilities (Indian Point, Roseton, Bowline Point), that average annual entrainment included 16.9 million American shad, 303.4 million striped bass, 409.6 million bay anchovy, 468 million white perch, and 826.2 million river herring (NYSDEC 2003b). The loss of such large numbers of forage fish species and the potential impact on higher level piscivores is of high concern. The FEIS also viewed the overall effect of the CWIS impacts on the aquatic community as analogous to habitat degradation rather than overfishing. This judgment was based on evidence that the entire aquatic community was affected rather than only specimens of higher trophic level species.

The FEIS considered the role of other major environmental factors currently or historically present in the Hudson River. These factors have the capacity to affect fish populations either positively (enhancements) or negatively (stressors). Relevant factors include, but are not limited to: improvements to water quality due to upgrades to sewage treatment facilities, invasions by exotic species (e.g., zebra mussel), chemical contamination by toxins (e.g., PCBs and heavy metals), global climate shifts such as increases in annual mean temperatures and higher frequencies of extreme weather events (e.g., the El Nino-Southern Oscillation), and stricter management of individual species stocks such as striped bass (USEPA 2006a).

In April 2010, the NYSDEC denied a request by Indian Point for a CWA section 401Water Quality Certificate. The CWA requires that, prior to any federal agency issuing a license or permit for a particular project (in this case, the approval of the State Discharges Permit Elimination System [SPDES] permit), it must certify that the project meets State water quality standards. The NYSDEC denial letter cited, among other concerns, continuing concerns over IM&E including potential impacts to two species protected under the Endangered Species Act (ESA) —the Shortnose Sturgeon (endangered) and the Atlantic Sturgeon (endangered).

2.6.3 Indian River Power Plant

The Indian River Generating Station (IRGS) is a 784 MW facility located in Sussex County, Delaware, on the south shore of the Indian River. Cooling water for three of the IRGS's four coal-fired steam-electric units is withdrawn upstream from the freshwater portion of Indian River via an intake canal at a maximum rate of 411 mgd, or 21 times the average flow rate of Indian River. Heated return water is discharged via a canal into the upper reaches of Island Creek, a small tributary of Indian River, entering at Ward Cove. Island Creek and Ward Cove are part of a large estuarine stretch (approximately 150 acres) of Indian River that provides important fish and crab habitat. Its lower salinity and location in the estuary make it attractive to important species such as bay anchovy, spot, menhaden larvae, and young blue crabs.

Indian River Power Plant has impact on important local species:

The 2003 316(b) Comprehensive Demonstration Study for the Indian River Power Plant reported IM&E for a number of important species (Entrix 2003, as described in Bason 2008). This IM&E has been recalculated by a local stakeholder group as A1E for bay anchovy (1.6 million), blue crab (300,000), croaker (270,000), and menhaden (60,000) (Bason 2008).

Due to the size of the heated discharge relative to the receiving water, thermal effects of the facility were also investigated. Based upon monitoring data collected from 1998 to 1999, the 316(a) report assessed the effects of elevated water temperatures on ecosystem communities with a focus on eight important fish species: bay anchovy, menhaden, winter and summer flounder, croaker, spot, striped bass, and weakfish. This report determined that juvenile and adult target species, although able to avoid areas of high water temperature, were not permanently restricted from most stretches of the Indian River, nor did they suffer loss of habitat services associated with these segments. The study concluded an overall condition of no adverse effect, or no appreciable harm, on the fish and shellfish populations in the Indian River and Delaware Bay (Entrix 2001).

Despite the overall conclusion of no adverse effect, the report documented localized thermal impacts of consequence. For example, during warmer months, the thermal discharge reached potential adverse levels in Island Creek, often extending downstream to Ware Cove (Entrix 2001). The mortality associated with sub-adult stages of fish and crabs and the avoidance of the area by sub-adult and adult fish were substantial issues. In addition to direct thermal impacts to biota, temperature-related reductions in DO were observable (mean reduction = 0.6 mg/l) in the discharge canal. These reductions contributed to the amplitude of the day-night (diel) cycle of DO concentrations, already widely fluctuating due to cumulative effects of eutrophication in the river (Bason 2008).

2.7 Conclusions

Considerable information is available on the direct effects of CWIS and IM&E (Chapter 3) on commercially (Chapter 6) and recreationally important (Chapter 7) species derived from the accumulated data from facility-specific basis 316(b) studies and investigations. This information allowed EPA to monetize the potential commercial and recreational fishing benefits for the final rule and other options EPA considered. However, as demonstrated in this section, much less information and high uncertainty exist regarding the magnitude and importance of indirect and/or cumulative impacts of CWIS, particularly effects on lower trophic organisms or ecosystem functions. This condition is due to the limitations of 316(b) sampling programs, as well as the failure of permitting process to consider the additive or cumulative effects of other major anthropogenic stressors. While EPA can identify and hypothesize regarding the direction and relative importance of impacts of CWIS on the totality of the aquatic ecosystem (i.e., not just focused on selected higher trophic level predator species and common prey), EPA is currently unable to connect these effects with quantifiable environmental benefits. Thus, it is highly likely that the total environmental and monetary impacts of CWIS are significantly underestimated, and that characterization of the fuller spectrum of benefits arising from reducing or eliminating IM&E will await future, targeted research efforts.

3 Assessment of Impingement and Entrainment Mortality

3.1 Introduction

This chapter discusses the methods EPA used to convert results from IM&E sampling studies into metrics suitable as inputs for EPA's section 316(b) benefits analysis.[9] Section 3.2 provides a brief overview of IM&E metrics, and outlines how they were used in the benefits analysis. Section 3.3 presents IM&E, by region, under baseline conditions, and the reductions in these losses under alternative regulatory options. Section 3.4 discusses limitations and uncertainties in the IM&E analysis.

EPA's IM&E assessment methods are discussed in detail in Chapter A-1 of the Regional Benefits Analysis for the Final Section 316(b) Phase III Existing Facilities Rule (Regional Benefits Analysis) (USEPA 2006b). Changes in methodology since EPA's Phase III analysis include: (1) the addition of new IM&E data for several California facilities, (2) engineering reductions for power generators were estimated for sample facilities that received the detailed questionnaire rather than for all regulated generators, and (3) estimated changes in the proportionate reduction in IM&E under the final rule and Proposal Options 2 and 4. Other modifications are identified in relevant portions of Section 3.2.

3.2 Methods

3.2.1 Objectives of IM&E Analysis

EPA's evaluation of IM&E data had four main objectives:

- To develop regional and national estimates of the magnitude of IM&E;
- To standardize IM&E using common biological metrics that allow comparison across species, years, facilities, and geographical regions;
- To provide IM&E metrics suitable for use in national economic benefits analysis; and,
- To estimate changes in metrics as a result of estimated reductions in IM&E under the final rule and Proposal Options 2 and 4.

EPA's use of these methods for national rulemaking does not imply that these methods are the best or most suitable for studies of single facilities. In many cases, site-specific details on local fish populations and waterbody conditions may make other assessment approaches, such as population or ecosystem modeling, possible.

3.2.2 IM&E Loss Metrics

Three loss metrics were derived from facility IM&E monitoring data available to EPA: (1) age-one equivalents (A1E), (2) forgone fishery yield, and (3) production forgone. These metrics are described

9 For the purposes of its national analysis, EPA assumed 100 percent entrainment mortality. This assumption is discussed at length in Chapter A7 of the Regional Analysis Document for the Final Section 316(b) Existing Facilities Rule (USEPA 2004a). Briefly, EPA assessed 37 entrainment survival studies and found them variable, unpredictable, unreliable, and not defensible. As such, these studies support an assumption of 0 percent survival for entrained organisms in benefits assessments.

briefly below. Equations used to calculate metrics and other details are provided in Chapter A-1 of EPA's Regional Benefits Analysis (USEPA 2006b).

3.2.2.1 Age-One Equivalents

The Equivalent Adult Model (EAM) is a method for converting organisms of different ages (life stages) into an equivalent number of individuals in any single age (Goodyear 1978; Horst 1975). For its 316(b) analyses, EPA standardized all IM&E into equivalent numbers of 1-year-old fish, a value referred to as A1Es. This conversion allows losses to be compared among species, years, facilities, and regions.

To conduct EAM calculations requires a life history schedule, for each species, incorporating age-specific mortality rates. Using these species-specific survival tables, a conversion rate between all life history stages and age 1 is calculated. For life history stages younger than 1 year of age, the conversion rate is calculated as the product of all stage-specific survival rates between the stage at which IM&E occurs and age 1. Consequently, the loss of an individual younger than age 1 results in a conversion rate less than 1. For individuals older than 1 year, the conversion rate is calculated as the quotient of all stage-specific survival rates between the stage at which IM&E occurs and age 1. Consequently, the loss of an individual older than age 1 results in a conversion rate greater than 1.

Additional details on the EAM calculation are provided in Chapter A-1 of EPA's Regional Benefits Analysis (USEPA 2006b). For the results presented in this chapter, the treatment of early life stages in this calculation considers all larval life stages reported in the original IM&E studies.

3.2.2.2 Forgone Fishery Yield of Commercial and Recreational Species

Fishery yield is a measure of the biomass harvested from a cohort of fish.[10] EPA expressed IM&E of harvested species in terms of forgone (lost) fishery yield. To convert losses to forgone fishery yield, EPA used the Thompson-Bell equilibrium yield model (Ricker 1975) with the assumptions that 1) IM&E reduce the future yield of harvested adults, and 2) reductions in IM&E will lead to an increase in harvested biomass.

The Thompson-Bell model is based on the principles used to estimate the expected yield in any harvested fish population (Hilborn and Walters 1992; Quinn and Deriso 1999). The general procedure involves multiplying age-specific harvest rates by age-specific weights to calculate an age-specific expected yield. The lifetime expected yield for a cohort of fish is the sum of all age-specific expected yields. Details of these calculations are provided in Chapter A-1 of EPA's Regional Benefits Analysis (USEPA 2006b).

3.2.2.3 Production Forgone for All Species

Production forgone is an estimate of the biomass that would have been produced had individuals not been impinged or entrained (Rago 1984). It is calculated for all forage species from species- and age-specific growth rates and survival probabilities. This forgone biomass represents a decrease in prey availability for predator species, and is calculated because IM&E for forage species are not included in the forgone fishery yield calculations. Additional details regarding the calculation of production forgone are provided in Chapter A-1 of EPA's Regional Benefits Analysis (USEPA 2006b).

3.2.3 Valuation Approach

EPA's benefits analysis focused on increased commercial and recreational fishery harvests estimated from projected reductions in IM&E. For consistency with reported harvest data, commercial harvest is

[10] A cohort of fish refers to fish produced in the same year, also referred to as a year-class of fish.

reported in pounds and recreational harvest is reported in numbers of fish. To project changes in fishery harvests, EPA integrated two components of fishery yield that change as a consequence of IM&E: direct contributions of commercially and recreationally harvested species (hereafter fishery species), and indirect contributions of forage species consumed by fishery species (Figure 3-1). The direct contribution of fishery species to yield (left side of Figure 3-1) is calculated by converting A1E mortality to forgone yield as described in Section 3.2.2. The contribution of forage species to fishery yield is measured as a biotic transfer of mass through the food web to fishery species that are subsequently harvested (right side of Figure 3-1). EPA used a simple trophic transfer model for this purpose (discussed in Chapter A-1 of EPA's Regional Benefits Analysis (USEPA 2006b), assuming a trophic transfer efficiency of 0.10 (Pauly and Christensen 1995).[11] Trophic transfer efficiency represents the fraction of forage species biomass incorporated into predator (fishery) species biomass. EPA estimated total changes to commercial and recreational harvest yield as the sum of the contributions of fishery and forage species. For benefits analysis, total yield was separated into commercial and recreational fractions based on the proportion of harvest occurring within each type of fishery, and benefits were calculated for harvestable adult fish. Details of the commercial and recreational fishing benefits analysis are provided in Chapters 6 and 7 of this report, respectively.

3.2.4 Rationale for EPA's Approach to Valuation of IM&E

EPA's approach to estimating changes in fish harvest assumed that IM&E result in a reduction in the number of harvestable adults, and that IM&E reductions result in increases to future fish harvests. This approach estimates incremental fishery yield forgone because of IM&E and does not require knowledge of population size or total yield of a fishery.

EPA's forgone fishery yield analysis requires species- and stage-specific schedules of natural mortality (M), fishing mortality (F), and weight-at-age. The yield model assumes that these key parameters (F, M, and weight-at-age) are independent of IM&E for all species. EPA recognizes that this assumption does not fully reflect the dynamic nature of fish populations. However, by conducting benefits analysis using estimates of forgone yield, EPA was able to use a simple and direct measure of the potential economic value associated with each IM&E-related death. Used of this approach was warranted given: (1) the scope and objectives of its analysis of harvested species, (2) data availability, and (3) difficulties in distinguishing the causes of population changes. Each of these factors is discussed below.

3.2.4.1 Scope and Objectives of EPA's Analysis of Harvest Species

EPA's overall objective was to develop regional- and national-scale estimates of the magnitude of IM&E at hundreds of facilities subject to the final rule. As a consequence of the large geographic scope and multiple ecosystems involved, EPA modeled fishery yield using a relatively simplified approach to estimate the vulnerability of dozens of species to IM&E on a national scale. Although sufficient data may exist to model the effects of IM&E on population and community-level impacts, sufficient data do not exist at the national scale to make such studies feasible.

[11] EPA notes that its model of trophic transfer is a very simple and idealized representation of trophic dynamics; it is not intended to capture the details of trophic transfer in actual aquatic ecosystems. In reality, food webs and trophic dynamics are much more complex than EPA's simple model implies, and include details that are specific to each particular aquatic ecosystem. This complexity was beyond the scope of EPA's analysis and the available data.

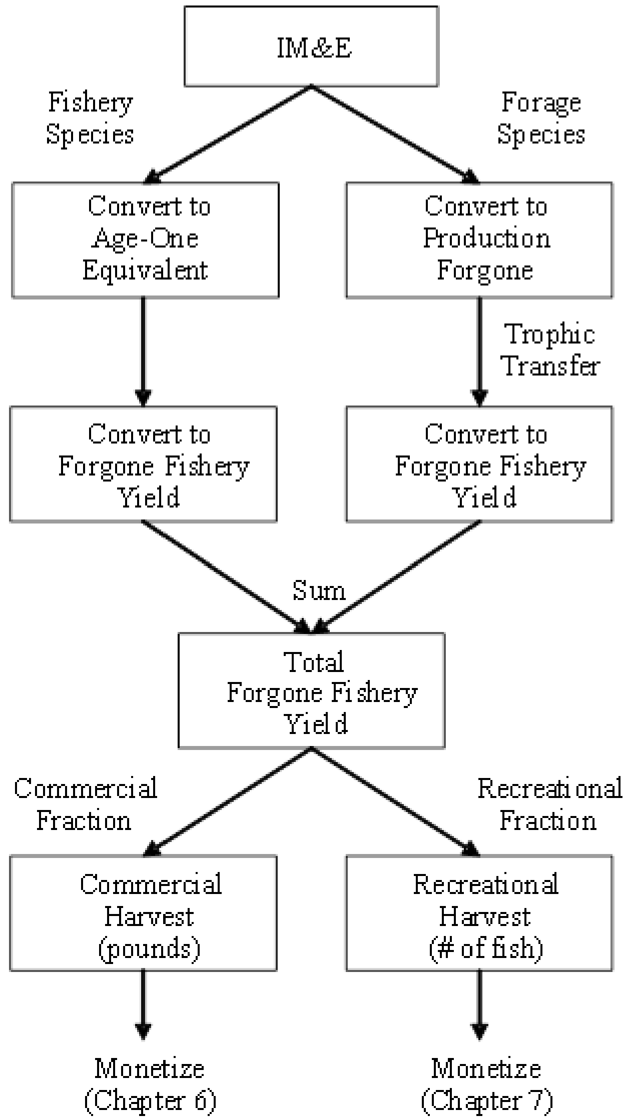

Figure 3-1: General Approach Used to Evaluate IM&E as Forgone Fishery Yield

3.2.4.2 Data Availability and Uncertainties Related to Modeling Fish Harvest

Forgone fishery yield and production forgone models used by EPA required age-specific life history data for all species analyzed. EPA acknowledges that many fish population models are available, and that these models may produce more accurate population-level impacts of IM&E. EPA did not pursue the development of species-specific population models for several reasons:

- Constructing population models requires a large set of parameters and numerous assumptions about the nature of stock dynamics for each species, including current stock size, stock-recruitment relationships, changes to growth and mortality rates as a function of stock size, and the separation of certain species into geographically based stock units. Because of these limitations, fewer than 40 percent of U.S.-managed commercially harvested fish stocks have been fully assessed (NMFS 2009; NMFS 2010a). As such, the information necessary to build more-complex population models is available only for a subset of harvested species, which represent a minor fraction of IM&E.

- Numerous difficulties exist in the definition of the size and spatial extent of fish stocks. As a result, it is often unclear how IM&E at particular cooling water intake structures (CWIS) can be related to specific stocks at a regional scale. For example, juvenile Atlantic menhaden (*Brevoortia tryannus*) found in Delaware Bay recruit from both local and long distances (Light and Able 2003). As a result, estimating the effects of local IM&E on recruitment rates would not be sufficient to understand the stock-recruitment relationship for Delaware Bay menhaden.

Consequently, issues of data availability and difficulties estimating the effects of localized IM&E on regional-scale fish stocks led EPA to determine that the construction of population models for all species subject to IM&E was not feasible. The level of uncertainty that would accompany the construction of such models (if constructing them were even possible) would be difficult to support with available data at both the national and population level for many species.

3.2.4.3 Difficulties Distinguishing Causes of Population Changes

It is fundamentally difficult to demonstrate a causal relationship between a single stressor and changes in fish population sizes. Fish populations are affected by multiple nonlinear stressors and are constantly in flux. As such, determining whether changes to fish populations are the consequence of an identifiable stressor due to natural fluctuation around an equilibrium stock size is difficult. Fish recruitment, the number of young fish surviving early life stages (e.g., egg, larvae, juvenile) to join an adult population, is a multidimensional process, and identifying and distinguishing the causes of variance in fish recruitment remains a fundamental problem in fisheries science, stock management, and impact assessment (Boreman 2000; Hilborn and Walters 1992; Quinn and Deriso 1999). Consequently, resolving issues of population fluctuation was beyond the scope and objectives of EPA's section 316(b) benefits analysis.

3.2.5 Extrapolation of IM&E to Develop Regional Estimates

EPA examined IM&E and the economic benefits of reducing these losses at a regional scale. EPA then aggregated estimated benefits across all regions to produce a national benefits estimate. Regions were based on regions used by fisheries management agencies such as the National Marine Fisheries Service (NMFS). The geographical scope of all regions is described in Chapter 1 (Section 1.2).

To obtain regional IM&E estimates, EPA extrapolated losses observed at 98 facilities with IM&E data (hereafter model facilities) to all regulated facilities within the same region. Extrapolation of IM&E rates was necessary because only a subset of all regulated facilities have conducted IM&E studies. To allow extrapolation, EPA assumed that all facilities, regardless of size, have similar IM&E rates after normalization by flow. IM&E data were extrapolated on the basis of operational flow, in millions of gallons per day (mgd), where mgd is the average operational flow over the period 1996-1998 as reported by facilities in response to EPA's Section 316(b) Detailed Questionnaire and Short Technical Questionnaire (USEPA 2000). Operational flow at all facilities was scaled using a multiplicative factor that reflected the effectiveness of in-place technologies used to reduce IM&E. During the extrapolation procedure, EPA also applied weighting factors to regulated facilities based on questionnaire results. Weighting factors for the current analysis were based on results of the Detailed Questionnaire. Additional details of EPA's extrapolation methods are provided in Appendix A.

The assumption that IM&E is proportional to flow is consistent with other published IM&E studies and models. Power facilities on the Great Lakes exhibit an increasing relationship (on a log-log scale) between facility size (measured as electrical output) and IM&E rates (Kelso and Milburn 1979), and Goodyear (1978) predicted entrainment on the basis of the ratio of cooling water flow to source water flow. Additionally, the Spawning and Nursery Area of Consequence (SNAC) model, used as a screening tool for assessing potential IM&E impacts at Chesapeake Bay facilities, assumes that entrainment is proportional to cooling water withdrawal rates (Polgar et al. 1979).

EPA recognizes that actual IM&E per mgd may vary substantially, resulting from a variety of time- and facility-specific features, such as sampling date, location and type of intake structure, as well as from ecological features that affect the abundance and species composition of fish in the vicinity of each facility. Consequently, EPA's extrapolation procedure relies heavily on the assumption that IM&E rates recorded at model facilities are representative of IM&E rates at other facilities in the region. Although this assumption may not be met in some cases, limiting the extrapolation procedure within regions reduces the likelihood that model facilities are unrepresentative.

This method of extrapolation makes the best use of a limited amount of empirical data, and is the only feasible approach for developing a national estimate of IM&E, and the associated benefits of IM&E reduction. While acknowledging that extrapolation introduces uncertainty into IM&E estimates, EPA has not identified information suggesting a systematic bias in regional loss estimates based upon extrapolation.

3.3 IM&E by Region

3.3.1 California Region

Table 3-1 and Table 3-2 present estimated baseline IM&E and reductions in IM&E under the final rule and other options considered. Estimated total baseline IM&E in the California region is 51.55 million A1Es per year, of which 24.56 million (47.6 percent) are forage fish. Approximately 5.6 percent of total baseline A1E mortality is assigned a direct use value from recreational or commercial fishing (Table 3-1). Table 1 of Appendix C presents species-specific data on impingement and entrainment under the baseline conditions and estimated reductions under all options. Among commercially and recreationally-harvested species, the greatest losses occur in crabs, rockfishes, and sea basses (Appendix Table C-1).

The majority of IM&E in the California region occur due to entrainment (Appendix C Table 1). Because the final rule and Proposal Option 4 do not reduce entrainment, they each reduce baseline A1E mortality by only 1.4 percent (0.73/51.55) and 1.3 percent (0.68/51.55), respectively (Table 3-1). Conversely, by requiring the installation of closed-cycle recirculating systems, which effectively reduce entrainment mortality, Proposal Option 2 reduces A1E mortality by 61.1 percent (31.52/51.55), providing more than 40 times the reduction in A1E mortality (Table 3-1).

Table 3-1: Summary of Baseline IM&E at All Regulated facilities (Manufacturing and Generating) in California, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
All Species (million A1E)	0.68	0.73	31.52	51.55
Forage Species (million A1E)	0.17	0.18	15.00	24.56
Commercial & Recreational Species (million A1E)	0.50	0.54	16.52	26.98
Commercial & Recreational Harvest (million fish)	0.05	0.06	1.76	2.88
A1E Losses with Direct Use Value (%)	8.0%	8.0%	5.6%	5.6%

Source: U.S. EPA analysis for this report

Production forgone due to baseline IM&E is estimated to be 19.65 million pounds of fish, leading to a decrease in fishery yield of 4.59 million pounds per year (Table 3-2). The final rule is estimated to result in increased fishery yields of 0.02 million pounds per year. Increases in fishery yields under other options considered range from 0.02 million pounds per year under Proposal Option 4 to 2.80 million pounds per year under Proposal Option 2. Estimated increases in fishery yields under Proposal Option 2 are more than 100 times greater than under the final rule and Proposal Option 4 (Table 3-2).

Table 3-2: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of IM&E at All Regulated facilities (Manufacturing and Generating) in California, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (million per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
Forgone Fishery Yield (lbs)	0.02	0.02	2.80	4.59
Forgone Commercial Catch (lbs)	<0.01	<0.01	1.18	1.93
Forgone Recreational Catch (fish)	0.04	0.04	0.88	1.43
Production Forgone (lbs)	0.09	0.10	12.00	19.65

Source: U.S. EPA analysis for this report

Raw numbers of IM&E in California can be found in Appendix Table C-2.

3.3.2 North Atlantic Region

Table 3-3 and Table 3-4 present estimated baseline IM&E and reductions in IM&E under the final rule and other options considered. Estimated total baseline IM&E in the North Atlantic region is 57.86 million A1Es per year, 78.4 percent (45.34 million) of which are forage fish. Approximately 2.1 percent of total baseline A1E mortality is assigned a direct use value from recreational or commercial fishing (Table 3-3). Table 3 of Appendix C presents species-specific data on impingement and entrainment under the baseline conditions and estimated reductions under all options. Briefly, the vast majority (99.0 percent) of all A1E mortality in the North Atlantic occur as a consequence of entrainment mortality (Appendix Table C-3). Notably, the combined IM&E of winter flounder, cunner, and sculpins account for 96.9 percent of all IM&E of commercially and recreationally-harvested species.

Because the final rule and Proposal Option 4 do not reduce entrainment, they reduce baseline IM&E A1E mortality by 1.6 percent (0.93/57.86) and 0.7 percent (0.40/57.86), respectively (Table 3-3). Conversely, by requiring the installation of closed-cycle recirculating systems, which effectively reduce entrainment mortality, Proposal Option 2 reduces A1E mortality by 76.7 percent (44.40/57.86) (Table 3-3).

Table 3-3: Baseline IM&E and IM&E Reductions at All Regulated Facilities (Manufacturing and Generating) in the North Atlantic, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
All Species (million A1E)	0.40	0.93	44.40	57.86
Forage Species (million A1E)	0.35	0.77	34.80	45.34
Commercial & Recreational Species (million A1E)	0.05	0.16	9.60	12.52
Commercial & Recreational Harvest (million fish)	<0.01	0.02	0.91	1.19
A1E Losses with Direct Use Value (%)	1.5%	1.8%	2.1%	2.1%

Source: U.S. EPA analysis for this report

Production forgone due to baseline IM&E is estimated to be 26.03 million pounds of fish, leading to a decrease in fishery yield of 0.98 million pounds per year (Table 3-4). The final rule will result in increased fishery fields of 0.01 million pounds per year. Increases in fishery yields under other options considered range from less than 0.01 million pounds under Proposal Option 4 to 0.75 million pounds under Proposal Option 2. Estimated increases in fishery yields under Proposal Option 2 are more than 75 times greater than under the final rule and Proposal Option 4 (Table 3-4).

Table 3-4: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of IM&E at All Regulated Facilities (Manufacturing and Generating) in the North Atlantic, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (million per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
Forgone Fishery Yield (lbs)	<0.01	0.01	0.75	0.98
Forgone Commercial Catch (lbs)	<0.01	<0.01	0.33	0.43
Forgone Recreational Catch (fish)	<0.01	<0.01	0.56	0.73
Production Forgone (lbs)	0.03	0.26	19.93	26.03

Source: U.S. EPA analysis for this report

Raw numbers of IM&E in the North Atlantic can be found in Appendix Table C-4.

3.3.3 Mid-Atlantic Region

Table 3-5 and Table 3-6 present estimated baseline IM&E and reductions in IM&E under the final rule and other options considered. Estimated total baseline IM&E in the Mid-Atlantic region is 630.97 million A1Es per year, including 475.89 million A1Es of forage fish (75.4 percent). Approximately 3.3 percent of total baseline A1E mortality are assigned a direct use value from recreational or commercial fishing (Table 3-5). Table 5 of Appendix C presents species-specific data on impingement and entrainment under the baseline conditions and estimated reductions under all options. Briefly, the vast majority (93.8 percent) of all A1E mortality in the Mid-Atlantic occur as a consequence of entrainment mortality. Nearly half (44.7 percent) of the IM&E estimated for commercially- and recreationally-harvested species occurs in Blue Crab, and substantial IM&E (i.e., greater than 13 million A1E) is estimated for Atlantic Croaker, Atlantic Menhaden, Spot, and White Perch.

Because of the high proportion of IM&E attributed to entrainment mortality, EPA estimates that the final rule and Proposal Option 4 reduce A1E mortality by 5.2 percent (32.99/630.97) and 4.8 percent (30.50/630.97), respectively (Table 3-5). Conversely, by requiring the installation of closed-cycle recirculating systems, Proposal Option 2 would reduce A1E mortality by approximately 87.4 percent (551.90/630.97).

Table 3-5: Baseline IM&E and IM&E Reductions at All Regulated Facilities (Manufacturing and Generating) in the Mid-Atlantic, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
All Species (million A1E)	30.50	32.99	551.90	630.97
Forage Species (million A1E)	11.63	12.75	415.46	475.89
Commercial & Recreational Species (million A1E)	18.87	20.25	136.44	155.08
Commercial & Recreational Harvest (million fish)	4.68	5.01	18.20	20.51
A1E Losses with Direct Use Value (%)	15.3%	15.2%	3.3%	3.3%

Source: U.S. EPA analysis for this report

EPA projects that baseline IM&E reduces fishery production by 52.74 million pounds, and decreases fishery yield by 15.07 million pounds per year (Table 3-6). The final rule will result in increased fishery yields of 3.89 million pounds per year. Increases in fishery yields under other options considered range from 3.63 million pounds per year under Proposal Option 4 to 13.38 million pounds per year under Proposal Option 2. Estimated increases in fishery yields under Proposal Option 2 are more than three times greater than under the final rule and Proposal Option 4 (Table 3-6).

Table 3-6: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of IM&E at All Regulated Facilities (Manufacturing and Generating) in the Mid-Atlantic, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (million per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
Forgone Fishery Yield (lbs)	3.63	3.89	13.38	15.07
Forgone Commercial Catch (lbs)	2.87	3.07	7.17	8.00
Forgone Recreational Catch (fish)	0.43	0.46	5.10	5.82
Production Forgone (lbs)	7.83	8.40	46.50	52.74

Source: U.S. EPA analysis for this report

Raw numbers of IM&E in the Mid-Atlantic region can be found in Appendix Table C-6.

3.3.4 South Atlantic Region

Table 3-7 and Table 3-8 present estimated baseline IM&E and reductions in IM&E under the final rule and other options considered. Estimated total baseline IM&E in the South Atlantic region is estimated to be 26.36 million A1Es per year, including 24.61 million forage fish A1Es. Approximately 1.1 percent of total baseline A1E mortality is assigned a direct use value from recreational or commercial fishing (Table 3-7). Table 7 of Appendix C presents species-specific data on impingement and entrainment under the baseline conditions and estimated reductions under all options. Unlike other regions, the majority (65.0 percent) of all A1E mortality in the South Atlantic occur as a consequence of impingement mortality. Among commercially- and recreationally-harvested species, IM&E is greatest in Drums and Croakers and Blue Crab.

Due to the high proportion of IM&E lost to impingement, the final rule and Proposal Option 4 are projected to reduce A1E mortality by 49.1 percent (12.93/26.36) and 44.0 percent (11.61/26.36), respectively. However, because the installation of closed-cycle recirculating systems reduces water usage, Proposal Option 2 is projected to reduce A1E mortality by 97.1 percent (25.60/26.36) (Table 3-7).

Table 3-7: Baseline IM&E and IM&E Reductions at All Regulated Facilities (Manufacturing and Generating) in the South Atlantic, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
All Species (million A1E)	11.61	12.93	25.60	26.36
Forage Species (million A1E)	10.98	12.21	23.91	24.61
Commercial & Recreational Species (million A1E)	0.63	0.72	1.69	1.75
Commercial & Recreational Harvest (million fish)	0.09	0.10	0.27	0.28
A1E Losses with Direct Use Value (%)	0.7%	0.8%	1.0%	1.1%
Source: U.S. EPA analysis for this report				

Production forgone due to baseline IM&E is estimated to be 0.71 million pounds per year, leading to a decrease in fishery yield of approximately 0.12 million pounds per year. The final rule will increase fishery yields of 0.05 million pounds per year. Increases in fishery yields under other options considered range from 0.04 million pounds per year under Proposal Option 4 to 0.12 million pounds per year under Proposal Option 2. Estimated increases in fishery yields under Proposal Option 2 are more than two times greater than under the final rule and Proposal Option 4 (Table 3-8).

Table 3-8: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of IM&E at All Regulated Facilities (Manufacturing and Generating) in the South Atlantic, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (million per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
Forgone Fishery Yield (lbs)	0.04	0.05	0.12	0.12
Forgone Commercial Catch (lbs)	0.04	0.04	0.08	0.08
Forgone Recreational Catch (fish)	0.01	0.02	0.10	0.11
Production Forgone (lbs)	0.12	0.15	0.67	0.71
Source: U.S. EPA analysis for this report				

Raw numbers of IM&E in the South Atlantic region can be found in Appendix Table C-8.

3.3.5 Gulf of Mexico Region

Table 3-9 and Table 3-10 present the estimated baseline IM&E and reductions in IM&E under the final rule and other options considered. Estimated total baseline IM&E in the Gulf of Mexico is estimated to be

147.01 million A1Es per year, including 50.15 million forage fish A1Es. Approximately 8.8 percent of total baseline A1E mortality are assigned a direct use value from recreational or commercial fishing (Table 3-9). Table 9 of Appendix C presents species-specific data on impingement and entrainment under the baseline conditions and estimated reductions under all options. The majority (63.6 percent) of all A1E mortality in the Gulf of Mexico occur as a consequence of entrainment mortality. Among commercially- and recreationally-harvested species, IM&E is greatest in Blue Crab, and Pink Shrimp, which together account for 67.8 percent of A1E mortality with direct use value. Other commercially- or recreationally-harvested fish species with substantial IM&E (i.e., greater than 5 million A1E) include Black Drum, Menhaden, and Silver Perch (Appendix Table C-9).

Due to the low proportion of IM&E lost to impingement, the final rule and Proposal Option 4 are projected to reduce A1E mortality by 27.4 percent (40.29/147.01) and 26.4 percent (38.82/147.01), respectively. In contrast, Proposal Option 2 is estimated to reduce A1E mortality by 70.3 percent (103.42/147.01) (Table 3-9), nearly triple the estimated reductions of the final rule or Proposal Option 4.

Table 3-9: Baseline IM&E and IM&E Reductions at All Regulated Facilities (Manufacturing and Generating) in the Gulf of Mexico, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
All Species (million A1E)	38.82	40.29	103.42	147.01
Forage Species (million A1E)	4.88	5.06	31.69	50.15
Commercial & Recreational Species (million A1E)	33.94	35.22	71.73	96.86
Commercial & Recreational Harvest (million fish)	5.15	5.35	9.83	12.92
A1E Losses with Direct Use Value (%)	13.3%	13.3%	9.5%	8.8%
Source: U.S. EPA analysis for this report				

Production forgone due to baseline IM&E is estimated to be 79.65 million pounds per year, 43.3 percent of which is forgone fishery yield. The final rule will result in increased fishery yields of 3.51 million pounds per year. Increases in fishery yields under other options considered range from 3.38 million pounds per year under Proposal Option 4 to 21.78 million pounds per year under Proposal Option 2. Estimated increases in fishery yields under Proposal Option 2 are more than six times greater than under the final rule and Proposal Option 4 (Table 3-10).

Table 3-10: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of IM&E at All Regulated Facilities (Manufacturing and Generating) in the Gulf of Mexico, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (million per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
Forgone Fishery Yield (lbs)	3.38	3.51	21.78	34.45
Forgone Commercial Catch (lbs)	1.64	1.70	4.27	6.03
Forgone Recreational Catch (fish)	0.75	0.78	2.14	3.08
Production Forgone (lbs)	6.54	6.78	49.81	79.65
Source: U.S. EPA analysis for this report				

Raw numbers of IM&E in the Gulf of Mexico can be found in Appendix Table C-10.

3.3.6 Great Lakes Region

Table 3-11 and Table 3-12 present estimated baseline IM&E and reductions in IM&E under the final rule and other options considered. Estimated total baseline IM&E in the Great Lakes is 261.26 million A1Es per year, including 240.01 million A1E of forage fish. Approximately 1.7 percent of total baseline A1E mortality is assigned a direct use value from recreational or commercial fishing (Table 3-11). Table 11 of Appendix C presents species-specific data on impingement and entrainment under the baseline conditions and estimated reductions under all options. Briefly, among commercially and recreationally-harvested species, the greatest losses occur in Smelts.

The vast majority (90.6 percent) of IM&E in the Great Lakes occur due to impingement (Appendix Table C-11). Accordingly, the final rule and Proposal Option 4 are projected to reduce baseline A1E mortality by 81.5 percent (202.58/248.47) and 70.4 percent (184.04/261.26), respectively (Table 3-11). By requiring the installation of closed-cycle recirculating systems, which reduce the volume of water required for cooling purposes, Proposal Option 2 reduces A1E mortality by 95.1 percent (248.47/261.26) (Table 3-11).

Table 3-11: Baseline IM&E and IM&E Reductions at All Regulated Facilities (Manufacturing and Generating) in the Great Lakes, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
All Species (million A1E)	184.04	202.58	248.47	261.26
Forage Species (million A1E)	175.88	193.58	230.50	240.01
Commercial & Recreational Species (million A1E)	8.16	9.00	17.97	21.25
Commercial & Recreational Harvest (million fish)	2.58	2.84	3.98	4.35
A1E Losses with Direct Use Value (%)	1.4%	1.4%	1.6%	1.7%
Source: U.S. EPA analysis for this report				

Production forgone due to baseline IM&E is estimated to be 63.28 million pounds of fish, leading to a decrease in fishery yield of 4.14 million pounds per year (Table 3-12). The final rule will result in increased fishery yields of 2.69 million pounds per year. Increases in fishery yields under other options considered range from 2.44 million pounds per year under Proposal Option 4 to 3.78 million pounds per year under Proposal Option 2. Estimated increases in fishery yields under Proposal Option 2 are over 40 percent greater than under the final rule or Proposal Option 4 (Table 3-12).

Table 3-12: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of IM&E at All Regulated Facilities (Manufacturing and Generating) in the Great Lakes, and Reductions Under the Final Rule and Other Options Considered				
IM&E Loss Metric (million per year)	**Reductions in Losses**			**Baseline Losses**
	Proposal Option 4	**Final Rule**	**Proposal Option 2**	
Forgone Fishery Yield (lbs)	2.44	2.69	3.78	4.14
Forgone Commercial Catch (lbs)	1.12	1.24	1.70	1.84
Forgone Recreational Catch (fish)	1.33	1.47	2.04	2.23
Production Forgone (lbs)	30.67	33.79	55.61	63.28
Source: U.S. EPA analysis for this report				

Raw numbers of IM&E in the Great Lakes region can be found in Appendix Table C-12.

3.3.7 Inland Region

Table 3-13 and Table 3-14 present estimated baseline IM&E and reductions in IM&E under the final rule and other options considered. Estimated total baseline IM&E in the Inland region is 755.97 million A1Es per year, including 599.13 million A1E of forage fish. Approximately 1.6 percent of total baseline A1E mortality is assigned a direct use value from recreational or commercial fishing (Table 3-13). Table 13 of Appendix C presents species-specific data on impingement and entrainment under the baseline conditions and estimated reductions under all options. Briefly, the majority (63.0 percent) of all A1E mortality in the Inland region occur as a consequence of impingement mortality (Appendix Table C-13). Notably, the IM&E of sunfish account for 78.4 percent of the IM&E of recreationally-harvested species.

The final rule and Proposal Option 4 are projected to reduce baseline A1E mortality by 47.8 percent (361.55/755.97) and 46.0 percent (348.12/755.97), respectively (Table 3-13). The installation of closed-cycle recirculating systems under Proposal Option 2 reduces A1E mortality by 83.6 percent (632.19/755.97), providing a benefit more than 70 percent larger than the benefits of the final rule or Proposal Option 4 (Table 3-13).

Table 3-13: Baseline IM&E and IM&E Reductions at All Regulated Facilities (Manufacturing and Generating) in the Inland Region, and Reductions Under the Final Rule and Other Options Considered				
IM&E Loss Metric (per year)	**Reductions in Losses**			**Baseline Losses**
	Proposal Option 4	**Final Rule**	**Proposal Option 2**	
All Species (million A1E)	348.12	361.55	632.19	755.97
Forage Species (million A1E)	324.34	336.25	507.31	599.13
Commercial & Recreational Species (million A1E)	23.79	25.31	124.88	156.84
Commercial & Recreational Harvest (million fish)	3.57	3.73	9.70	11.90
A1E Losses with Direct Use Value (%)	1.0%	1.0%	1.5%	1.6%
Source: U.S. EPA analysis for this report				

The decrease in production due to baseline IM&E is estimated to be 384.55 million pounds of fish, leading to a decrease in fishery yield of 10.41 million pounds per year (Table 3-14). The final rule will result in increased fishery yields of 3.25 million pounds per year. Increases in fishery yield under other options considered range from 3.11 million pounds per year under Proposal Option 4 to 8.48 million pounds per year under Proposal Option 2. Estimated increases in fishery yields under Proposal Option 2 are over two times greater than under the final rule and Proposal Option 4 (Table 3-14).

Table 3-14: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of IM&E at All Regulated Facilities (Manufacturing and Generating) in the Inland Region, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (million per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
Forgone Fishery Yield (lbs)	3.11	3.25	8.48	10.41
Forgone Commercial Catch (lbs)	<0.01	<0.01	<0.01	<0.01
Forgone Recreational Catch (fish)	3.57	3.73	9.70	11.90
Production Forgone (lbs)	84.97	89.40	309.65	384.55
Source: U.S. EPA analysis for this report				

Raw numbers of IM&E in the Inland region can be found in Appendix Table C-14.

3.3.8 National Estimates

Table 3-15 and Table 3-16 present estimated baseline IM&E and reductions in IM&E under the final rule and other options considered. Estimated total baseline IM&E nationally is 1,930.97 million A1Es per year, including 1,459.70 million A1E of forage fish. Approximately 2.8 percent of total baseline A1E mortality is assigned a direct use value from recreational or commercial fishing (Table 3-15). Table 15 of Appendix C presents species-specific data on impingement and entrainment under the baseline conditions and estimated reductions under all options. Briefly, the majority (57.3 percent) of all A1E mortality nationally occur as a consequence of entrainment mortality (Appendix Table C-15).

The final rule and Proposal Option 4 are projected to reduce baseline A1E mortality by 33.8 percent (652.00/1,930.97) and 31.8 percent (614.16/1,930.97), respectively (Table 3-15). The installation of closed-cycle recirculating systems under Proposal Option 2 reduces A1E mortality by 84.8 percent (1,637.49/1,930.97), providing a benefit more than twice as large as the benefits of the final rule or Proposal Option 4 (Table 3-15).

Table 3-15: Baseline IM&E and IM&E Reductions at All Regulated Facilities (Manufacturing and Generating) Nationally, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
All Species (million A1E)	614.16	652.00	1637.49	1930.97
Forage Species (million A1E)	528.22	560.80	1258.67	1459.70
Commercial & Recreational Species (million A1E)	85.94	91.20	378.82	471.28
Commercial & Recreational Harvest (million fish)	16.13	17.11	44.66	54.02
A1E Losses with Direct Use Value (%)	2.6%	2.6%	2.7%	2.8%
Source: U.S. EPA analysis for this report				

The decrease in production due to baseline IM&E is estimated to be 626.60 million pounds of fish, leading to a decrease in fishery yield of 69.76 million pounds per year (Table 3-16). The final rule is estimated to result in an increased fishery yield 13.42 million pounds per year. Increases in fishery yields under other options considered range from 12.63 million pounds per year under Proposal Option 4 to 51.11 million pounds per year under Proposal Option 2. Estimated increases in fishery yields under Proposal Option 2 are nearly four times greater than under than final rule or Proposal Option 4 (Table 3-16).

Table 3-16: Baseline Losses in Fishery Yield, Catch, and Production Forgone as a Consequence of IM&E at All Regulated Facilities (Manufacturing and Generating) Nationally, and Reductions Under the Final Rule and Other Options Considered

IM&E Loss Metric (million per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
Forgone Fishery Yield (lbs)	12.63	13.42	51.11	69.76
Forgone Commercial Catch (lbs)	5.68	6.07	14.72	18.32
Forgone Recreational Catch (fish)	6.13	6.50	20.53	25.31
Production Forgone (lbs)	130.25	138.89	494.17	626.60

Source: U.S. EPA analysis for this report

Raw numbers of national IM&E can be found in Appendix Table C-16.

3.4 Limitations and Uncertainties

Four major kinds of uncertainty may lead to imprecision and bias in EPA's IM&E analysis: data, structural, statistical, and engineering uncertainty. Data limitations and uncertainty refers to uncertainty and inconsistency in sampling methodologies used in facility-specific IM&E studies. Structural uncertainty reflects the simplification built into any model of a complex natural system. Parameter uncertainty refers to uncertainty in the numeric estimates of model parameters. Finally, engineering uncertainty refers to the fact that facilities do not operate in the exact same manner on an annual basis.

3.4.1 Data Limitation and Uncertainty

EPA based its quantification of regional and national IM&E on cumulative data generated by collection at individual facilities. In turn, these data are heterogeneous products of location-specific investigations set in differing geographic and ecological provinces. Interpretation of the significance and trends of IM&E at regional and national scales (and of the accompanying ecological benefits upon mitigation) must consider the strengths and weaknesses of this data.

The IM&E data from model facilities constitute a heterogeneous composite of results from many facility-specific studies. Sampling effort and data quality control vary tremendously among IM&E studies and baseline source water characterization programs. There is little uniformity among studies as to the intensity, frequency and duration of data collection as well as the scope of target biota collected, identified, and enumerated. Sampling regimes may be properly adjusted to ensure that changes in local biotic activity associated with diurnal, tidal, and lunar cycles are incorporated; or may reflect regularly spaced sampling points with little concern paid to capturing environmental variability.

In addition to the differences in environmental scope, sampling methods are not uniform among studies with regard to the types and meshes of sampling nets, deployment location of sampling nets (e.g., outside or within the intake structure), length and weight measurements, observations of field conditions, characterization of reference areas, etc. In addition to different sampling methods and timing, some sampling programs are designed primarily to estimate IM&E for a select suite of recreational or commercially important aquatic organisms. Studies differ in their taxonomic sorting classes and specificity of identification of impinged and entrained organisms (e.g., eggs, ichthyoplankton, zooplankton, etc.). Thus, many IM&E studies are poorly suited to provide insight into the direct and indirect impacts to forage fish species, non-vertebrate organisms (zooplankton, tunicates, algae, worms, etc.), or community/ecosystem impacts. For older facilities, sampling data commonly lack pre-operational (i.e., baseline) samples or community surveys to compare to the results of more-current IM&E data. Finally, few IM&E studies are designed to allow evaluation of community impacts or ecosystem effects (Section 2.4).

Within regions, studies of IM&E from model facilities are typically composed of data from a relatively limited number of facilities. Most facility-specific IM&E studies are limited to one or two years, and are rarely replicated within a time period that allows direct comparison of trends without historical complications due to fishery stock trends, climatic changes, or shifts in collection methods or water quality. Thus, studies within a regional database may not accurately represent average climatic and oceanographic conditions (e.g., El Nino years). Additionally, studies within the database may include historical (>20 years ago) and recent data, thus incorporating considerable uncertainty due to the annual variability of highly dynamic fish stocks. Thus, extrapolation from regional collections of facility-specific studies may not provide a true regional estimate because the available data may or may not be fully representative of regional trends and/or of associated ecological benefits derived from mitigating IM&E impacts.

3.4.2 Structural Uncertainty

The models EPA used to evaluate IM&E simplify complex processes. The degree of simplification is substantial, but necessary, because of limited data availability and the need to generate estimates on a national scale. Simplification occurs with respect to many processes within the model, to ensure computational tractability and national applicability (Table 3-17).

While EPA recognizes these uncertainties, addressing each of these uncertainties in a defensible way would require data that does not currently exist (see Section 3.2.4.2), would be time-consuming and resource-intensive to develop, and could lead to greater parameter uncertainty (Section 3.4.3).

Table 3-17: Structural Uncertainties

Aspect of Model	General Description	Specific Treatment in Model
Biological submodels	Life history traits are fixed	Life history parameters in the models (i.e., growth, survival) are constant through time and are thus independent of biological conditions (e.g., fish densities, seasonality, weather, recruitment variability, food availability, fisheries pressure, etc.).
	No trophic effects	Indirect food web effects such as trophic cascades, growth and population limitations due to a lack of food, etc., are not considered. Trophic transfer is treated simplistically.
	Outside impacts not addressed	IM&E loss rates are affected by a variety of outside influences not included in the model (e.g., fisheries pressure, pollution, future development, invasive species, climate change, etc.).
Valuation structure	National nonuse benefits	Fish species grouped into two categories: harvested or not harvested (i.e., forage for harvested species). Harvested fish are assigned use values within the national analysis. EPA used benefit transfer to estimate nonuse values for the North Atlantic and Mid-Atlantic regions (Chapter 8). Nonuse values for other regions are not included in the comparison of benefits and costs for the final rule. EPA also conducted a stated preference survey to assess total values (Chapter 10). EPA, however, did not include survey estimates in its benefits totals for the rule but the estimates illustrate the potential magnitude of total values.
	Fishing pressure constant	The valuation procedure assumes that fisheries harvests will increase proportionately to decreases in IM&E, independent of Federal and State policies on commercial and recreational fishing (i.e., fisheries quotas, closures, bag limits, etc.).

3.4.3 Parameter Uncertainty

Parameter uncertainty refers to variability in the value of parameters used in biological and economic modeling. EPA must estimate all parameters from sampling studies that cannot identify the true values of interest due to statistical and logistical limitations. These limitations are broadly driven by three processes, including parameter fluctuation through time, geographic location, and sampling.

The true value of many biological parameters fluctuates on an annual basis, due to changes in weather, food availability, indirect food-web effects, and compensatory population dynamics. Consequently, parameter values used within biological submodels, despite being based upon the best available data obtained from the scientific literature, cannot be without error due to annual variability in fish growth and (natural and fisheries) mortality rates. Similarly, because IM&E rates are driven by a combination of intake flow and the presence of vulnerable fish, actual IM&E cannot remain constant through time.

True values of biological parameters and facility IM&E vary geographically. Biological parameters may vary substantially within regions due to changes in substrate, water temperature and salinity, etc., while facility IM&E data may be strongly connected to local substrates, distance from shore, depth, etc. It follows, then, that using biological data and extrapolating facility-specific IM&E rates to the regional scale will result in parameter variability based solely on geographic considerations.

Finally, all model parameters contain uncertainty because they are small samples taken from a much larger dataset. Biological parameters such as mortality rates must be estimated using incomplete sampling data. Facility-reported IM&E studies necessarily subsample cooling water, and often do not take replicate samples across tidal periods, seasons, time of day, and between years. Moreover, these studies often present IM&E with limited taxonomic detail (i.e., the identification of eggs, larvae, and juveniles is not species-specific), and do not have standard methodologies. As is the case with retrospective data, these studies also reflect the biological and physical state of the waterbody when studies were conducted. In some cases, the state of the waterbody itself has changed substantially since sampling was conducted.

EPA recognizes many sources of parameter uncertainty in its models (Table 3-18), all of which lead to uncertainty in point estimates of IM&E. The nature of these uncertainties, however, does not inherently bias the point estimate. EPA reported all biological and physical parameters in good faith, and as such, parameter estimates are unlikely to be biased in aggregate, but distributed both above and below true parameter values. Thus, parameter uncertainty has resulted in imprecision rather than inaccuracy in model output.[12]

3.4.4 Engineering Uncertainty

EPA's evaluation of IM&E was also affected by uncertainty about the engineering and operating characteristics of the study facilities. It is unlikely that facility operating characteristics (e.g., seasonal, diurnal, or intermittent changes in intake water flow rates) are constant throughout any particular year. As such, the timing of sampling, and the annual repeatability of IM&E, may be biased by facility operating conditions. EPA assumed that the facilities' loss estimates were provided in good faith and did not include any biases or omissions that significantly modified loss estimates.

[12] Accuracy refers to the degree of closeness of model results to the actual value. Precision refers to the reproducibility of model output, or the degree to which repeated measurements (or samples, for example from different model facilities) under similar conditions will result in the same model output.

Table 3-18: Parameters Included in EPA's IM&E Analysis Subject to Uncertainty		
Model Aspect	**Parameter**	**Description**
IM&E monitoring /loss rate estimates	Sampling regimes	Sampling regimes are subject to numerous facility-specific details. No established guidelines or performance standards for how to design and conduct sampling regimes. Not all sampling studies measured both impingement and entrainment mortality.
	Extrapolation assumptions	Extrapolation of monitoring data to annual IM&E rates assumes sampling occurred under average conditions, and that diurnal/seasonal/annual cycles in fish presence and vulnerability and various technical factors (e.g., net collection efficiency; hydrological factors affecting IM&E rates) do not play a substantial role in the accuracy of extrapolation. No established guidelines or consistency in sampling regimes.
	Species selection	Criteria for the selection of species evaluated in IM&E studies are neither well-defined nor uniform across facilities. At many facilities, IM&E data was collected for only a subset of species, usually only fish and shellfish.
	Sensitivity of fish to IM&E	Entrainment mortality was assumed by EPA to be 100 percent. Back-calculations were done in cases where facilities reported entrainment rates that assumed <100 percent mortality. These calculations were limited by data reporting (i.e., species-specific survival rates were not always provided). Impingement survival was included if presented in facility documents.
Biological/life history	Natural mortality rates	Natural mortality rates (M) difficult to estimate, and vary with time and geography. Model results are highly sensitive to M.
	Growth rates	Simple exponential growth rates or simple size-at-age parameters used, and assumed constant across all locations and years.
	Geographic considerations	Migration patterns; IM&E occurring during spawning runs or larval out-migration; location of harvestable adults; intermingling with other stocks.
	Forage valuation	Harvested species assumed to be food limited; trophic transfer efficiency to harvested species estimated by EPA based on general models; no consideration of trophic transfer to species not impinged and entrained.
Fish stock characteristics	Fishery yield	For most harvested species, only one species-specific value for fishing mortality rate (F) was used for all stages subject to harvest. Used stage-specific constants for fraction vulnerable to fishery.
	Harvest behavior	No assumed dynamics among harvesters to alter fishing rates or preferences in response to changes in stock size. Recreational access assumed constant (no changes in angler preferences or effort).
	Stock interactions	IM&E assumed to be part of reported fishery yield rates on a statewide basis. No consideration of possible substock harvest rates or interactions, no unreported catch.
Ecological system	Fish community	Long-term trends in fish community composition or abundance were not considered (general food webs assumed to be static), nor were indirect trophic interactions. Used constant value for trophic transfer efficiency, and specific trophic interactions were not considered. Trophic transfer to organisms not impinged and entrained is not considered.
	Spawning dynamics	Sampled years assumed to be typical with respect to choice of spawning areas and timing of migrations that could affect vulnerability to IM&E (e.g., presence of larvae in vicinity of intake structure).
	Hydrology	Sampled years assumed to be typical with respect to flow regimes and tidal cycles that could affect vulnerability to IM&E (e.g., presence of larvae in vicinity of CWIS).
	Meteorology	Sampled years assumed to be typical with respect to vulnerability to IM&E (e.g., presence of larvae in vicinity of intake structure).

4 Economic Benefit Categories

Changes in CWIS design or operations resulting from the final section 316(b) rule for regulated facilities are expected to reduce IM&E of fish, shellfish, and other aquatic organisms, thereby increasing the numbers of aquatic organisms and local and regional fishery populations.

The aquatic organisms affected by CWIS provide a wide range of ecosystem services. Ecosystem services are the physical, chemical, and biological functions performed by natural resources and the human benefits derived from those functions, including both ecological and human use services (Daily 1997; Daily et al. 1997). Scientific and public interest in protecting ecosystem services is increasing with the recognition that these services are vulnerable to a wide range of human activities and are difficult, if not impossible, to replace with human technologies (Meffe 1992).

In addition to their importance in providing food and other goods of direct use to humans, the organisms lost to IM&E are critical to the continued functioning of the ecosystems of which they are a part. Fish are essential for energy transfer in aquatic food webs, regulation of food web structure, nutrient cycling, maintenance of sediment processes, redistribution of bottom substrates, the regulation of carbon fluxes from water to the atmosphere, and the maintenance of aquatic biodiversity (Holmlund and Hammer 1999; Peterson and Lubchenco 1997; Postel and Carpenter 1997; Wilson and Carpenter 1999). Many of these ecosystem services can be maintained only by the continued presence of all life stages of fish and other aquatic species in their natural habitats. Section 2.3 provides detail on potential CWIS impacts on aquatic ecosystems, but because of inadequate data, EPA could not evaluate or monetize many of these impacts.

In addition to economic benefits categories associated with the reductions in IM&E, EPA also assessed benefits associated with changes in carbon dioxide (CO_2) emissions. EPA monetized these benefits based on the social cost of carbon. Social cost of carbon is an "estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year" and it "is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change" (Interagency Working Group 2010, p.1). The following sub-sections focus on benefits categories associated with IM&E reductions. See Chapter 9 for additional discussion of benefits from changes in emissions based on the social cost of carbon.

4.1 Economic Benefit Categories of the Rule

The economic benefits of reducing IM&E at regulated facilities stem from both market and nonmarket goods and services that the affected resources provide. These benefits can be divided into the following categories (Table 4-1, below).

- **Market benefits:** Market benefits are positive welfare impacts that can be quantified using money-denominated measures of consumer and producer surplus. The most obvious example of market benefits from reduced IM&E is benefits to commercial fisheries. Changes in IM&E will directly affect the price, quantity, and/or quality of fish harvests. The monetary value of the changes can be measured directly through market measures of consumer and producer behavior. Market benefits may be further categorized in terms of direct and indirect benefits. By definition, all market benefits are use benefits, as they involve either direct or indirect uses of goods or services.

- **Market direct use benefits:** These benefits are related to goods directly used, and bought and sold in markets; for example, fish caught for sale to consumers.
- **Market indirect use benefits:** These benefits occur through indirect or secondary effects on marketed goods and contribute indirectly to an increase in welfare for users of the resource. For example, an increase in the number of forage fish may increase the population of commercially valuable species, which are marketed to consumers. Thus, reducing IM&E of forage species can result in indirect welfare gains for commercial fishers and consumers who purchase fish.

- **Nonmarket benefits:** Nonmarket benefits consist of goods and services that are not traded in the marketplace, but are nonetheless positively affected by reduced IM&E. Higher catch rates for recreational fishing are a nonmarket benefit. Anglers place a high value on catching fish during their fishing trips, so higher catch rates from reduced IM&E will translate directly to greater utility from participation in recreational fishing. Because the monetary value of these improvements cannot be established by observing market transactions, nonmarket valuation techniques must be employed to estimate such benefits. Nonmarket benefits may be further categorized in terms of direct and indirect use benefits, and nonuse benefits.
  - **Nonmarket direct use benefits:** These benefits consist of goods and services that have direct uses, but are not traded in the marketplace. Higher catch rates for recreational fishing provide a typical nonmarket direct use benefit.
  - **Nonmarket indirect use benefits:** These benefits contribute indirectly to an increase the welfare of those who engage in nonmarketed uses of a resource. For example, positive impacts on local fisheries may generate an improvement in the population levels and diversity of fish-eating bird species. In turn, bird watchers might obtain greater enjoyment from their outings, as they are more likely to see a wider mix or greater numbers of birds. The increased welfare of the bird watchers is thus an indirect consequence of the initial impact on fish.
  - **Nonuse benefits:** These benefits occur when individuals value improved environmental quality without any past, present, or anticipated future use of the resource in question. Individuals may gain utility simply from knowing that a particular good exists (existence value), or from knowing that a good is available for others to use now and in the future (bequest value). Nonuse, or passive, benefits of reduced IM&E may include increased biodiversity, improved conditions for the recovery of T&E species that have no direct or indirect uses and welfare gains to nonusers when reduced IM&E to forage species improve overall ecosystem function.

Table 4-1 presents the benefit categories EPA considered for regulated facilities. The table also presents the various data needs, data sources, and estimation approaches associated with each category. A complete list of the ecosystem services potentially affected by reduction in IM&E is presented in Chapter 2 (Table 2-4).

In addition the approaches presented in Table 4-1, EPA developed and implemented an original stated preference (SP) study to estimate the total monetary value (use plus nonuse value) of aquatic resource improvements from the 316(b) rule.[13] EPA has not accounted for values estimated from the survey in the quantitative comparison of costs and benefits. EPA plans to obtain Science Advisory Board (SAB) review

13 SP surveys, in general, ask questions that elicit individuals' values for carefully specified changes in an environmental amenity (Freeman III 2003)

of the SP survey, and considers the inclusion of benefits based on the survey to be premature prior to the completion of the SAB review. Chapter 11 presents preliminary survey results to illustrate the potential magnitude of benefits.

Table 4-1: Summary of Benefit Categories, Data Needs, Potential Data Sources, Approaches, and Analyses Completed

Benefit Category	Basic Data Needs	Potential Data Sources/ Approaches/Analyses Completed
Market Goods, Direct Use		
➢ Increased commercial landings	➢ Estimated change in landings of specific species ➢ Estimated change in total economic impact	➢ Based on facility-specific IM&E data and ecological modeling. ➢ Changes in commercial fishery landings estimated using a market-based approach. ➢ Indirect economic impacts not estimated due to data constraints.
Market Goods, Indirect Use		
Increase in: ➢ Equipment sales, rental, and repair ➢ Bait and tackle sales ➢ Consumer market choices ➢ Choices in restaurant meals ➢ Property values near the water ➢ Ecotourism (charter trips, festivals, other organized activities with fees, such as riverwalks)	➢ Estimated change in landings of specific species ➢ Relationship between increased fish/shellfish landings and secondary markets ➢ Local activities and participation fees ➢ Estimated numbers of participating individuals	➢ Indirect market impacts not estimated due to data constraints such as lack of information on the relationship between increased fish/shellfish yield and secondary impacts.
Nonmarket Goods, Direct Use		
➢ Improved value of a recreational fishing trip due to increased catch of targeted/preferred species and incidental catch ➢ Improved value of subsistence fishing ➢ Value of additional recreational participation and additional fishing trips	➢ Value of an improvement in catch rate ➢ Estimated number of affected anglers or estimate of potential anglers ➢ Value of a fishing day	➢ Changes in the value of a recreational fishing trip estimated based on benefit transfer (including recreational use values of selected T&E species). ➢ Changes in the value of subsistence fishing not estimated. ➢ Number of affected anglers and increase in trips not estimated due to data constraints.

Table 4-1: Summary of Benefit Categories, Data Needs, Potential Data Sources, Approaches, and Analyses Completed

Benefit Category	Basic Data Needs	Potential Data Sources/ Approaches/Analyses Completed
Nonmarket Goods, Indirect Use		
➢ Increase in value of boating, scuba-diving, and near-water recreational experience from observing fish while boating, scuba-diving, hiking, or picnicking, and watching aquatic birds fish or catch aquatic invertebrates ➢ Increase in boating, scuba-diving, and near-water recreation participation	➢ Estimated number of affected near-water recreationists, divers, and boaters ➢ Value of boating, scuba-diving, and near-water recreation experience ➢ Value of a recreation day	➢ Increased trip value not estimated due to data constraints such as number of affected recreational users. ➢ Changes in recreational participation were not estimated. They are expected to be negligible at the regional level because fishery yield impacts are generally small.
Nonuse Goods		
Increase in nonuse values such as: ➢ Existence (stewardship) ➢ Altruism (interpersonal concerns) ➢ Bequest (interpersonal and intergenerational equity) motives ➢ Appreciation of the importance of ecological services apart from human uses or motives (Table 2-4)	➢ IM&E estimates ➢ Primary valuation research using stated preference approach ➢ Applicable studies upon which to conduct benefit transfer ➢ Location of CWIS and T&E species ranges	➢ Estimate nonuse values for an increase in relative fish abundance within two benefits regions using benefit transfer. Not estimated for other regions due to a lack of applicable studies. ➢ Used geographic information system (GIS) data to identify T&E species potentially impacted by CWIS based on the overlap of CWIS locations and T&E species ranges. ➢ EPA used the results of the 316(b) stated preference survey to illustrate total values for the 316(b) rule, including nonuse values. However, did not include estimates based on the 316(b) SP survey in its comparison of costs and benefits of the rule.

4.2 Market and Nonmarket Direct and Indirect Use Benefits from Reduced IM&E

Direct use benefits from reduced IM&E are the simplest to envision. The welfare of commercial, recreational, and subsistence fishers is improved when fish stocks increase, and catch rates rise or effort decreases. Higher catch rates increase the revenue and growth of commercial fisheries, the enjoyment of recreational fishing trips, and the availability of food for subsistence fishers—all of which are quantifiable benefits arising directly from changes in IM&E. Methodologies for estimating use values for recreational and commercial species are well developed, and some of the species affected by IM&E have been studied extensively. As a result, estimation of associated use values is often straightforward.

Indirect use benefits refer to welfare improvements for those individuals whose activities are enhanced as an indirect consequence of fishery or habitat improvements. For example, an improvement in the population of a forage fish species may be of no direct consequence to recreational or commercial fishers. However, the increased presence of forage fish will have an indirect effect on commercial and recreational fishing values if it increases food supplies for commercial and recreational predatory species. Thus, improvements in forage species populations can result in a greater number (and/or greater individual size) of those fish that are targeted directly by recreational or commercial fishers. In such an instance, the incremental increase in recreational and commercial fishing benefits would be an indirect consequence of the effect on forage fish populations.

The following sections discuss the benefits estimates presented in each chapter of this report, and techniques for estimating benefits of reduced IM&E for each category of benefits.[14]

4.2.1 Commercial Fisheries

Commercial fishing benefits include both direct and indirect market use values. The social benefits derived from increased landings by commercial fishers can be valued by examining the markets through which the landed fish are sold. The first step of the analysis involves a fishery-based assessment of IM&E-related changes in commercial landings (pounds of commercial species as sold dockside by commercial harvesters). The changes in landings are then valued according to market data from relevant fish markets (dollars per pound) to derive an estimate of the change in gross revenue to commercial fishers. The final steps entail converting the IM&E-related changes in gross revenues into estimates of social benefits. These social benefits consist of the sum of the producers' and consumers' surpluses that are derived as the changes in commercial landings work their way through the multi-market commercial fishery sector.

Indirect use values in markets occur through increases in commercial species caused by increased numbers of forage fish. An improvement in the population of a forage fish species may be of no direct consequence to commercial fishers. However, the increased presence of forage fish will have an indirect effect on commercial fishing values if it increases food supplies for commercial predatory species. Thus, improvements in forage species populations can result in a greater number (and/or greater individual size) of those fish that are targeted directly by commercial fishers. In such an instance, the incremental increase in commercial fishing benefits would be an indirect consequence of the final rule's effect on forage fish populations. See Chapter 3 for a discussion on the indirect influence of forage fish on abundance of commercial and recreational species.

Chapter 6 provides more detail on EPA's analysis of commercial fishing benefits from reducing IM&E at the regulated facilities' cooling water intakes.

4.2.2 Recreational Fisheries

Recreational fishing benefits include both direct and indirect nonmarket use values. Recreational use benefits cannot be tracked in the market because much of the recreational activity associated with these fisheries occurs as nonmarket events. However, a variety of nonmarket valuation methods exist for estimating use value, including both "revealed" and "stated" preference methods (Freeman III 2003). These methods use other observable behavior to infer users' value for environmental goods and services. Examples of revealed preference methods include travel cost, hedonic pricing, and random utility models. Compared to nonuse values, nonmarket use values are often considered relatively easy to estimate, due to their relationship to observable behavior, the variety of revealed preference methods available, and public familiarity with the recreational services that surface waterbodies provide.

To evaluate the recreational benefits of the regulatory options for regulated facilities, EPA developed a benefit transfer approach based on a meta-analysis of recreational fishing valuation studies. The analysis was designed to measure the various factors that determine WTP for catching an additional fish per trip.

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14 Many of the fish species affected by IM&E at CWIS sites are harvested both recreationally and commercially. To avoid double-counting the economic impacts of IM&E of these species, EPA determined, based on historic NMFS landings data, the proportions of total species landings attributable to recreational and commercial fishing, and applied these proportions to the total number of affected fish.

The estimated meta-model allows EPA to calculate the marginal value per fish for different species, based on resource and policy context characteristics.

Indirect use values for forage species occur through increases in recreational species caused by increased numbers of forage fish. An improvement in the population of a forage fish species may be of no direct consequence to recreational anglers. However, the increased presence of forage fish will have an indirect effect on recreational fishing values if it increases food supplies for recreational predatory species. Thus, improvements in forage species populations can result in a greater number (and/or greater individual size) of those fish that are targeted directly by recreational anglers. In such an instance, the incremental increase in recreational fishing benefits would be an indirect consequence of the effect on forage fish populations. See Chapter 3 for a discussion on the indirect influence of forage fish on abundance of commercial and recreational species.

Chapter 7 provides detail on the application of the meta-regression model EPA used to estimate recreational fishing benefits of the final rule and regulatory options it considered.

4.2.3 Subsistence Fishers

Subsistence fisheries benefits include both direct and indirect nonmarket use values. Subsistence use of fishery resources can be important in areas where socioeconomic conditions (e.g., the number of low-income households) or the mix of ethnic backgrounds make such fishing economically or culturally significant to a component of the community. In cases of Native American use of affected fisheries, the value of an improvement can sometimes be inferred from settlements in legal cases, e.g., compensation agreements between affected tribes and various government or other institutions in cases of resource acquisitions or resource use restrictions. For the general population, the value of improved subsistence fisheries may be estimated from the costs saved in acquiring alternative food sources. This method may underestimate the value of a subsistence fishery meal to the extent that the store-bought foods may be less preferred by some individuals than consuming a fresh-caught fish. Subsistence fishery benefits are not included in EPA's benefits regional analyses. Impacts on subsistence fishers may constitute an important environmental justice consideration, which could result in EPA underestimating the total benefits of the final rule and regulatory options it considered. EPA's Environmental Justice analysis is presented in Chapter 12 of the economic analysis of the final 316(b) rule (USEPA 2014a).

4.2.4 Benefits from Improved Protection to T&E Species

T&E and other special status species can be adversely affected in several ways by CWIS. T&E species can suffer direct harm from IM&E; they can suffer indirect impacts if IM&E at CWIS adversely affects another species upon which the T&E species relies within the aquatic ecosystem (e.g., as a food source); or they can suffer impacts if the CWIS disrupts their habitat (e.g., via thermal discharges). The loss of individuals of listed species from IM&E at CWIS is particularly important because, by definition, these species are already rare and at risk of irreversible decline because of other stressors.

Benefits from improved protection of T&E species can include both direct and indirect nonmarket use values, as well as nonuse values. EPA identified nine special status fish species, six in California and three in the Inland region, for which IM&E data were available. Due to their special status as well as the fact that most of these species have either very limited or no direct uses, the major portions of the value for T&E species are nonuse values. However, some of these species have potentially significant recreational and commercial use values, for example, sturgeon and paddlefish. EPA applied benefit transfer to estimate recreational use values for a subset of T&E species for which limited catch and release fisheries exist. EPA did not estimate potential commercial use values of these species due to the lack of market data.

Chapter 5 provides more detail on EPA's analysis of T&E species benefits from reducing IM&E at CWIS of regulated facilities.

4.3 Nonuse Benefits from Reduced IM&E

Comprehensive estimates of total resource value include both use and nonuse values, such that the resulting total value estimates may be compared to total social cost. Recent economic literature provides substantial support for the hypothesis that nonuse values, such as option and existence values, are greater than zero. In fact, small per capita nonuse values held by a substantial fraction of the population can be very large in the aggregate. "Nonuse values, like use values, have their basis in the theory of individual preferences and the measurement of welfare changes. According to theory, use values and nonuse values are additive" (Freeman III 1993).[15] Consequently, both EPA's own Guidelines for Preparing Economic Analysis and the Office of Management and Budget's (OMB) Circular A-4 governing regulatory analysis, support the need to assess nonuse values (USEPA 2010a; USOMB 2003). Excluding nonuse values from consideration is likely to understate substantially total social values.

Reducing IM&E of fish and shellfish may result in both use and nonuse benefits. Of the organisms that EPA anticipates will be protected by the section 316(b), only about 3 percent of A1E will eventually be harvested by commercial and recreational fishers, and therefore can be valued with direct use valuation techniques. The remainder, which were not assigned direct use value in this analysis, constitute the majority—97 percent—of the total estimated reductions in IM&E. Table 4-2 summarizes baseline IM&E and reductions in IM&E by four loss categories: all species, forage species, total commercial and recreational species, and harvested commercial and recreational species. Although unlanded forage fish contribute to the yield of harvested fish and therefore have an indirect use value that is captured by the direct use value of the commercial species, this indirect use value represents only a portion of the total value of unlanded fish. Society also values both landed and unlanded fish for reasons unrelated to use—for example, individual welfare may be affected simply by knowing these fish exist. Additionally, nonuse values are likely to be substantial because fish and other species found within aquatic habitats impacted directly and indirectly by CWIS provide other valuable ecosystem goods and services. These include nutrient cycling and ecosystem stability. Therefore, a comprehensive estimate of the welfare gain from reducing IM&E must include an estimate of nonuse benefits.

In contrast to direct and indirect use values, nonuse values are oftenmore difficult to estimate. SP methods, or benefit transfer based on SP studies, are the generally accepted techniques for estimating these values (USEPA 2010a; USOMB 2003). SP methods rely on carefully designed surveys, which either ask individuals about their WTP for particular ecological improvements, such as increased protection of aquatic species or habitats with particular attributes, or to choose among competing hypothetical "packages" of ecological improvements and household cost in which the choice implies WTP. In either case, values are estimated by statistical analysis of survey responses.

15 This additive property holds under traditional conditions related to resource levels and prices for substitute goods in the household production model (Freeman III 1993).

Table 4-2: Summary of Baseline National IM&E and Reductions in IM&E, for the Final Rule and Other Options Considered

IM&E Loss Metric (per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
All Species (million A1E)	614.16	652.00	1637.49	1930.97
Forage Species (million A1E)	528.22	560.80	1258.67	1459.70
Commercial & Recreational Species (million A1E)	85.94	91.20	378.82	471.28
Commercial & Recreational Harvest (million fish)	16.13	17.11	44.66	54.02
A1E Losses with Direct Use Value (%)	2.6%	2.6%	2.7%	2.8%

Source: U.S. EPA analysis for this report

Nonuse values may be more difficult to assess than use values for several reasons. First, nonuse values are not associated with easily observable behavior. Second, nonuse values may be held by both users and nonusers of a resource. Because nonusers may be less familiar with particular services provided by a resource, they may value the resource differently compared to users of the same resource. Third, the development of a defensible SP survey is often a time- and resource-intensive process. Fourth, even carefully designed surveys may be subject to certain biases associated with the hypothetical nature of survey responses (Mitchell and Carson 1989). Finally, efforts to disaggregate total WTP into its use and nonuse components have proved troublesome (Carson et al. 1999).

Although EPA is not always able to estimate changes in nonuse values as part of regulatory development, an extensive body of environmental economics literature demonstrates that the public holds significant value for service flows from natural resources well beyond those associated with direct uses (Boyd et al. 2001; Fischman 2001; Heal et al. 2001; Herman et al. 2001; Ruhl and Gregg 2001; Salzman et al. 2001; Wainger et al. 2001). Studies have documented public values for the services provided by a variety of natural resources potentially affected by environmental impacts, including fish and wildlife (Loomis et al. 2000; Stevens et al. 1991); wetlands (Woodward and Wui 2001); wilderness (Walsh et al. 1984); critical habitat for T&E species (Hagen et al. 1992; Loomis and Ekstrand 1997; Whitehead and Blomquist 1991); shoreline quality (Grigalunas et al. 1988); and beaches, shorebirds, and marine mammals (Rowe et al. 1992), among others. However, given EPA's regulatory schedule, developing and implementing SP surveys to elicit total value (i.e., nonuse and use) of environmental quality changes resulting from environmental regulations is often not feasible. In this case, EPA designed and implemented an original SP survey to estimate total monetary value (including use and nonuse value) of potential aquatic resource improvements that might occur as a result of the final 316(b) rule. As described in Section 4.1, EPA does not include the benefits it estimated based on the survey in the comparison of costs and benefits for the final rule. Chapter 11 provides additional details on the survey, implementation, and presents preliminary benefits estimates to illustrate the potential of magnitude of total benefits. EPA also developed a benefit transfer based on another existing SP survey to estimate nonuse benefits resulting from the final 316(b) rule for the North and Mid-Atlantic regions. The benefit transfer is described in Chapter 8.

Existing SP studies suggest that nonuse benefits of aquatic habitat improvements may be significant. For example, results from a study of public values of migratory fish restoration projects in Rhode Island showed that nonuse motives such as existence and bequest were rated as "important" or "very important" by 62 and 76 percent of survey respondents, respectively. Use motives such as commercial and recreational fishing, on the other hand, were rated as "important" or "very important" by only 38 and 43 percent of the survey respondents, respectively (Johnston et al. 2012, unpublished data). Additional detail regarding the Rhode Island study is provided in Chapter 8, Section 8.3.1.

Many ecosystems affected by CWIS provide goods and services that contribute to societal well-being (see Chapter 2), but may be generally unrecognized because of the indirect nature of the effect. As such, even valuations based on SP approaches are unlikely to capture the full economic value of the affected ecosystem services (Costanza and Folke 1997). Despite these limitations, benefit transfer based on SP studies is the generally accepted techniquefor estimating total (use and nonuse) values. EPA was able to identify a single existing study that could be used to estimates total values (nonuse and use values) for reductions in IM&E in some regions. Chapter 8 provides more detail on EPA’s quantitative analysis of nonuse benefits from reducing IM&E at the CWIS of regulated facilities.

5 Impacts and Benefits on Threatened and Endangered Species

5.1 Introduction

T&E species are species vulnerable to future extinction or at risk of extinction in the near future, respectively. These designations may be made because of low or rapidly declining population levels, loss of essential habitat, or life history stages that are particularly vulnerable to environmental alteration, disturbance, or other human impacts.

The withdrawal of cooling water from streams, rivers, estuaries and coastal marine waters leads to IM&E of a large number of aquatic organisms. For species vulnerable to future extinction, IM&E from CWIS may represent a substantial portion of annual reproduction. Consequently, IM&E may either lengthen recovery time, or hasten the demise of these species. For these reasons, the population-level and social values of T&E losses are likely to be disproportionately higher than the absolute number of losses that occur.

Adverse effects of CWIS on T&E species may occur in several ways:

- Populations of T&E species may suffer direct harm as a consequence of IM&E. This direct loss of individuals may be particularly important because T&E species have severely depressed population levels that are approaching local, national, or global extinction.
- T&E species may suffer indirect harm if the CWIS substantially alters the food web in which these species interact. This might occur as a result of altered populations of predator or prey species, the removal of foundation species, or (for species with parasitic life history stages) the loss of a host species.
- CWIS may alter habitat that is critical to the long-term survival of T&E species. This might occur as a consequence of changes in the thermal characteristics of local waterbodies, altered flow regimes, turbidity, or changes in substrate characteristics as a consequence of any of these changes (Chapter 2).

By definition, T&E species are characterized by low population levels. As such, it is unlikely that these species will be recorded in IM&E monitoring studies due to the logistical limitations of sampling and identification effort, time of day, season, and year. For T&E species to be recorded in monitoring studies, 1) an individual of a T&E species must be captured during the (often short) sampling window, and 2) the organism must be identifiable. Thus, despite the fact that the population impacts of IM&E on T&E species may be high, the effects are difficult to ascertain and quantify within a framework designed for common, more-abundant species. Thus, EPA identifies spatial overlap between CWIS and T&E species habitat ranges to estimate the potential for adverse IM&E impacts.

As noted, T&E species affected by CWIS may have both use and nonuse values. However, despite the existence of T&E species with potentially high use values (e.g., Pacific salmonids), the majority of T&E species affected by IM&E are relatively unknown, and those that are unidentifiable may not have any direct use values (e.g., delta smelt). Given that protecting of T&E species implies value, and that the majority of T&E species may not have direct use value, the majority of the economic value for T&E species must come from nonuse values. Species-specific estimates of nonuse values held for the protection of T&E species can be derived only by primary research using stated preference techniques. However, EPA did not have the resources necessary to develop such estimates for T&E species for this rulemaking. As an alternative, EPA used a benefit transfer approach that relies on information from existing studies (USEPA 2010a).

EPA was able to use a benefit transfer approach to estimate changes in recreational use values for a subset of T&E species that are highly valued by recreational anglers (i.e., paddlefish[16] and sturgeon). Commercial and nonuse values are not monetized for any of the affected species. Therefore, benefit estimates presented in this chapter are incomplete and highly conservative (i.e., low).

In this chapter, EPA explores the extent to which CWIS may affect species protected by the Endangered Species Act on national and regional scales (Section 5.2), documents the value society places on the protection of T&E species (Section 5.3), and applies economic valuation studies of T&E species to case studies of sea turtles and finfish in the Inland region (Section 5.4).

5.2 T&E Species Affected by CWIS

To assess the potential impacts of CWIS on T&E species, EPA constructed a database that identifies spatial overlap between CWIS and vulnerable life history stages of all aquatic T&E species for which data are available. The database allowed EPA to estimate the potential for adverse IM&E impacts on T&E species.

5.2.1 T&E Species Identification and Data Collection

First, all species currently listed under the Endangered Species Act (as of August 6, 2012) with aquatic life history stages were identified using the US Fish and Wildlife Service Environmental Conservation Online System (USFWS 2012a). This primary list of all T&E species was filtered to include only species with life history stages vulnerable to CWIS mortality according to life history data. Examples of vulnerable stages include planktonic egg stages occurring near- or in-shore (e.g., marine species spawning offshore were excluded unless other vulnerable stages are found near- or in-shore), free-swimming larval stages residing near- or in-shore, and adult life history stages that occur near- or in-shore. Life history data used to exclude species from further consideration was obtained from a wide variety of sources (AFSC 2010; ASMFC 2012; Froese and Pauly 2009; NatureServe 2012; NEFSC 2010; PIFSC 2010a; PIFSC 2010b; SEFSC 2010; SWFSC 2010; USFWS 2012a). After filtering by life history data, the list of T&E species potentially affected by IM&E contained 287 species.

Whenever possible, EPA obtained the geographical distribution of T&E species susceptible to IM&E in geographic information system (GIS) format as polygon (shape) files, line files (for inhabitants of small creeks and rivers) and as a subset of geodatabase files. Data sources include the US Fish and Wildlife Service (USFWS 2010a), including shapefiles for critical habitat designated under the Endangered Species Act, NOAA's Office of Response and Restoration (NOAA 2010), NatureServe (NatureServe 2012), and NOAA NMFS (NMFS 2010a; NMFS 2010b; NMFS 2010c). For several freshwater species, geographic ranges were available only as 6-digit hydrologic unit codes (HUC) (NatureServe 2012; USFWS 2010a). For these species, GIS data layers were generated using a GIS HUC database obtained from the USGS (Steeves and Nebert 1994). For several species, no GIS data could be acquired. For these species, species distribution descriptions were compared with mapped CWIS, and inspected for geographic overlap. In all such cases (e.g., the "inarticulated brachiopod," *Lingula reevii*, endemic to

16 Note: the American Paddlefish is listed on T&E species lists for many states, but is not currently protected nationally under the US Endangered Species Act. A review of the species' status in 1992 revealed that although the species did not then meet the requirements to be listed as threatened at the federal level, the US Fish and Wildlife Service expressed its concern for the future of the species.

Kaneohe Bay, HI) no regulated facilities were located within 10 kilometers, and further inspection was not warranted.

5.2.2 Number of T&E Species Affected per Facility

To investigate the potential for individual facilities to affect a wide variety of T&E species, EPA calculated the number of T&E species affected on a per-facility basis. This calculation allowed EPA to assess the magnitude of differences between regions of CWIS effects on T&E species.

Nationally, 99 of the 287 aquatic T&E species (34 percent) had vulnerable life history stages that either overlapped with CWIS, or records of IM&E (Table 5-1). These species overlapped with 523 of 738 regulated facilities (71 percent) (Figure 5-1). Among facilities, the variability in the number of T&E species potentially affected ranges between 0 and 32 species (Table 5-1), with more than 90 percent of facilities affecting fewer than 7 T&E species, and more than 99 percent of facilities affecting fewer than 12 species (Figure 5-2).

Excluding facilities whose CWIS that do not overlap with at least one T&E species, the average number of species per facility is 4.13 (minimum 1, maximum 32) (Table 5-1). Sea turtles, snails and freshwater mussels had the highest overlap rate on a per-facility basis, averaging 4.7, 4.1 and 3.7 species per facility, respectively. Anadromous and freshwater fish had lower overlap rates with CWIS, averaging slightly higher than one species per interacting facility (Table 5-1).

Driven by the high number of IM&E freshwater mussels overlapping with facility CWIS, the majority of all species by facility interactions occur in the inland region. However, the shape of cumulative distribution plots is similar among regions after accounting for sample size, suggesting that the overall probability of a facility affecting one or more T&E species is not a function of geographic region (Figure 5-3).

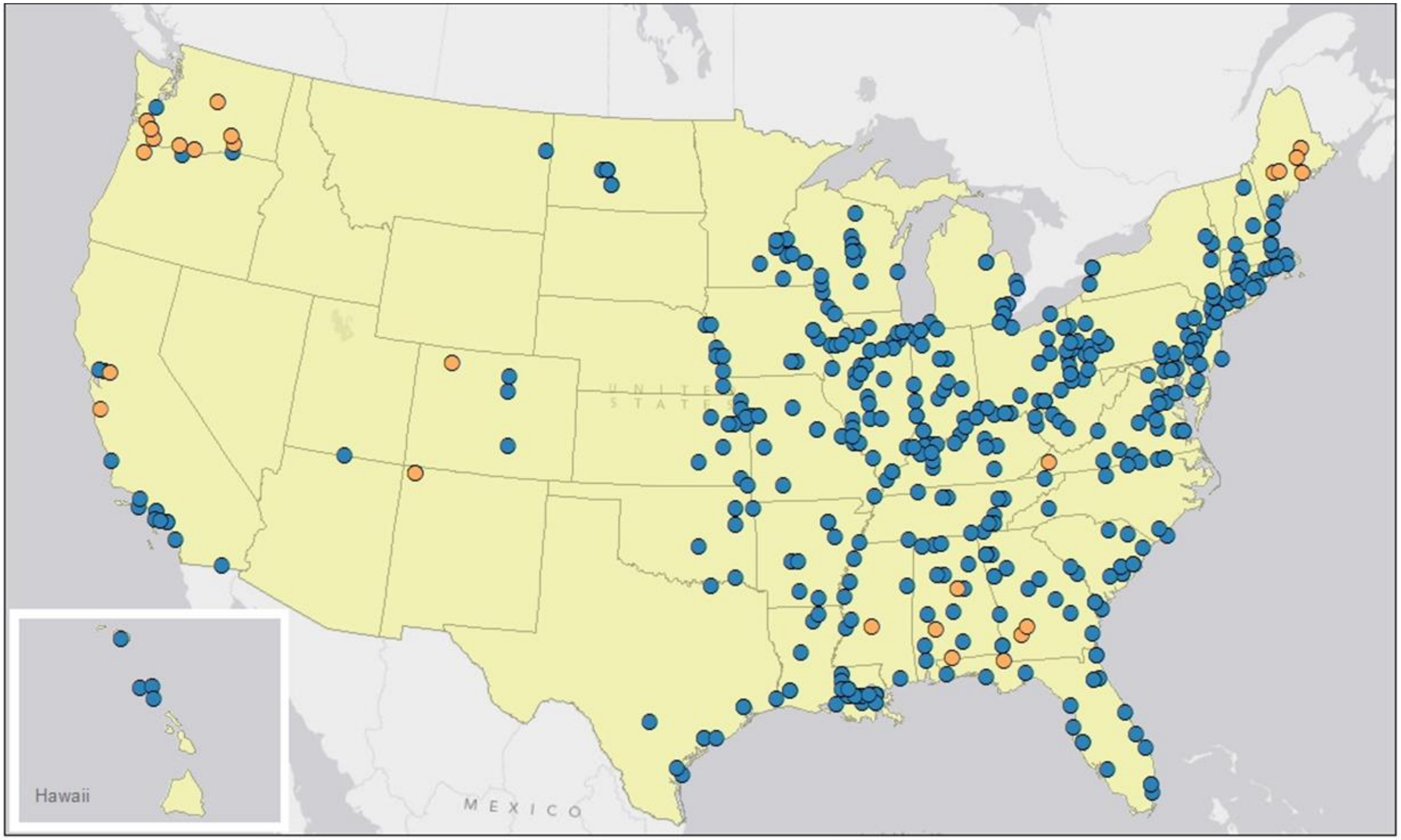

Figure 5-1: Map of overlap of CWA section 316(b) existing facilities and T&E species habitat ranges (all circles, 523 facilities) or overlapping with critical habitat (orange circles, 27 facilities). Because critical habitat is a subset of total T&E species habitat, a total of 523 facilities overlap the habitat of one or more T&E species.

Table 5-1: Number of T&E Species with Geographical Distributions Overlapping Regulated Facilities, on a Per-facility Basis

Subset of Affected Species[a]	# Species	T&E Species per Facility[c]			
		All Facilities		Interacting Facilities[b]	
		Avg	Max	Avg	Max
All T&E Species	99	2.9	32	4.1	32
T&E Freshwater Mussels	53	1.9	22	3.7	22
T&E Anadromous Fish	12	0.3	5	1.2	5
T&E Freshwater Fish	21	0.1	4	1.4	4
T&E Snails	7	0.3	7	4.1	7
T&E Sea Turtles	6	3.8	5	4.7	5

[a] T&E species include species listed as threatened or endangered by the US Fish and Wildlife Service (fresh water) or NOAA National Marine Fisheries Service (marine)
[b] Interacting Facilities = all facilities with CWIS inside the range of at least one T&E species
[c] Avg = Average, Max = Maximum
Source: U.S. EPA analysis for this report

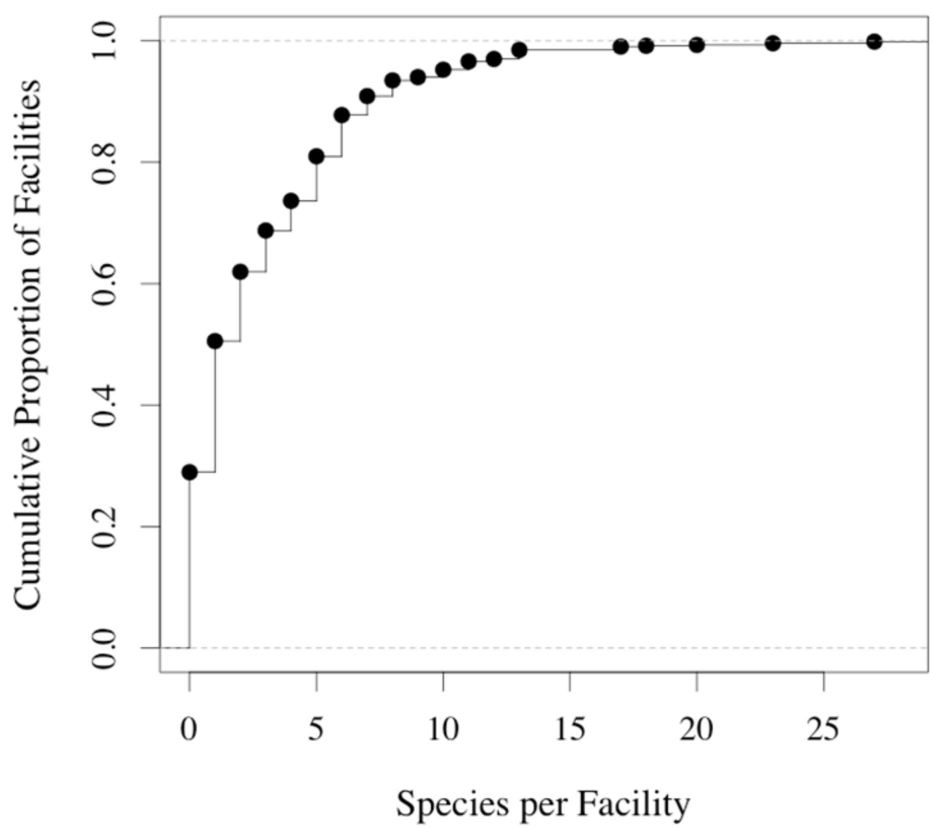

Figure 5-2: Empirical cumulative distribution function plot of the number of T&E species potentially affected on a per-facility basis by regulated facilities nationwide. Sample size is 738.

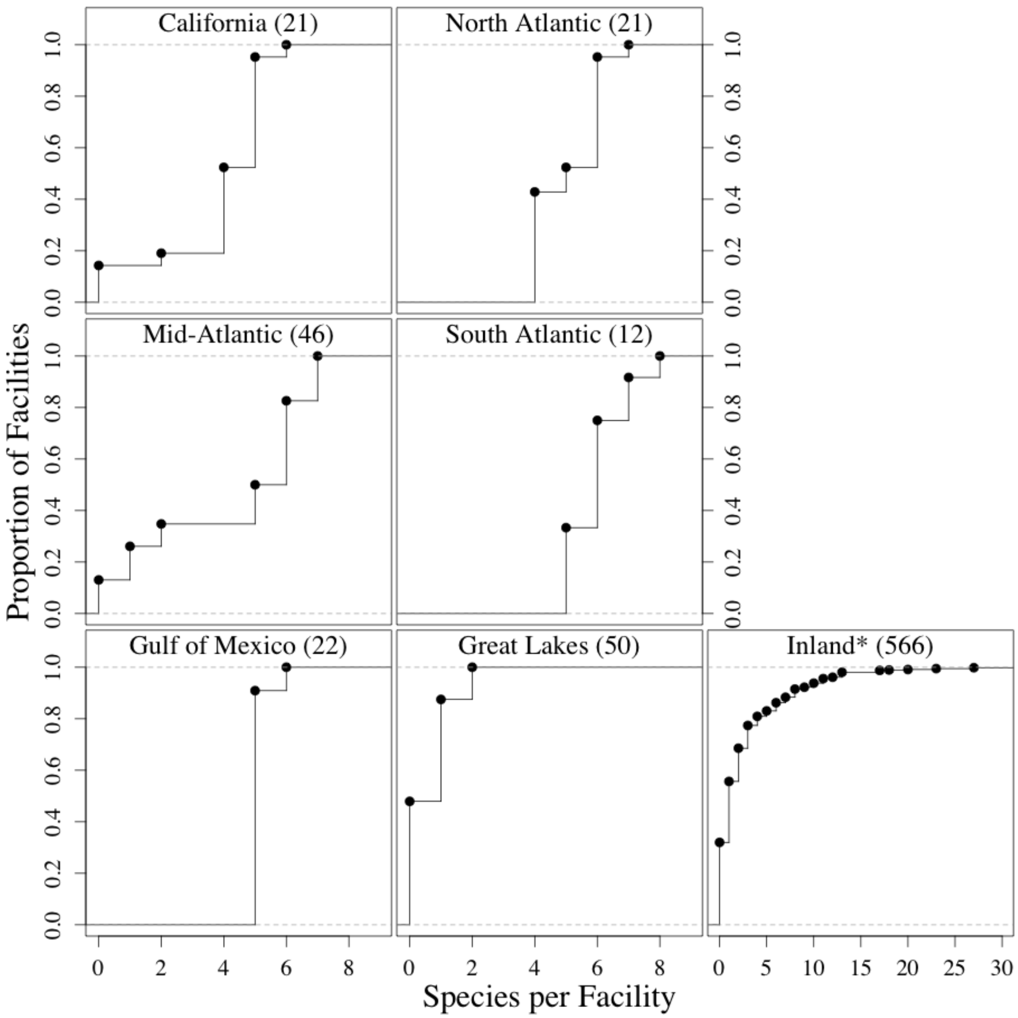

Figure 5-3: Cumulative distribution plot of the number of T&E species potentially affected on a per-facility basis by regulated facilities nationwide. Sample sizes (i.e., number of regulated facilities) are noted in parentheses. The horizontal axis is equivalent in all plots, with the exception of the Inland region (noted with an asterisk *).

5.2.3 Number of Facilities Affecting Individual T&E Species

To investigate the cumulative potential for CWIS to affect individual T&E species, EPA calculated the number of facilities affecting each T&E species. There are 2,158 examples of overlaps between species and facilities across 99 T&E species nationally, resulting in an average of 21.8 facilities per species (Table 5-2). Consequently, many T&E species are likely to be affected by a large number of facilities. Thus, even if individual facilities have low IM&E of T&E species, the cumulative effect of regulated facilities on these populations may be substantial. The variation among species was large and ranged between 1 and 103 facilities per species (Table 5-2). Overall, 10 percent of species are affected by 1 facility, 53 percent of species are affected by up to 6 facilities 73 percent of species are affected by up to 25 facilities, and 92 percent are affected by up to 74 facilities (Figure 5-4).

Table 5-2: Number of Facilities with CWIS Within the Geographical Distribution of T&E Species, on a Per-species Basis

Subset of Affected Species[a]	Species	Overlaps	Facilities per T&E Species	
			Average	Maximum
All T&E Species	99	2158	21.8	103
T&E Freshwater Mussels	53	1176	21.8	103
T&E Anadromous Fish	12	235	19.6	101
T&E Freshwater Fish	21	65	3.1	7
T&E Snails	7	199	28.4	49
Sea Turtles	6	483	80.5	102

[a] T&E species included species listed as threatened or endangered by the US Fish and Wildlife Service (fresh water) or NOAA National Marine Fisheries Service (marine).
Source: U.S. EPA analysis for this report

When subsets of related species were assessed, sea turtles had the highest average number of overlapping facilities (80.5) (Table 5-2), a value skewed by these species' extensive ranges (i.e., entire Atlantic, Gulf of Mexico, and/or Pacific coast), and the potential for IM&E impacts at all life stages. Following sea turtles, snails and freshwater mussels had the highest average number of overlapping facilities (28.4 and 21.8 facilities per species, respectively). Excepting turtles, freshwater mussels accounted for 8 of the top 10 species sorted by the count of CWIS overlap (Figure 5-5). Following freshwater mussels, anadromous fish species were most likely to be affected, with an average of 19.6 facilities per species (Table 5-2). This average, however, is highly skewed by two species of fish (the pallid sturgeon, *Scaphirhynchus albus* and the shortnose sturgeon, *Acipenser brevirostrum)* which accounted for 70 percent of all overlap between facilities and anadromous fish species (Figure 5-5). Finally, freshwater fish species averaged 3.1 facilities with potential IM&E per species (Table 5-2, Figure 5-5).

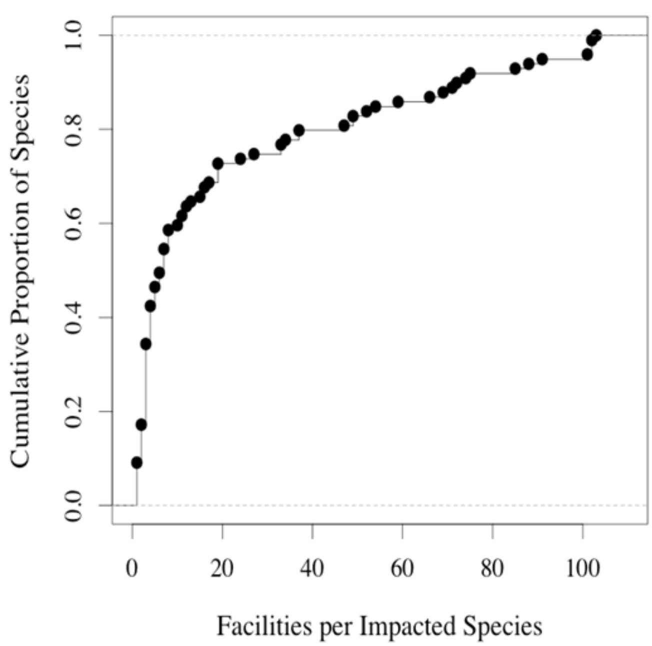

Figure 5-4: Empirical cumulative distribution function plot of the number of facilities that overlap geographically with vulnerable life history stages of T&E species. Species represented on the plot are those that overlap with a minimum of one regulated facility. Sample size is 99.

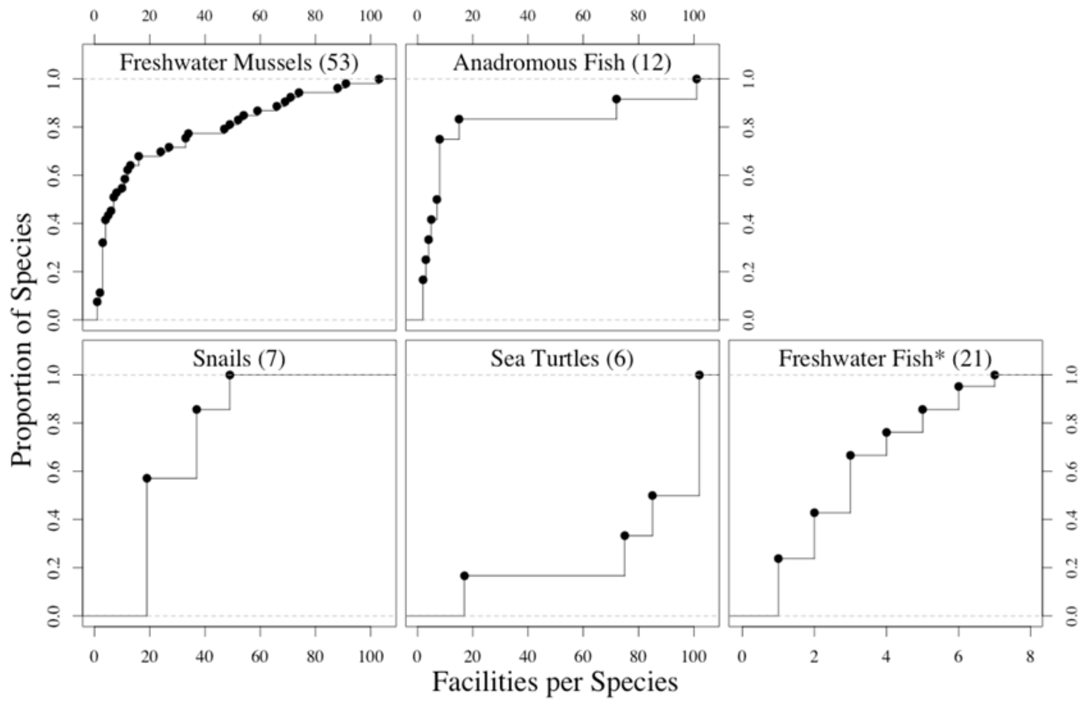

Figure 5-5: Cumulative distribution plots of the number of facilities likely to affect individual threatened or endangered species, grouped by species life history trait. Sample sizes (species per life history trait) are in parentheses, and represent those species potentially affected by a minimum of one regulated facility. The horizontal axis is equivalent in all plots, with the exception of Freshwater Fish (noted with an asterisk *).

5.2.4 Summary of Overlap between Cooling Water Intake Structures and T&E Species

Nationally, 34 percent of T&E species with vulnerable life history stages overlap with a minimum of one CWIS (Table 5-1), and 71 percent of CWIS overlap with at least one T&E species. This suggests a high probability that T&E populations are affected by IM&E. The potential for these impacts is widespread: T&E species overlap CWIS in all geographical regions of the country (Figure 5-3), in all waterbody types, and across multiple life histories (Figure 5-5). Finally, EPA's analysis includes only federally listed T&E species. Thus, the number of T&E species (including those species defined as threatened or endangered under state law) affected by IM&E is likely understated.

5.2.5 Summary of Overlap between Cooling Water Intake Structures and Critical Habitat

At some point following the listing of a species under the ESA, the US Fish and Wildlife Service or NOAA will designate critical habitat. Critical habitat is defined as areas occupied by the species at the time of listing which either 1) contain physical or biological features essential to conservation which require special management considerations or protection, or 2) is essential for conservation.

To investigate the impact of regulated facilities on critical habitat, EPA assessed the number of facilities with CWIS located within critical habitat. Overall, 27 facilities overlapped with critical habitats designated for 21 species protected by the ESA (Figure 5-1). Of these 27 facilities, 14 overlapped with critical habit for only one species; no facility overlapped with more than 8 species.

5.2.6 Effect of the Final Rule on Facilities Overlapping T&E Species Habitat

To estimate the potential effect of the final rule on T&E species, EPA estimated the number of regulated facilities overlapping the habitat of one or more T&E species. Based upon data from the 316(b) industry survey (USEPA 2000), EPA estimates there are 143 facilities likely to be in compliance with the final rule (final determination of compliance will be based on site-specific determination of BTA for entrainment), and that a minimum of 192 facilities will be required to implement measures to reduce IM&E. There was insufficient data for EPA to estimate compliance status for the remaining 188 facilities (Figure 5-6).

5.2.7 Species with Documented IM&E

Although difficult to observe and quantify, EPA identified 14 T&E species with documented IM&E from facility IM&E studies (Table 5-3). Notably, several of these IM&E studies were conducted prior to the listing of some of the T&E species identified (i.e., delta smelt, longfin smelt). Therefore, current annual IM&E may be lower for these species, particularly if species' populations have decreased or if facilities have been required to install additional technologies during the permitting process. Alternatively, IM&E may be similar in magnitude at facilities whose operating permits have been administratively continued while these new species were listed.

In addition to identifying T&E species reported in IM&E studies, EPA also identified taxa in these studies not identified by species but whose genus matched T&E species overlapping with the reporting facility location (Table 5-3). Although these instances are not confirmed IM&E of T&E species, they provide evidence that additional T&E species are likely to be directly affected by IM&E.

Including only individuals identified by species, EPA identified more than 95,000 baseline losses of T&E species (Table 5-3). However, for several reasons, T&E species suffering IM&E are likely to be underreported. First, T&E species are found at low population densities, and the volume of water sampled by facility-level impingement and entrainment studies is low. Thus, it is likely that many T&E species suffered IM&E outside of sampling periods and were never recorded. Second, because a high proportion of all IM&E occurs during early life history stages (i.e., egg, larvae) when species identification is more challenging, T&E species may not be recognized during sampling. For example, endangered species of darter, including the Cherokee and duskytail darters, may be reported as "darter," or "unidentified darter".

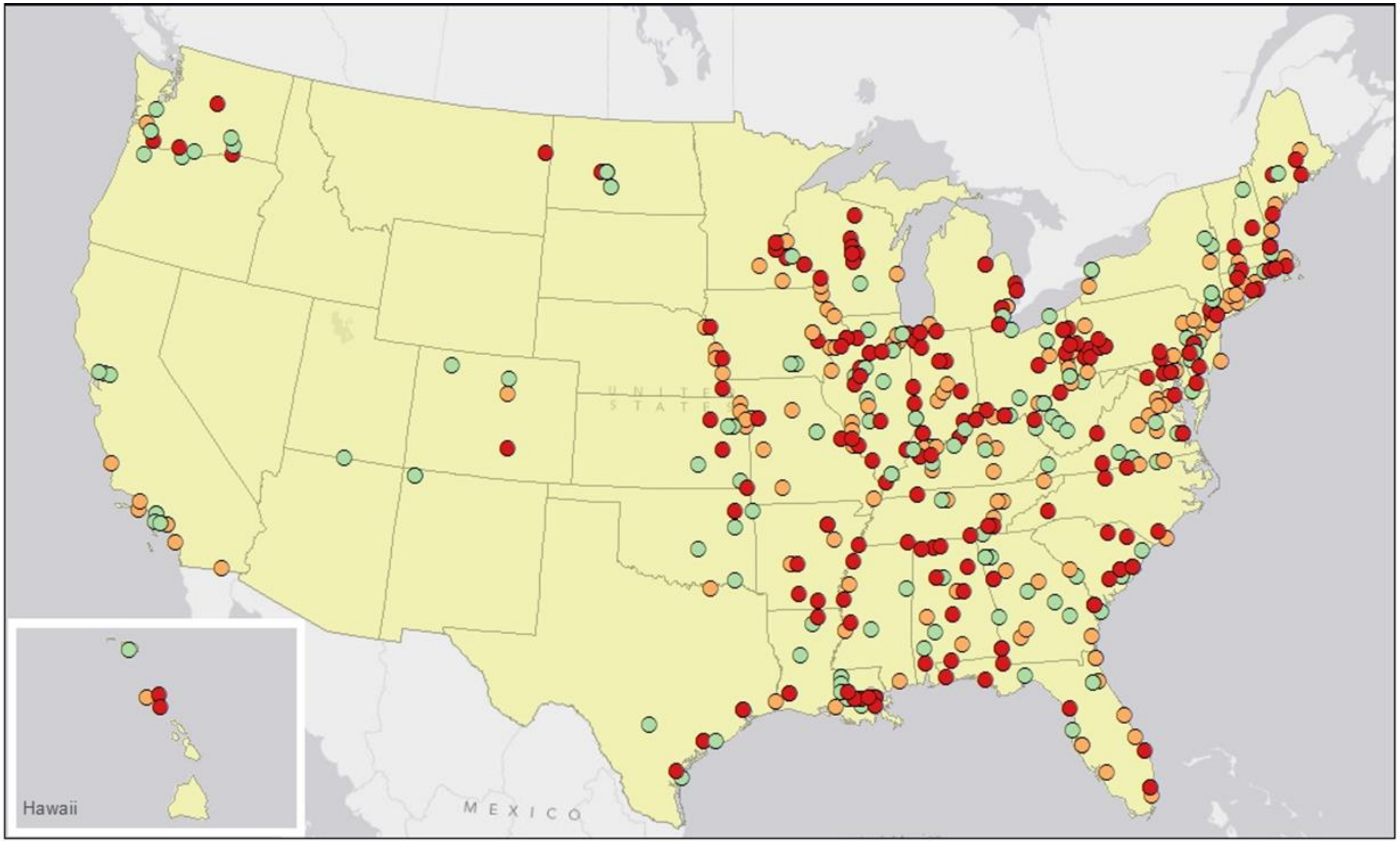

Figure 5-6: Map of 316(b) existing facilities with CWIS overlapping the habitat of one or more T&E species, and these facilities' compliance with the final rule. Overall, EPA estimates that 143 facilities are likely to be in compliance with the final rule (green circles), 192 facilities are not yet in compliance with the final rule (red circles), and there is insufficient data for EPA to estimate compliance status for the remaining 188 facilities (orange circles).

Table 5-3: Documented IM&E of T&E Species[a]

Resolution	Common Name	Latin Name	Baseline IM&E			
			Qualitative[b]	Not Extrapolated	Extrapolated	Estimated IM&E[c]
Species	Atlantic Salmon	*Salmo salar*	✓	□	□	-
	Chinook Salmon	*Oncorhynchus tshawytscha*	□	✓	□	5,470
	Coho Salmon	*Oncorhynchus kisutch*	✓	□	□	-
	Delta Smelt	*Hypomesus transpacificus*	□	✓	□	62,526
	Green Sea Turtle	*Chelonia mydas*	✓	□	□	-
	Hawksbill Sea Turtle	*Eretmochelys imbricata*	✓	□	□	-
	Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	✓	□	□	-
	Leatherback Sea Turtle	*Dermochelys coriacea*	✓	□	□	-
	Loggerhead Sea Turtle	*Caretta caretta*	□	✓	□	5-50
	Longfin Smelt	*Spirinchus thaleichthys*	□	✓	□	24,919
	Olive Ridley Sea Turtle	*Lepidochelys olivacea*	✓	□	□	-
	Pallid Sturgeon	*Scaphirhynchus albus*	□	□	✓	50
	Steelhead Trout	*Oncorhynchus mykiss*	□	✓	□	5
	Topeka Shiner	*Notropis topeka*	□	✓	□	15
Genus	Alabama Sturgeon	*Scaphirhynchus suttkusi*	□	✓	□	8,174
	Atlantic Sturgeon	*Acipenser oxyrinchus oxyrinchus*	□	□	✓	785,667
	Blackside Dace	*Phoxinus cumberlandensis*	□	✓	□	10
	Chum Salmon	*Oncorhynchus keta*	□	□	✓	22
	Green Sturgeon	*Acipenser medirostris*	□	□	✓	785,667
	Gulf Sturgeon	*Acipenser oxyrinchus desotoi*	□	□	✓	785,667
	Shortnose Sturgeon	*Acipenser brevirostrum*	□	□	✓	785,667

[a] Species listed as threatened or endangered under state laws, such as the American Paddlefish (*Polyodon spathula*), are not included in this list.
[b] "Qualitative" indicates the species is reported by name from a minimum of one facility, but no loss estimates are provided.
[c] Baseline IM&E reported for genera reflect IM&E for all species within the genus. Losses are likely dominated by more-common congeners.
Source: U.S. EPA analysis for this report

5.3 Societal Values for Preservation of T&E Species Affected by IM&E

This section examines governmental spending, policy decisions, and private donations associated with the preservation and restoration of T&E species. This section provides evidence of societal preferences for T&E preservation and spending related to ensuring sustainability of T&E species.

The U.S. Fish and Wildlife Service (FWS) reports annual expenditures for the conservation of T&E species. Using the report for fiscal year 2011 (USFWS 2012b) EPA calculated total government (federal and state) expenditures for the 99 federally listed T&E species with vulnerable life history stages that overlap CWIS (Table 5-4). Excluding expenditures on T&E species (and distinct population segments) not subject to IM&E, federal and state expenditures on T&E species potentially affected by CWIS exceeded $593.2 million during FY 2011, and accounted for 68 percent of all governmental spending on fish, marine reptiles, crustaceans, corals, clams, aquatic snails and marine mammals listed under the ESA (USFWS 2012b).

Table 5-4: Federal and State Expenditures for T&E Species Overlapping with CWIS

Species Group	Expenditure (2011$, millions)
Anadromous Fish	$483.4
Freshwater Fish	$57.6
Freshwater Mussels	$13.0
Snails	$0.1
Sea Turtles	$39.1
All Species Overlapping CWIS	$593.2
All Fish, Marine Reptile, Crustaceans, Coral, Marine Mammal, Aquatic Snail and Clam Species	$869.1

Source: USFWS (2012b)

In addition to direct governmental spending associated with the protection of T&E species that overlap with CWIS, the presence of these species often guides policy discussions, and may require the installation of abatement technologies that reduce T&E species mortality and allow these species to migrate. For example, the life history of the American paddlefish (*Polyodon spathula*) (listed on many state T&E species lists, but not protected under the ESA) is occasionally discussed during Federal Energy Regulatory Commission relicensing of dams, because of the animal's highly migratory life history. In the Wisconsin River, for example, Alliant Energy has been required to install a multi-million dollar fishway at the Prairie du Sac dam, primarily to allow the passage of paddlefish and lake sturgeon (WPLC v. FERC 2004). Considerations for T&E species have also been responsible for changes in water diversions on the San Joaquin-Sacramento River delta, limiting water for downstream users. Under current regulations, the volume of water removed from the San-Joaquin-Sacramento River at the Banks Pumping Plant is limited from December to June, to protect delta smelt (NRDC v. Kempthorne 2007). This restriction limits the volume of water available for consumption as drinking water and for use in large-scale irrigation projects. Water restrictions attributable due to the potential for negative effects on delta smelt populations, have been estimated to result in the loss of 21,100 farm-related jobs and $703 million in agricultural revenue in 2009 alone (Boxall 2010; Howitt et al. 2009).[17]

Although government spending and policy decisions made to protect or enhance stocks of T&E species are not direct indications of economic benefits, they indicate that society does place a significant value on protecting and restoring species at risk of extinction.

5.4 Assessment of Benefits to T&E Species

5.4.1 Economic Valuation Methods

Estimating the benefits of preserving T&E species by reducing IM&E is difficult for several reasons. First, the contribution to ecosystem stability, ecosystem function, and life history remain relatively unknown for many T&E species. Second, because much of the wildlife economic literature focuses on commercial and recreational benefits that are not relevant for many protected species (i.e., use values), a paucity of economic data focuses on the benefits of preserving T&E species. Consequently, nonuse values comprise the principal source of benefit estimates for most T&E species.

To obtain an accurate estimate of the nonuse values of T&E species affected by IM&E, first, quantitative IM&E impacts, and the benefits of policy options, must be estimated for T&E species. Second, an economic value must be obtained for the value of reducing IM&E as a consequence of increased population sizes, extinction avoidance, and, for certain species (e.g., Salmonids), the potential for re-establishment of a commercial fishery.

Benefit transfer involves extrapolating existing estimates of nonmarket values to geographic locations or species that differ from the original analytical situation. Thus, the approach transfers estimates of values for preserving T&E species in one region to another region, or to a similar species. Ideally, the resource (i.e. species), policy variable (e.g., change in species status, recovery interval, population size, etc.), and the benefitting population (i.e., defined human population) are identical. Such a match rarely occurs. Despite discrepancies in these variables, however, a benefit transfer approach can provide useful insights into the social benefits gained by reducing IM&E of T&E species.[18]

5.4.2 Case Studies

EPA attempted to estimate the benefits of the final rule for all T&E species with documented and quantified IM&E at CWIS. In most cases, EPA was unable to locate or calculate key components of the analysis necessary to apply a benefit transfer approach. However, EPA was able to obtain sufficient data to estimate the economic benefits to two categories of T&E species: a subset of T&E fish species in the Inland region, and loggerhead sea turtles. The case studies of potential economic benefits from a decrease in T&E mortality are discussed below.

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[17] Water diversion in the San Joaquin-Sacramento River is currently undergoing active litigation. See *San Luis & Delta-Mendota Water Authority, et al. v. Salazar, et al.,* USDC Case No. 1:09-CV-407 OWW GSA, and consolidated cases.

[18] Types of benefit transfer studies are discussed at length in U.S. EPA (2010).

5.4.2.1 Inland Region

Baseline IM&E of Special Status Species and Reductions in IM&E Under the Final Rule and Options Considered

EPA estimated IM&E for three T&E species in the Inland region: pallid sturgeon, American paddlefish, and Topeka shiner. However, sufficient data were available to estimate the benefits of the final rule for only the pallid sturgeon (*Scaphirhynchus albus*) and the American paddlefish (*Polyodon spathula)*. As such, benefits estimates address only 73 to 83 percent of estimated T&E A1E losses in the Inland region (Table 5-5).

The pallid sturgeon is listed as an endangered species under the ESA; the American paddlefish is not listed federally. In the early 1990s, the U.S. FWS conducted a review of the paddlefish for threatened status, but ultimately did not list the species (Allardyce 1991). However, the review noted that immediate efforts were needed to restore stocks and degraded habitats (Allardyce 1991). Although not currently protected federally, paddlefish are protected by 11 states.

The American paddlefish is a large species (85 inches length and more than 220 lbs) with roe suitable for caviar. The species once supported a large commercial fishery in the Mississippi Valley, and currently supports a limited recreational fishery in some states. Likewise, the pallid sturgeon is one of the largest (30 to 60 inches) fish found in the Missouri-Mississippi River drainage, with specimens weighing up to 85 pounds. Because their large size makes them a desirable commercial and trophy sport fish, and because they have roe suitable for caviar, both pallid sturgeon and American paddlefish have potentially significant direct use values. All extractive uses of the pallid sturgeon, however, are prohibited under the ESA.

To estimate total baseline IM&E, EPA used the EAM to model A1Es for each of the three T&E species (Chapter 3).[19] The choice of facilities used to extrapolate IM&E from model facilities was based on species' historic ranges and current distributions. In addition to baseline estimates of IM&E for pallid sturgeon, paddlefish, and Topeka shiner, EPA calculated reductions in IM&E under the final rule and Proposal Options 2 and 4 (Table 5-5).

Table 5-5: Annual Baseline IM&E and Reductions in Baseline IM&E of T&E Species at Regulated facilities in the Inland Region, by Regulatory Option (A1E)

T&E Species	Proposal Option 4	Final Rule	Proposal Option 2	Baseline
Paddlefish	7,930	8,245	15,660	18,841
Pallid Sturgeon	65	68	78	90
Topeka Shiner	2,911	3,010	3,472	3,985
Total	**10,906**	**11,323**	**19,210**	**22,916**

[a] The IM&E data used to develop regional estimates are from sampling at the Wabash and Cayuga facilites in 1976, the only year of sampling data for these facilities.
Source: U.S. EPA analysis for this report

[19] IM&E of Paddlefish and pallid sturgeon as observed at nine and two model facilities, respectively.

Benefit Transfer Approach: Estimated WTP for Protection of Inland T&E Species

Nonuse Values

EPA identified two studies that estimated both nonuse and use values for sturgeon. One study found that citizens of Maine are willing to pay $38.87 (2011$) as a one-time tax to create a self-sustaining population of shortnose sturgeon (Kotchen and Reiling 2000), a species listed as endangered under the ESA (NMFS 2004). A separate study found that lake sturgeon is a popular wildlife-viewing species in Wisconsin, and that viewers place a substantial value on protection of lake sturgeon populations. The average viewer's WTP to maintain the current sturgeon population of Wisconsin's Lake Winnebago system was $127.37 (2011$). With an estimated 3,176l sturgeon viewers in 2002, total WTP for sturgeon-viewing opportunities in the Winnebago system was $0.41 million (2011$). Together, the results of these studies indicate that nonuse values for preservation of sturgeon are likely to be significant. However, EPA was unable to monetize total nonuse benefits from reduced IM&E because reliable population estimates needed to transfer the values were unavailable.

Use Values

- Pallid sturgeon and paddlefish have potentially high commercial use values as sources of roe. This value has increased dramatically owing to the collapse of Caspian Sea sturgeon populations (Speer et al. 2000). Paddlefish roe have been reported to sell for more than $300 per pound, and as much as three pounds of roe may be harvested from a large female (McKean 2007). Despite these reports, EPA was unable to reliably quantify total commercial values for these species due to a lack of market data.
- Recreational use values for sturgeon and paddlefish caught in inland waters or paddlefish were not available. Based on a review of literature describing these species, EPA determined that sturgeon species (including white, green, and pallid sturgeons) and paddlefish share many characteristics, including roe suitable for caviar and their value as game fish. Consequently, WTP values for sturgeon obtained in California were used to value recreational use of these species in the Inland region. A limited recreational fishery (mostly catch and release) exists for paddlefish in several states; although harvesting pallid sturgeon is illegal, the species is sometimes caught by recreational anglers.

To estimate recreational use values for paddlefish and pallid sturgeon, EPA applied estimates from a random utility model (RUM) analysis conducted to evaluate recreational fishing benefits of the 2004 Section 316(b) Phase II Final Rule. Model results indicate that California anglers were willing to pay $73.27 (2011$) to catch a sturgeon (USEPA 2004a), a value transferred to anglers for pallid sturgeon and paddlefish in the Inland region (Table 5-6).[20]

The recreational use value from eliminating baseline IM&E of pallid sturgeon and paddlefish is approximately $1.2 million using a 3 percent discount rate and $1.1 million using a 7 percent discount rate. Annualized benefits for the final rule will be $415,000 using a 3 percent discount rate and $320,000 using a 7 percent discount rate. Annualized benefits for other options considered range from $399,000 to $664,000 using a 3 percent discount rate and $307,000 to

[20] The Phase II analysis did not estimating WTP for catching a sturgeon in other states. Given similarity in species characteristics, EPA used WTP for sturgeon caught in California to value sturgeon and paddlefish species in the Inland region.

$460,000 using a 7 percent discount rate. EPA notes that these are underestimates of the total values of reducing IM&E to T&E species in the Inland region because both nonuse and commercial values, which are likely to be substantial, are not incorporated.

Table 5-6: Estimated Annual WTP for Eliminating or Reducing IM&E of Special Status Fish Species at Regulated facilities in the Inland Region, for the Final Rule and Other Options Considered (2011$)[a]

T&E Species	Annualized Benefits (2011$, 1,000s)			
	Proposal Option 4	Final Rule	Proposal Option 2	Baseline
Paddlefish	$581.0	$604.1	$1,147.4	$1,380.5
Pallid Sturgeon	$4.8	$5.0	$5.7	$6.6
Total Undiscounted	**$585.8**	**$609.1**	**$1,153.1**	**$1,387.0**
3% Discount Rate				
Annualized Value	**$399.1**	**$415.0**	**$663.9**	**$1,210.7**
7% Discount Rate				
Annualized Value	**$307.2**	**$319.5**	**$460.1**	**$1,116.7**

[a] The IM&E data used to develop regional estimates are from sampling at the Wabash and Cayuga facilities in 1976, the only year of sampling data for these facilities.

Source: U.S. EPA analysis for this report

5.4.2.2 Potential Nonuse Values for T&E Species in the Inland Region

To illustrate the potential magnitude of nonuse values for T&E species affected by IM&E in the Inland region, EPA applied a WTP meta-analytical model (Richardson and Loomis 2009) to hypothetical scenarios. Because EPA currently does not have region-wide IM&E for all T&E species, nor population models to estimate the effect of IM&E on population size, EPA presents estimates only to assess the range of benefits potentially resulting from the final rule and other options considered. The modeled scenarios estimate the WTP for 0.25 percent and 0.5 percent increases for all T&E fish populations in the Inland region.

The model EPA used to estimate nonuse values using benefit transfer is a double log specification (Model 4 from Richardson and Loomis (2009)), where:

ln WTP (2006$) = -153.231 + 0.870 ln CHANGESIZE + 1.256 VISITOR + 1.020 FISH + 0.772 MARINE + 0.826 BIRD – 0.603 ln RESPONSERATE+ 2.767 CONJOINT + 1.024 CHARISMATIC – 0.903 MAIL + 0.078 STUDYYEAR

Model variables are described in Table 5-7. Excepting all policy-relevant variables, EPA used the mean values for all model parameters, and converted estimates to 2011$ using the consumer price index (USBLS 2011).

For a 0.25 percent change in T&E fish population size, projected WTP per household per year is $1.07. With 59.9 million households[21], total WTP for T&E fish in the Inland region is $63.1 million. For a 0.5 percent change in T&E fish populations, WTP per household is $1.94 per year, resulting in WTP values of $114.3 million in the Inland region (all values 2011$).

[21] Household number in the Inland region is calculated for states where at least one T&E species affected by IM&E is found.

Table 5-7: Variables in the Richardson and Loomis (2008) Meta-Analysis Model and Values Used in EPA's Application

Variable Name	Description	Value Used in EPA's Application
ln WTP	Natural log of willingness to pay	Estimated by model
ln CHANGESIZE	Natural log of the percentage change in the population of the species of interest	Log of percentage change in fish population: ln(.25) and ln(.5)
VISITOR	= 1 if survey respondents are visitors rather than full-time residents	0.0
FISH	= 1 for fish species	1.0
MARINE	= 1 for marine mammals	0.0
BIRD	= 1 for bird species	0.0
ln RESPONSERATE	Natural log of the survey response rate	4.0
CONJOINT	= 1 for conjoint method surveys	0.0
CHARISMATIC	= 1 for charismatic species	0.0
MAIL	Indicates mail surveys	0.9
STUDY YEAR	Year of study	2007

Sources: Richardson and Loomis (2008), U.S. EPA analysis for this report

5.4.2.3 Sea Turtles

Six species of sea turtles live in U.S. waters: green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), Kemp's Ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), loggerhead (Caretta caretta), and Olive Ridley (*Lepidochelys olivacea*) sea turtles. All have extensive ranges, migrate long distances during their lifetime, and are listed as either threatened or endangered (T&E) under the ESA. Because of these large ranges, substantial overlap exists between sea turtle habitat and CWIS for regulated power generating and manufacturing facilities. Additionally, because individuals of all ages and sizes are susceptible to impingement and entrainment (Norem 2005), more than 730 potential interactions between species and CWIS may result in the injury or death of these T&E species (Table 5-1, details in Appendix F, Section 1).

Evidence for Public Values for Sea Turtles

In addition to research sponsored by the National Science Foundation and various private philanthropic organizations, federal and state governmental spending on sea turtle protection under the ESA totaled $33.8 million in FY2008 (Table 5-4). Moreover, dozens of academic, nonprofit, and ecotourism organizations recruit thousands of volunteers every year to participate in sea turtle conservation and research projects (Appendix Table F-2). Volunteers are often required to undergo substantial training at their own expense and commit to spend long hours working, often during the night. For example, the nonprofit organization Earthwatch matches volunteers with academic researchers working at field stations around the world. By paying to spend time working with scientists on research projects, volunteers support sea turtle research and conservation both financially and logistically, and gain first-hand experience of conservation issues. Trips may last from days to several weeks, and often require a commitment of 10 or more hours per day. For example, on one 10-day volunteer trip with a cost of $2,450 (plus airfare), volunteers spend time tagging, measuring, and weighing leatherback seat turtles in Trinidad, patrolling beaches from sundown to the early hours of the morning (Earthwatch Institute 2010).

Baseline IM&E of Special Status Species and Potential IM&E Reductions Under the Final Rule and Options Considered

Several passive-use (e.g., wildlife viewing and photography) and nonuse values are associated with U.S. sea turtle populations. Many households express passive use value by participating in ecotourism activities, such as visiting sea turtle nesting areas, or by participating in sea turtle conservation activities (Frazer 2005). Additionally, a high proportion of governmental expenditures on T&E species are for turtle species (Table 5-4), suggesting that the public values the preservation of sea turtle populations.

Electric generating facilities are known to impinge and entrain all six species of sea turtles found in U.S. waters (Norem 2005), with more than 730 occurrences of overlap between species ranges and CWIS (Table 5-1). Incidences of mortality have been reported at facilities in California, Texas, Florida, South Carolina, North Carolina, and New Jersey (National Research Council 1990; Plotkin 1995). These facilities span a wide range of intake flows (less than 30 mgd to more than 1,400 mgd AIF), suggesting that sea turtle mortality is not limited to large intakes. Although quantitative reports are available from a few power stations, high-quality data is available from only one source, the St. Lucie Nuclear Power Plant, at Hutchinson Island, FL, where annual capture rates range from 350 to 1,000 turtles (Appendix Table F-1). Despite estimates of mortality rates due to entrainment of less than 3 percent, approximately 85 percent of entrained organisms show evidence of injury as a result of entrainment (Norem 2005). As such, true mortality rates from CWIS may be higher than reported, particularly for individuals captured repeatedly (37 percent of green and 13 percent of loggerhead sea turtles entrained between May and December 2000 were recaptured individuals) (Norem 2005).

Although the magnitude of IM&E is small relative to fishing-related mortality, the cumulative impact of IM&E is unclear. The only study presenting a quantitative estimate of annual IM&E estimated mortality rates to be between 5 and 50 individuals per year (Plotkin 1995). Consequently, sufficient data does not exist to estimate baseline sea turtle mortality due to entrainment and impingement at regional or national scales. However, the lower population sizes, long life-span, and high reproductive potential of adult turtles (Crouse et al. 1987), mean the final existing facilities rule is likely to have only a small effect on the long-term viability of turtle populations.

Potential Benefits of Protecting Sea Turtle Species

Per-household WTP

EPA identified a study that used a stated preference valuation approach to estimate the total economic value (i.e., use and nonuse values) of a management program designed to reduce the risk of extinction for loggerhead sea turtles (Whitehead 1993). The mail survey asked North Carolina households whether they were willing to pay for a management program that reduces the probability that loggerhead sea turtles will be extinct in 25 years. EPA used Whitehead (1993) to assess the range of benefits potentially resulting from the final rule and Proposal Options 2 and 4 (detailed methodology in Appendix F, Section 2). EPA included the resulting benefits estimates here as an illustrative example and did not include them its national benefit totals for the final rule and options considered.

EPA reviewed the available data sources and biological models to assess the potential impact of baseline IM&E and reductions in IM&E on the probability of sea turtle extinction in 25 years. Although analyses of sea turtle extinction risk have been conducted (e.g., Conant et al. 2009), EPA was unable to identify an existing model or analysis that could be readily used in conjunction with available mortality data to estimate the marginal impacts of CWIS on sea turtle extinction risk. Estimates from the literature suggest that IM&E is of relatively low importance compared to other human-induced mortality such as shrimp trawling and other fisheries (Plotkin

1995). However, Crouse *et al.* (1987) found that mortality at juvenile and subadult life stages can have a substantial effect on population growth, which suggests that small changes in survival at these age classes could have a measurable impact on extinction risk. For this illustrative example, EPA assumed a marginal change in extinction probability of loggerhead sea turtles due to the final rule is of 0.01 (i.e., a 1 percent decrease in the probability of extinction in 25 years). EPA bases this assessment upon reports that IM&E may result in the loss of more than 100 turtles per year (Appendix Table E-1), and because turtle population growth rates are known to be sensitive to changes in juvenile and subadult mortality (Crouse et al. 1987).

EPA used a value of 0.01 within Whitehead's (1993) modeling framework to estimate household values for changes in extinction risk for loggerhead sea turtles as a consequence of the final rule (details of this calculation are in Appendix Section F-2). Although EPA did not base this assessment on formal quantitative analysis of extinction risk, it illustrates the magnitude of potential benefits associated with reductions in sea turtle IM&E. Using the published mean values for all other model parameters, EPA calculated an annual household value of $0.37 (2011$). Estimates were converted to 2011dollars using the consumer price index (USBLS 2011).

Total WTP for all Households

Whitehead's (1993) study for loggerhead sea turtle management activities was based on a state-wide survey of North Carolina residents. However, the large geographic range of sea turtles suggests that households of many coastal states through their U.S. range would value activities that decrease their extinction risk. There is also the potential for differential values within and across states. Households farther away from the resource may value sea turtle survival less than households near the ocean because they are less likely to participate in passive uses of the resource. Although EPA recognizes that the application of the benefit transfer may overestimate household values for states with population centers far from sea turtle habitat, evidence from the literature suggests that households may value changes in environmental resource that are occurring at great distances. For example, Pate and Loomis (1997) found that respondents were willing to ascribe stated preference values to environmental amenity changes in other states. As such, by focusing on residents of coastal states only, estimated benefits may undervalue national willingness to pay for the preservation of loggerhead sea turtles.

As noted above, EPA includes its calculations for the benefits of protecting sea turtles here as an illustrative example. For this example, EPA focused solely on impacts to loggerhead sea turtles (one of six T&E sea turtle species in the United States). By focusing only on loggerhead sea turtles, EPA notes that estimated benefits are likely to be lower than those held by individuals for all T&E turtle species. EPA chose this species of turtles because they are late-maturing, have an existing population model (Crouse et al. 1987), an existing valuation study (Whitehead 1993), and are the most commonly affected species of turtle (Appendix F). The U.S. range of loggerhead sea turtles includes the Gulf of Mexico, South Atlantic, Mid-Atlantic, and North Atlantic 316(b) regions (USFWS 2010b). Assuming affected populations include all households within states with regulated facilities that potentially have an impact on loggerhead sea turtles, 54.83 million households would be willing to pay for improved protection of this species (Table 5-8). EPA applied the mean household WTP of $0.37 (2011$) to all four regions because the Whitehead (1993) function does not include income or other demographic variables that allow estimation of state-specific WTP. The total annual WTP for a 1 percent increase in the survival probability of loggerhead sea turtles annualized at a 3 percent discount rate is $19.3 million. Annualized benefits for each region are presented in Table 5-8, assuming that benefits begin to accrue in 2014 and continue throughout the compliance period. Because EPA does not currently have accurate national estimates of IM&E for turtle species, nor are population models available that estimate the effect of the existing facilities rule on population size and extinction risk, EPA is presenting these estimates only to assess the potential range of benefits, and is not including them in national benefits totals for the final rule and options considered. Actual benefits may be higher or lower than these estimates, with Proposal Option 2 likely to provide substantially greater benefits than the final rule and Proposal Option 4.

Table 5-8: Benefits of a 1 Percent Increase in the Probability that Loggerhead Sea Turtles Will Not Be Extinct in 25 Years

Region	States Included	Number of Households (millions)	Annualized Benefits (2011$, millions)	
			3% Discount Rate	7% Discount Rate
North Atlantic	CT, MA, ME, NH, RI	5.41	$1.90	$1.86
Mid-Atlantic	DE, MD, NJ, NY, PA, VA	21.11	$7.41	$7.25
South Atlantic	FL, GA, NC, SC	12.06	$4.24	$4.14
Gulf of Mexico[a]	FL, LA, MS, TX	16.26	$5.71	$5.59
Total	-	**54.83**	**$19.26**	**$18.84**

[a] Florida households are included in both the South Atlantic and Gulf of Mexico regions. To prevent double-counting, Florida households were apportioned between these regions based on relative AIF.
Note: Because of uncertainty in estimates of increased survival probability, and because benefits were not calculated for options, these values are not included in national totals.
Source: U.S. EPA analysis for this report

5.4.3 Limitation and Uncertainties

Table 5-9 summarizes the caveats, omissions, biases, and uncertainties known to affect the estimated benefits for sea turtles (Section 5.4.2.3), and T&E finfish in the Inland region (Section 5.4.2.1).

Table 5-9: Caveats, Omissions, Biases, and Uncertainties in the T&E Species Benefits Estimates

Issue	Impact on Benefits Estimate	Comments
Change in T&E populations due to IM&E is uncertain	Estimates understated	Projected changes in number of fish affected may be underestimated because neither cumulative impacts of IM&E over time nor interactions with other stressors are considered.
IM&E effects are not estimated for all T&E species and all regions	Estimates understated	EPA was unable to estimate IM&E of T&E species for all regions due to lack of data. The large amount of overlap between T&E ranges and CWIS suggests that many affected species are likely to be missing from IM&E reports.
Benefit estimates include only a subset of species identified as affected	Estimates understated	EPA was unable to apply benefit transfer of values for all affected species. Benefits estimates address 80 to 84 percent of documented T&E A1E losses in the Inland region.
Benefit estimates used in benefit cost analysis include only recreational use values	Estimates understated	EPA applied recreational use values to estimate benefits for the species included in the analysis. Values held for T&E species are primarily nonuse values, which were not monetized. In addition, some of the affected species have commercial use values, which were not estimated.
Benefit transfer introduces uncertainties	Uncertain	EPA applied a recreational use value for sturgeon in California to value sturgeon and paddlefish in the Inland region. This value may over- or understate recreational values of sturgeon and paddlefish in the Inland region.
Ecological consequences of reduced numbers of T&E species	Estimates understated	WTP values are unlikely to include damage to food-webs and ecosystem stability as a consequence of the removal or restoration of T&E species.
Effects of thermal impacts from CWIS on T&E populations is uncertain	Uncertain	EPA has few data on the effect of thermal discharge on T&E species.

6 Commercial Fishing Benefits

Commercial fisheries can be adversely affected by IM&E in addition to many other stressors. Commercially landed fish are exchanged in markets with observable prices and quantities; however, estimating the change in economic surplus from increases in the number of commercially landed fish requires consideration of various conceptual and empirical issues. This chapter provides an overview of these issues, and presents how EPA estimated the change in commercial fisheries-related economic surplus associated with the elimination of, and reduction in, baseline IM&E under the final rule and regulatory options it considered.

This chapter includes a review of the concept of economic surplus, and describes economic theory and empirical evidence regarding the relationship between readily observable dockside prices and quantities and the economic welfare measures of producer and consumer surplus that are suitable for benefit-cost estimation.

Section 6.1 describes the methodology used to estimate the commercial fisheries-related benefits, including conceptual and empirical discussions of producer and consumer surplus. Section 6.2 presents the commercial fisheries-related benefits by region, and Section 6.3 presents the limitations and uncertainties associated with EPA's analysis.

6.1 Methodology

The methodology EPA employed to estimate the commercial fishing benefits associated with the regulatory options for the final rule closely follows the analysis EPA conducted for the Section 316(b) Phase III Final Rule (USEPA 2006b). Changes from that analysis include updated estimates of baseline IM&E and IM&E reductions, and updated dockside prices. EPA estimated dockside prices based on the five-year average price between 2007 and 2011, from commercial fishing landings data obtained from the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) (NMFS 2012a).

EPA measured commercial fishing benefits as changes in producer surplus. Estimated benefits for each region are presented in Section 6.2. EPA also considered potential consumer surplus values associated with IM&E, but did not estimate changes in consumer surplus for the final rule and options considered because it found that dockside prices would not change enough to produce measurable shifts in consumer surplus. Appendix H presents the details of EPA's assessment of consumer surplus.

6.1.1 Estimating Consumer and Producer Surplus

The total loss to the economy from IM&E impacts on commercially harvested fish species is determined by the sum of changes in both producer and consumer surplus (Hoagland and Jin 2006). EPA modeled IM&E using the methods presented in Chapter 3. EPA assumed a linear relationship between stock and harvest. That is, if 10 percent of the current commercially targeted stock were harvested, EPA assumed that 10 percent of any increase in that species due to lower IM&E would be harvested. Thus, EPA assumed that the percentage increase in harvest is the same as the percentage increase in the fish population. The percentage of fish harvested is based on historical fishing mortality rates. EPA used historical NMFS landings data on commercial and recreational catch to determine the proportions of total species landings attributable to recreational and commercial fishing. EPA applied these proportions to the estimated total change in harvest to distribute benefits between commercial and recreational fisheries.

Producer surplus provides an estimate of the economic benefits to commercial fishers. Welfare changes can also be expected to accrue to final consumers of fish and to commercial consumers, including processors, wholesalers, retailers, and middlemen, if the projected increase in catch due to the rule is accompanied by a decrease in price. These impacts can be expected to flow through the tiered commercial fishery market (as described in Holt and Bishop (2002)).

Holt and Bishop (2002) used a fishery market model to estimate changes in welfare as a result of changes in the level of the commercial fishing harvest. The market model takes as inputs the expected change in harvest and baseline gross revenues, and provides as outputs the expected change in producer and consumer surplus. In general, the analysis of market impacts involves the following steps (Bishop and Holt (2003)):

1. Assessing the net welfare changes for fish consumers due to changes in fish harvest and the corresponding change in fish price.
2. Assessing net welfare changes for fish harvesters due to the change in total revenue, which could be positive or negative.
3. Calculating the change in net social benefits when the fish harvest changes.

Figure 6-1 illustrates a simplified fishery market model as shown in Bishop and Holt (2003). For simplicity, the authors assume that the fishery is managed on quota basis with the baseline quota shown as F^1 and baseline dockside or ex-vessel price as P^1. They use an inverse demand function, *P(F),* because fish are perishable, with the quantity harvested driving price in the short run.

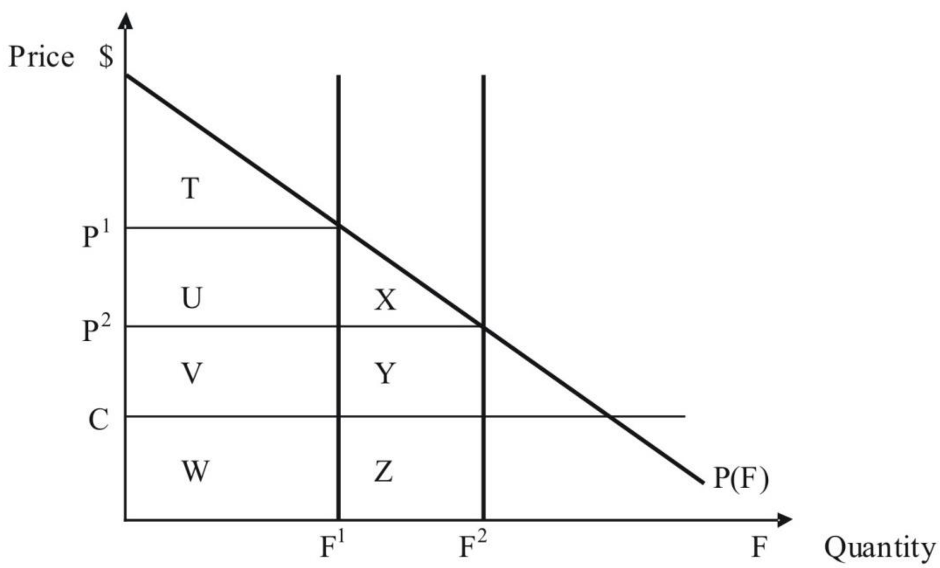


Figure 6-1: Fishery Market Model, reproduced from Bishop and Holt (2003)

6.1.1.1 Step 1: Assessing Benefits to Consumers

The downward sloping line labeled *P(F),* depicted in Figure 6-1, represents a general equilibrium demand function that accounts for markets downstream of commercial fishers. As described above, the vertical curve F^1 is the quantity of fish supplied to the market by commercial fishers under the baseline conditions. Equilibrium is attained at the point where $P(F)$ equals F^1. The intersection of these two lines gives the price P^1 at which quantity F^1 is sold. In this case the total amount paid by consumers for fish is equal to $P^1 \times F^1$, which is equal to the area of the boxes $U + V + W$ in the graph. The consumer surplus, or benefit to consumers, is equal to the area of the triangle T.

The measurement of the benefits from reducing IM&E relies on the assumption that a decrease in mortality of fish, larvae, and eggs under a scenario of reduced IM&E would increase fish populations and the quantity of fish supplied to consumers (i.e., an increase from F^1 to F^2). If the quantity of fish available to the market increases from F^1 to F^2, this in turn would result in a lower market price for fish (i.e., P^2). The total amount paid by consumers changes to $P^2 \times F^2$, which is equal to the area of the boxes $V + W + Y + Z$. This area may be smaller or larger than area $U + V + W$, but unequivocally increases the consumer surplus so that it is equal to the area of the triangle $T + U + X$. The difference in consumer surplus between the reduced IM&E scenario and the current baseline scenario (i.e., $U + X$) is the measure of benefits to consumers from reducing IM&E.

Estimating the change in the price of fish from changes in commercial fish harvest requires the following input data: (1) an estimate of the baseline prices and quantities of the commercial fishing harvest, (2) the estimated change in the commercial fishing harvest under the reduced IM&E scenario, and (3) an understanding of the price elasticity of demand for fish. The price elasticity of demand for fish measures the percentage change in demand in response to a percentage point change in fish price. Thus, the inverse elasticity, or price flexibility, measures the percent change in price for a given percent change in quantity.

To properly estimate price changes, it is necessary to consider the contribution of the species to the overall market. Because individual demand functions incorporating substitutes are not available for most species, EPA estimated price changes in the following way.

The Agency estimated the total baseline harvest for relevant species (commercial species of similar types to those affected by IM&E) using NMFS landings data from 2007 to 2011in three categories: finfish, shrimp, and crabs.[22] EPA aggregated the species to account for substitution. The totals for finfish were summed for the East Coast and Gulf, and for the West Coast, while totals for shrimp and crabs were summed across all coastal regions.[23] EPA summed estimated harvest increases from the elimination of baseline IM&E according to the same species and regional categories (column 3 in Table 6-1).

EPA estimated price elasticity of demand based on a review of the economics literature (Asche et al. 2005; Capps Jr. and Labregts 1991; Cheng and Capps Jr. 1988; Davis et al. 2007; Lin et al. 1988; Tsoa et al. 1982) (column 6 in Table 6-1) . The percentage change in price was calculated by dividing percentage change in harvest by elasticity. As shown in Table 6-1, the expected price changes resulting from eliminating baseline levels of IM&E are very small, ranging from 0.21 percent to 2.5 percent. EPA expects that price changes would be substantially less for the final rule due to much lower reductions in IM&E. Appendix H of this document presents the detailed calculations and results.

22 For example, offshore species such as tuna and swordfish, baitfish species, and shellfish were not included.

23 Harvests for Alaska and Hawaii were not included in the totals.

Table 6-1: Estimated Average Percentage Change in Ex-Vessel Price by Region and Species Group from the Elimination of Baseline IM&E

Region	Species Group	Increase in Harvest from Elimination of Baseline IM&E[a] (lbs)	Total Average Annual Harvest[a]	Percentage Change in Harvest	Elasticity	Percentage Change in Price[b]
California	Finfish	1,920,625	489,705,990	0.39%	-1.89	-0.21%
East Coast and Gulf	Finfish	12,548,060	265,617,830	4.72%	-1.89	-2.50%
All Regions	Crabs	1,373,553	258,973,619	0.53%	-1.31	-0.40%
All Regions	Shrimp	369,750	279,365,691	0.13%	-0.63	-0.21%

[a] Sum of total landings for all relevant species.
[b] Percentage changes in price reflect the average across all species within the species group and region.
Sources: U.S. EPA analysis for this report, NMFS (2012a)

EPA did not include estimates of changes in consumer surplus for commercial species. Prices must change in order for consumer surplus to change. Most species of fish have numerous close substitutes. The literature suggests that when there are plentiful substitute fish products, numerous fishers, and a strong ex-vessel market, individual fishers are generally price takers. Although there are exceptions, fisheries economics studies often make these assumptions in analyzing regional effects from harvest changes (e.g., Herrmann 1996; Thunberg et al. 1995) and international markets (e.g., Clarke et al. 1992). Consumer surplus measures that NMFS has estimated for past environmental impact statements tend to be quite low. NMFS fisheries analyses incorporate price changes for large changes in regional or national harvest, such as stock rebuilding. However, for small changes in landings, such as those EPA expects under the final rule, it is standard to assume that prices are fixed.[24]

6.1.1.2 Step 2: Assessing Producer Surplus

In an unregulated fishery, the long-run change in producer surplus due to an increase in fish stocks will be zero percent of the change in gross revenues because in open access fisheries, excess profits are always driven to zero at the margin. Most fisheries are, however, regulated with quotas or restrictive permits to prevent overfishing. Thus, lasting economic benefits accrue to commercial fishers from reductions in IM&E and the subsequent increase in harvest. Fishery regulations seek to create sustainable harvests that maximize resource rents.[25] In a regulated fishery, IM&E impacts reduce the number of fish available to harvest. This reduction may lead to more-stringent regulations and decreases in harvest. In this case, the change in producer surplus can be related to the change in harvest and the resulting gross revenue.

In Figure 6-1, the line C represents the cost to the producer of supplying a pound of fish. The model assumes that average cost is equal to marginal cost, that is, C is constant for all pounds produced.[26] When the supply of fish is equal to F^1, the commercial fishers sell F^1 pounds of fish at a price of P^1 and earn revenues equal to $U + V + W$. The area between P^1 and C is the producer

24 Personal communications with NMFS economists Cindy Thomson (2008), Eric Thunberg (2008), Steve Freese (2008), and Sabrina Lovell (2013).

25 In addition, even in open access fisheries, intramarginal rents are earned by at least some boats (Thunberg 2008).

26 If marginal costs increase as harvest increases, some of the producer surplus per unit will be lost due to the increased costs.

surplus that accrues to producers for each pound of fish. Total producer surplus realized by producers is equal to $(P^1 - C) \times F^1$. In the example, this producer surplus is equal to the area of $U + V$. The area W is the amount that producers pay for capital and labor and to suppliers if the harvest equals F^1 (e.g., fishing gear and the costs of operating in the market).

When supply increases to F^2, the producers sell F^2 pounds of fish at a price of P^2. The total cost to produce F^2 increases from W to $W + Z$. The total producer surplus changes from $U + V$ to $V + Y$. This change may be either positive or negative, depending on the relative elasticity of demand, which changes the relative sizes of areas U and Y.

In theory, producer surplus is equal to normal profits (total revenue minus fixed and variable costs), minus the opportunity cost of capital. The fixed costs and inputs are incurred independently of the expected marginal changes in the level of fish landings (Squires et al. 1998; Thunberg and Squires 2005). Total variable costs including labor, fuel, ice, and other supplies, however, *vary directly* with the level of landings. Furthermore, because EPA estimated the opportunity cost of capital to be only about 0.4 to 2.6 percent of producer surplus, EPA assumed that normal profits are a sufficient proxy for producer surplus (USEPA 2004a). As a result, EPA's assessment of producer surplus is a relatively straightforward calculation in which the change in producer surplus is calculated as a species- and region-specific fraction of the change in gross revenue due to increased landings.

The change in producer surplus, captured by "normal profits," is assumed to be equivalent to a fixed proportion of the change in gross revenues. EPA estimated gross revenue change from the change in the commercial harvest due to reducing IM&E, and the change in prices associated with the increased commercial harvest. As discussed above, EPA estimated price changes to be negligible, and therefore did not include price changes in the model. EPA estimated species- and region-specific Net Benefits Ratios, which represent the fractional share of gross revenue associated with net benefits. EPA's approach for estimating Net Benefits Ratios using available data on variable costs from sources such as the NMFS is described in more detail in Section A4-10 of US EPA (2006). EPA then applied the Net Benefits Ratio to the estimated change in gross revenue under the 316(b) final rule and regulatory options EPA considered to estimate the increase in producer surplus.

Table 6-2 to Table 6-7 present the Net Benefit Ratios, which range from 0.15 to 0.85, by regions and species.[27,28] See Chapter 1, Section 1.2 for descriptions of the seven study regions. EPA excluded the Inland region from the analysis because of a negligible commercial fishing harvest in this region. EPA notes that this approach yields an estimate of benefits to commercial fisherman, not benefits to society as a whole because changes in consumer surplus are not captured, and because people may also have nonmarket values for commercial fish (e.g., recreational and existence values). As described in Section 6.1.1.1, EPA did not estimate changes in consumer surplus because the expected changes in consumer surplus due to the final rule will

[27] Positive Net Benefits Ratios reflect the assumption that commercial fishers will accrue rents (profits) in regulated fisheries. When calculating the Net Benefits Ratios, EPA assumed that the predicted changes in harvest are such that fixed costs and variable costs per ton will not change. If costs remain constant, a marginal change in harvest is more likely to result in increases in profit and positive producer surplus.

[28] In the case of species aggregates (e.g., forage species), EPA assumed that the net benefit ratio is equal to the simple average of all empirically estimated net benefit ratios in the region. Species aggregates are listed as "Other" in Table 6-2 to Table 6-7.

be minor. EPA's analysis of nonmarket benefits for fisheries improvements is presented in Chapter 8.

Table 6-2: California Region, Management Method, Gear Type, Status of Stock, and Net Benefits Ratio, by Species

Species	Main Management Method	Main Gear Type	Status of Stock[a]	Net Benefits Ratio
Anchovies	Annual landings	Roundhaul	Not subject to overfishing	0.64
Cabezon	Total allowable catch	Hook-and-line	Not overfished or subject to overfishing	0.52
Crabs	Seasonal closures	Pots and traps	Undefined	0.74
Drum and Croaker	Permits	Nets	Unknown	0.42
Dungeness Crab	Size, no females, closed during molting season	Traps	Unknown	0.74
Flounders	Quotas	Bottom trawl	Not overfished or subject to overfishing	0.64
California Halibut	Total allowable catch	Longline	Unknown	0.58
Other	N/A	N/A	N/A	0.53
Rockfish	Quotas	Trawls	Not overfished or subject to overfishing[b]	0.62
California Scorpionfish	Quotas	Otter trawl	Not overfished	0.47
Sculpin	Nonrestrictive permits	Trawls	Unknown	0.64
Sea Bass	Season, size, gear restrictions	Gillnets	Unknown	0.66
Shad, American	None	Nets	Unknown	0
Shrimp	Seasonal closures	Trawl	Unknown	0.15
Smelt	Seasonal closures	Nets	Unknown	0.66
Surfperch	Quotas	Handlines	Overfished but not subject to overfishing[b,c,d]	0.37

N/A = not applicable
[a] Status of stock designations based on data from the NMFS, Summary of Stock Status, 2nd Quarter 2012 (NMFS 2012b).
[b] Species group consists of many individual component species with conflicting stock status. The most common stock status among the component species was designated the Status of Stock for the species group.
[c] "Perch" species were used as a proxy for surfperch.
[d] "Overfished but not subject to overfishing" means that the fish stock is at a low level but is expected to rebuild given current rates of commercial fishing.

Table 6-3: North Atlantic Region, Management Method, Gear Type, Status of Stock, and Net Benefits Ratio, by Species

Species	Main Management Method	Main Gear Type	Status of Stock[a]	Net Benefits Ratio
Bluefish	Quotas	Gillnets	Not overfished or subject to overfishing	0.63
Butterfish	Quotas	NA	Not subject to overfishing	0.64
Atlantic Cod	Time/area closures	Otter trawl	Overfished or subject to overfishing	0.66
Crab	Size, sex, season	Traps	Unknown	0.57
American Plaice	Size	Otter trawl	Not overfished or subject to overfishing	0.63
Windowpane	Time/area closures	Bottom trawl	Overfished but not subject to overfishing[b,c]	0.63
Winter Flounder	Quotas	Otter trawls	Overfished but not subject to overfishing[b]	0.64
Flounder	Total allowable landing	Bottom trawl	Overfished or subject to overfishing[b]	0.63
Red Hake	Quotas	Otter trawls	Not overfished or subject to overfishing	0.62
Silver Hake	Quotas	Otter trawls	Not overfished or subject to overfishing	0.63
Atlantic Herring	Total allowable catch	Purse seine	Not overfished or subject to overfishing	0.76
Atlantic Mackerel	Annual quota	Unknown	Not overfished or subject to overfishing	0.77
Atlantic Menhaden	Not reg. In this area	Unknown	Subject to overfishing but not overfished	0.68
Other	N/A	N/A	N/A	0.57
White Perch	Size limits	Unknown	Unknown	0.82
Pollock	Time/area closures	Bottom trawl	Not overfished or subject to overfishing	0.71
Sculpin	Open access	Unknown	Unknown	0
Scup	Quotas	Otter trawls	Not overfished or subject to overfishing	0.69
Searobin	Open access (by catch)	Unknown	Unknown	0
Shad, American	Mortality targets	Unknown	Overfished	0.6
Skate	Catch limits	Otter trawl	Not overfished or subject to overfishing[b]	0.68
Tautog	Possession limits	Otter trawl	Unknown	0.46
Weakfish	Size limits	Trawls	Overfished but not subject to overfishing	0.76

N/A = not applicable

[a] Status of stock designations based on data from the National Marine Fisheries Service, Summary of Stock Status, 2nd Quarter 2012 (NMFS 2012b). Supplemental stock status designations based on data from the Atlantic States Marine Fisheries Commission (ASMFC 2012).

[b] Species group consists of many individual component species with conflicting stock status. The most common stock status among the component species was designated the Status of Stock for the species group.

[c] "Overfished but not subject to overfishing" means that the fish stock is at a low level but is expected to rebuild given current rates of commercial fishing.

Table 6-4: Mid-Atlantic Region, Management Method, Gear Type, Status of Stock, and Net Benefits Ratio, by Species

Species	Main Management Method	Main Gear Type	Status of Stock[a]	Net Benefits Ratio
Alewife	Bans, species of concern	Fish weirs	Overfished	0.85
American Shad	Chesapeake fishery closed	Unknown	Overfished	0.84
Atlantic Croaker	Gear restrictions	Gillnets	Not overfished or subject to overfishing	0.74
Atlantic Menhaden	Open access	Purse seine, otter trawl, gill net	Not overfished or subject to overfishing	0.67
Black Drum	Quotas	Unknown	Unknown	0.7
Blue Crab	Limits on female crabs, size	Pots	Unknown	0.57
Bluefish	Quotas	Gillnets	Not overfished or subject to overfishing	0.63
Butterfish	Quotas	Unknown	Not subject to overfishing	0.64
Crab	Season, size	Unknown	Unknown	0.57
Drum and Croaker	Gear restrictions, quotas	Nets	Not subject to overfishing	0.74
Flounder	Quotas	Bottom trawl	Not overfished or subject to overfishing	0.65
Other	N/A	N/A	N/A	0.73
Red Hake	Quotas	Otter trawls	Not overfished or subject to overfishingb	0.62
Scup	Quotas	Otter trawls	Not overfished or subject to overfishing	0.69
Searobin	Open access	Unknown	Unknown	0
Silver Hake	Quotas	Otter trawls	Not overfished or subject to overfishingb	0.63
Spot	License	Haul seines	Unknown	0.84
Striped Bass	Quotas	Gill nets	Not overfished or subject to overfishing	0.67
Striped Mullet	Gear restrictions	Cast nets	Unknown	0.7
Tautog	Possession limits	Otter trawl	Overfished and subject to overfishing	0.46
Weakfish	Size limits	Trawls	Overfished but not subject to overfishingc	0.76
White Perch	Size limits	Unknown	Unknown	0.82

N/A = not applicable

[a] Status of stock designations based on data from the NMFS, Summary of Stock Status, 2nd Quarter 2012 (NMFS 2012b). Supplemental stock status designations based on data from the Atlantic States Marine Fisheries Commission (ASMFC 2012).

[b] Estimates from the North Atlantic region are presented because red and silver hake stocks were not reported in the Mid-Atlantic region.

[c] "Overfished but not subject to overfishing" means that the fish stock is at a low level but is expected to rebuild given current rates of commercial fishing.

Table 6-5: South Atlantic Region, Management Method, Gear Type, Status of Stock, and Net Benefits Ratio, by Species

Species	Main Management Method	Main Gear Type	Status of Stock[a]	Net Benefits Ratio
Blue Crab	Size limits	Pots	Unknown	0.57
Crab	Size, sex, season limits	Traps	Unknown	0.57
Drum and Croaker	Open access (by catch)	Otter trawl bottom, gill nets	Not subject to overfishing	0.54
Atlantic Menhaden	Five year annual cap on reduction fishery in Chesapeake	Unknown	Subject to overfishing but not overfished	0.76
Other	N/A	N/A	N/A	0.59
Spot	License	Haul seines	Unknown	0.7
Stone Crab	Size limits	Traps	Unknown	0.58
Weakfish	Size limits	Trawls	Overfished but not subject to overfishing[b]	0.64

[a] Status of stock designations based on data from the NMFS, Summary of Stock Status, 2nd Quarter 2012 (NMFS 2012b). Supplemental stock status designations based on data from the Atlantic States Marine Fisheries Commission (ASMFC 2012).
[b] "Overfished but not subject to overfishing" means that the fish stock is at a low level but is expected to rebuild given current rates of commercial fishing.

Table 6-6: Gulf of Mexico Region, Management Method, Gear Type, Status of Stock, and Net Benefits Ratio, by Species

Species	Main Management Method	Main Gear Type	Status of Stock[a]	Net Benefits Ratio
Blue Crab	Limited entry, pot limits	Pots	Unknown	0.72
Black Drum	Limited access permits	Hand lines, gill nets	Unknown	0.69
Leatherjacket	N/A	Rod/reel, hand and long lines, pots and traps	Unknown	0
Mackerels	Quotas	Hook-and-line	Not overfished or subject to overfishing	0.75
Menhaden	Seasonal/area closures	Purse seines	Unknown	0.76
Other	N/A	N/A	N/A	0.46
Sea Basses	Quotas	Traps	Unknown	0.72
Sheepshead	Size	Cast net	Unknown	0.84
Shrimp	Same as pink shrimp	Unknown	Not overfished or subject to overfishing[b]	0.43
Spot	License	Haul seines	Unknown	0.54
Stone Crab	Size	Traps	Not subject to overfishing	0.71
Striped Mullet	Gear restrictions	Strike nets	Unknown	0.79
Striped Mullet	Gear restrictions	Strike nets	Unknown	0.79

[a] Status of stock designations based on data from the NMFS, Summary of Stock Status, 2nd Quarter 2012 (NMFS 2012b).
[b] Species group consists of many individual component species with conflicting stock status. The most common stock status among the component species was designated the Status of Stock for the species group.

Table 6-7: Great Lakes Region, Management Method, Gear Type, Status of Stock, and Net Benefits Ratio, by Species

Species	Main Management Method	Main Gear Type	Status of Stock	Net Benefits Ratio
Bullhead	State specific	Gill and trap nets	Unknown	0.29
Freshwater Drum	State specific	Gill and trap nets	Unknown	0.29
Other	State specific	Gill and trap nets	Unknown	0.29
Smelt	State specific	Gill and trap nets	Unknown	0.29
White Bass	State specific	Gill and trap nets	Unknown	0.29
Whitefish	State specific	Gill and trap nets	Unknown	0.29
Yellow Perch	State specific	Gill and trap nets	Unknown	0.29

6.1.1.3 Step 3: Estimating Net Social Benefits When the Fishing Harvest Increases

EPA estimated the change in net social benefits when the commercial fishing harvest increases from F^1 to F^2 by adding the results from Steps 1 and 2. Because area *U* is a transfer from commercial fishers to consumers, it does not affect social benefits. Therefore, the change in net social benefits is area $X + Y$ (see Figure 6-1). However, if demand elasticity is such that changes in price are negligible, as EPA expects (Section 6.1.1.1), area *X* will be negligible relative to *Y*, and total social benefits will be measured by area *Y*.

6.2 Benefits Estimates for Regional Commercial Fishing

The first step of the analysis of commercial fishing benefits involves a fishery-based assessment of IM&E-related changes in harvested species landings. Many of the fish species affected by IM&E at CWIS sites are harvested both recreationally and commercially. As described in Section 6.1.1, EPA assumed a linear relationship between stock and harvest and used historical NMFS landings data on commercial and recreational catch to determine the proportions of total species harvest attributable to recreational and commercial fishing. EPA applied these proportions to the estimated total change in harvest to distribute benefits between commercial and recreational fisheries. EPA then used the estimated change in commercial fishery harvest as a basis for estimating changes in producer surplus in the commercial fishing industry.

EPA assessed whether potential harvest increases under the final rule and options considered are reasonable when compared to historic harvest data. For this assessment, EPA compared estimated increases in commercial yield from the elimination of baseline IM&E for each species to average regional commercial harvest from 2007 to 2011. Table 6-8 summarizes baseline IM&E and harvest data for fourteen species for which the potential increase in commercial yield from the elimination of baseline IM&E exceeds 10 percent of regional harvest.

Notably, none of the species identified include major fisheries: many are infrequently targeted, and several have historical commercial harvests which vary widely on an annual basis. In many cases, the species identified are not subject to a federal fisheries management plan, and the overall status of stock is unknown. These uncertainties may increase the error associated with the regional-scale effects occurring as a consequence of the extrapolation of IM&E. Moreover, it is possible that the regional extrapolation of species-specific results may be biased because available IM&E studies are old (and therefore reflect IM&E under substantially different populations), or because particularly high IM&E counts at one or more facilities measured during an anomalous year may result in erroneous estimates of IM&E.

The sixteen species for which the potential increase in commercial yield from the elimination of baseline IM&E exceeds 10 percent of regional harvest include cabezon, California halibut, rockfish, and sculpin in the California region; sculpin in the North Atlantic region; spot, and weakfish in the Mid-Atlantic region; black drum, drum and croaker, leatherjacket, spot, and striped mullet in the Gulf of Mexico region; and freshwater drum, smelt, and white bass in the Great Lakes region. No increases exceeding 10 percent were found in the South Atlantic region. Among these fourteen species, the potential harvest increases range from 12 percent for striped mullet in the Gulf of Mexico to 1,512 percent for sculpin in the North Atlantic.

EPA used harvest and fisheries data to develop reasonable caps on increases in commercial harvest from the elimination of baseline IM&E and IM&E reductions under the final rule and options considered. Economists and biologists with NMFS recommended using either maximum sustainable yield (MSY) or historical harvest to assign reasonable caps on projected total harvest under the post-compliance scenario.[29] NMFS biologists provided MSY for three species groups: California cabezon, California sculpin, and West Coast rockfishes.[30] While there is no stock assessment for halibut, NMFS biologists suggested averaging the most recent four peaks in harvest. For other species lacking MSY data, EPA capped post-compliance harvest at the 90th percentile of annual harvest from 1982 to 2011. This follows recommendations from NMFS scientists to use harvest data for 25 years or more.[31]

North Atlantic sculpin. Mid-Atlantic spot, and Great Lakes freshwater drum and white bass were the only four species estimated to reach these caps within EPA's analysis. Caps for these four species are shown in bold type in Table 6-8. Notably, historical commercial catch of both North Atlantic sculpin and Mid-Atlantic spot are widely variable. For example, between 1995 and 2011, there were several years with no commercial catch of sculpin reported. For spot, commercial harvests changed by more than 2 million pounds per year (alternating between increases and decreases) for each year between 2006 and 2011. For Northeast Atlantic sculpin and Mid-Atlantic spot, these data suggest that commercial catch may not be limited by fish population, and that a large and sustained increase in commercial landings beyond the cap due to the reduction of IM&E is unreasonable.

The following sections present estimated benefits from commercial harvest changes in six of the seven study regions and the total for the six regions. The Inland region is excluded from the analysis due to a negligible commercial fishing harvest in this region.

29 Cindy Thomson, NMFS, personal communication (2008).

30 NMFS biologists suggested that sculpin in California be evaluated in combination with scorpionfish, as these species are grouped when determining the MSY.

31 Many fish populations peaked more than 25 years ago, when virgin, non-exploited populations existed and maximum harvests were achievable.

Table 6-8: Potential Harvest Increase from Eliminating IM&E as a Percentage of Total Harvest and Potential Harvest Capping Rules Used in EPA's Analysis

Region and Species	Baseline Harvest 2007-2011 (1,000 lbs.)	Baseline IM&E (1,000 lbs.)	Potential % Increase in Harvest	Maximum Harvest 1982-2011 (1,000 lbs.)	90th Percentile of Max. Harvest (1,000 lbs.)	MSY or Other Capping Rule (1,000 lbs.)	Cap Used (1,000 lbs.)
California Cabezon	53.7	76.1	142%	374.2	261.2	207.2[a]	No Cap[e]
California Halibut	495.5	176.9	36%	1,337.1	1.238.4	982.1[b]	No Cap
California Drum and Croaker	53.8	6.9	13%	1,491.5	1,288.6		No Cap
California Rockfish	2,741.3	1,634.5	60%	58,286.7	42.942.2	77,161.8[c]	No Cap
California Sculpin	3.8	3.7	97%	19.5	7.6	482.8[d]	No Cap
North Atlantic Sculpins	1.6	24.2	1,512%	4.8	4.8		**4.8**
Mid-Atlantic Spot	3,478.4	1,303.1	37%	4,784.6	4,543.0		**4,543.0**
Mid-Atlantic Weakfish	267.4	503.7	188%	7,023.5	6,714.1		No Cap
Gulf of Mexico Black Drum	4,621.9	1,945.0	42%	10,644.4	7,314.6		No Cap
Gulf of Mexico Drum and Croaker	111.8	47.8	43%	2,934.7	663.8		No Cap
Gulf of Mexico Leatherjacket	61.0	107.1	176%	519.7	447.4		No Cap
Gulf of Mexico Spot	16.9	46.3	274%	473.4	356.4		No Cap
Gulf of Mexico Striped Mullet	10,800.3	1,343.6	12%	30,433.6	27,789.7		No Cap
Great Lakes Freshwater Drum	585.9	248.8	42%	905.1	795.0	209.1	**795.0**
Great Lakes Smelt	380.5	92.9	24%	4,105.0	3,672.0		No Cap
Great Lakes White Bass	523.6	916.5	175%	1,332.0	771.7	248.1	**771.7**

[a] MSY (maximum sustainable yield).
[b] Average of most recent four peaks in harvest.
[c] MSY for rockfishes for the West Coast.
[d] MSY for all scorpionfish and sculpins.
[e] "No Cap" indicates that no cap was used during benefit estimation because increases did not result in exceedance of the 90th percentile of maximum harvest, MSY, or other capping rule.
Sources: U.S. EPA analysis for this report; NMFS data on baseline harvest, historical landings, and MSY.

6.2.1 California Region

Baseline levels of IM&E account for 1.9 million pounds of commercial fishing losses annually in the California region, as shown in Table 6-9. Rockfish account for the major portion of overall losses in this region. EPA estimated the annual undiscounted commercial fishing benefits of eliminating baseline IM&E to be approximately $2.0 million, as shown in Table 6-9. Applying a

3 percent discount rate, EPA estimates the annualized benefits of eliminating baseline IM&E to be $1.7 million. Applying a 7 percent rate, these annualized benefits are approximately $1.5 million.

As shown in Table 6-9, EPA estimates that annual commercial harvest will increase by approximately 7,000 pounds under the final rule. Annualized benefits to commercial fishers under the file rule will be about $3,000 using a 3 percent discount rate and $2,000 using a 7 percent discount rate. For other options considered, the annual increase is commercial harvest would range from about 7,000 pounds under Proposal Option 4 to 1.2 million pounds under Proposal Option 2. The associated annual benefits under other options considered would range from about $3,000 to $651,000 using a 3 percent discount rate and $2,000 to $422,000 using a 7 percent discount rate (Table 6-9). Appendix H presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-9: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E Mortality Losses at Regulated Facilities in the California Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Commercial Harvest (1,000 lbs)	Annualized Benefits from Increase in Commercial Harvest (2011$, 1,000s)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Proposal Option 4	7	$5	$3	$2
Final Rule	7	$5	$3	$2
Proposal Option 2	1,177	$1,236	$651	$422
Baseline	1,929	$2,025	$1,698	$1,519

Source: U.S. EPA analysis for this report

6.2.2 North Atlantic Region

Baseline levels of IM&E account for 414,000 pounds of annual commercial fishing losses in the North Atlantic region, as shown in Table 6-10, with flounder playing a particularly important role. EPA estimated the annual undiscounted benefits to commercial fishers from eliminating baseline IM&E to be approximately $476,000, as shown in Table 6-10. EPA estimates the total annualized benefits from eliminating baseline IM&E, applying a 3 percent discount rate, to be $399,000. Applying a 7 percent rate, these annualized benefits are approximately $357,000.

As shown in Table 6-10, annual commercial harvest will increase by approximately 7,000 pounds under the final rule. Annualized benefits to commercial fishers under the final rule will be about $4,000 using 3 percent discount rates and $3,000 using 7 percent discount rates. For other options considered, the annual increase in commercial harvest ranges from about 3,000 pounds under Proposal Option 4 to 318,000 pounds under Proposal Option 2. The associated annual benefits under other options considered range from about $1,000 to $202,000 using a 3 percent discount rate and $1,000 to $136,000 using a 7 percent discount rate (Table 6-10). Appendix H presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-10: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E Mortality Losses at Regulated Facilities in the North Atlantic Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Commercial Harvest (1,000 lbs)	Annualized Benefits from Increase in Commercial Harvest (2011$, 1,000s)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Proposal Option 4	3	$2	$1	$1
Final Rule	7	$6	$4	$3
Proposal Option 2	318	$365	$202	$136
Baseline	414	$476	$399	$357

Source: U.S. EPA analysis for this report

6.2.3 Mid-Atlantic Region

Baseline levels of IM&E account for approximately 7.8 million pounds of commercial fishing losses annually in the Mid-Atlantic region, as shown in Table 6-11. Atlantic menhaden, blue crab, drum and croaker, spot, weakfish, and “other” species[32] are the primary drivers of IM&E in the Mid-Atlantic region. EPA estimated the annual undiscounted benefits to commercial fishers from eliminating baseline IM&E to be $2.6 million, as shown in Table 6-11. Applying a 3 percent discount rate, annualized benefits from eliminating baseline IM&E are estimated to be $2.2 million. Applying a 7 percent rate, these annualized benefits are approximately $1.9 million.

As shown in Table 6-11, EPA estimates that annual commercial harvest will increase by approximately 3.1 million pounds under the final rule. Annualized benefits to commercial fishers under the final rule will be about $260,000 using a 3 percent discount rate and $190,000 using a 7 percent discount rate. For other options considered, the annual increase in commercial harvest ranges from 2.9 million pounds under Proposal Option 4 to 7.1 million pounds under Proposal Option 2. The associated annual benefits under other options considered range from about $242,000 to $1.2 million using a 3 percent discount rate and $177,000 to $770,000 using a 7 percent discount rate (Table 6-11). Appendix H presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

[32] The “other” species category includes losses which could not be assigned to a specific species group.

Table 6-11: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E Mortality Losses at Regulated Facilities in the Mid-Atlantic Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Commercial Harvest (1,000 lbs)	Annualized Benefits from Increase in Commercial Harvest (2011$, 1,000s)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Proposal Option 4	2,873	$383	$242	$177
Final Rule	3,072	$411	$260	$190
Proposal Option 2	7,090	$2,373	$1,206	$770
Baseline	7,758	$2,586	$2,169	$1,939
Source: U.S. EPA analysis for this report				

6.2.4 South Atlantic Region

Baseline levels of IM&E account for 78,000 pounds of commercial fishing losses in the South Atlantic region, as shown in Table 6-12. The estimated undiscounted annual commercial fishing benefits of eliminating baseline IM&E are driven primarily by Atlantic menhaden, spot, and drum and croaker and total $20,000, as shown in Table 6-12. Applying a 3 percent discount rate, the annualized benefits of eliminating baseline IM&E are estimated to be $17,000. Applying a 7 percent rate, these annualized benefits are $15,000.

As shown in Table 6-12, EPA estimates that annual commercial harvest will increase by approximately 41,000 pounds under the final rule. Annualized benefits to commercial fishers under the final rule will be about $6,000 using 3 percent discount rates and $5,000 using 7 percent discount rates. For other options considered, the annual increase in commercial harvest ranges from 37,000 pounds under Proposal Option 4 to 76,000 pounds under Proposal Option 2. The associated annual benefits under other options considered range from $6,000 to $10,000 using a 3 percent discount rate and $4,000 to $7,000 using a 7 percent discount rate (Table 6-12). Appendix H presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-12: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E Mortality Losses at Regulated Facilities in the South Atlantic Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Commercial Harvest (1,000 lbs)	Annualized Benefits from Increase in Commercial Harvest (2011$, 1,000s)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Proposal Option 4	37	$9	$6	$4
Final Rule	41	$10	$6	$5
Proposal Option 2	76	$19	$10	$7
Baseline	78	$20	$17	$15
Source: U.S. EPA analysis for this report				

6.2.5 Gulf of Mexico Region

Baseline levels of IM&E account for more than 6.0 million pounds of commercial fishing losses in the Gulf of Mexico region annually, as shown in Table 6-13. These losses are driven by black drum, striped mullet, and Atlantic menhaden. The estimated undiscounted annual commercial fishing benefits from eliminating baseline IM&E are approximately $3.9 million, as shown in Table 6-13. Applying a 3 percent discount rate, estimated commercial fishing benefits from eliminating baseline IM&E are estimated to be $3.4 million. Applying a 7 percent rate, these annualized losses are approximately $3.2 million.

As shown in Table 6-13, EPA estimates that annual commercial harvest will increase by approximately 1.7 million pounds under the final rule. Annualized benefits to commercial fishers under the file rule will be about $515,000 using a 3 percent discount rate and $379,000 using a 7 percent discount rate. For other options considered, the annual increase in commercial harvest ranges from 1.6 million pounds under Proposal Option 4 to 4.3 million pounds under Proposal Option 2. The associated annual benefits under other options considered range from $497,000 to $1.7 million using a 3 percent discount rate and $365,000 to $1.3 million using a 7 percent discount rate (Table 6-13). Appendix H presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-13: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E Mortality Losses at Regulated Facilities in the Gulf of Mexico Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Commercial Harvest (1,000 lbs)	Annualized Benefits from Increase in Commercial Harvest (2011$, 1,000s)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Proposal Option 4	1,642	$779	$497	$365
Final Rule	1,704	$808	$515	$379
Proposal Option 2	4,265	$2,651	$1,702	$1,256
Baseline	6,033	$3,926	$3,427	$3,161

Source: U.S. EPA analysis for this report

6.2.6 Great Lakes Region

Baseline levels of IM&E account for more than 1.1 million pounds of commercial fishing losses in the Great Lakes region annually, as shown in Table 6-14. These losses are driven by the white bass, freshwater drum, and “other” species. EPA estimated the annual undiscounted commercial fishing benefits from eliminating baseline IM&E in this region to be approximately $279,000, as shown in Table 6-14. Total annualized commercial benefits from eliminating baseline IM&E, applying a 3 percent discount rate, are estimated to be $244,000. Applying a 7 percent rate, these annualized losses are $225,000.

As shown in Table 6-14, EPA estimates that annual commercial harvest will increase by 838,000 pounds under the final rule. Annualized benefits to commercial fishers under the final rule will be about $145,000 using a 3 percent discount rate and $110,000 using a 7 percent discount rate. For other options considered, the annual increase in commercial harvest ranges from 784,000 pounds under Proposal Option 4 to 1.1 million pounds under Proposal Option 2. The associated annual benefits under other options considered range from $135,000 to $162,000 using a 3 percent discount rate and $102,000 to $116,000 using a 7 percent discount rate (Table 6-14). Appendix H presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers.

Table 6-14: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E Mortality Losses at Regulated Facilities in the Great Lakes Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Commercial Harvest (1,000 lbs)	Annualized Benefits from Increase in Commercial Harvest (2011$, 1,000s)		
		Undiscounted	3% Discount Rate	7% Discount Rate
Proposal Option 4	784	$202	$135	$102
Final Rule	838	$217	$145	$110
Proposal Option 2	1,092	$266	$162	$116
Baseline	1,137	$279	$244	$225

Source: U.S. EPA analysis for this report

6.2.7 National Estimates

Nationally, baseline levels of IM&E account for more than 17.3 million pounds of commercial fishing losses annually, as shown in Table 6-15. EPA estimated the annual undiscounted commercial fishing benefits from eliminating baseline IM&E to be approximately $9.3 million, as shown in Table 6-15. Total annualized commercial benefits from eliminating baseline IM&E, applying a 3 percent discount rate, are estimated to be $8.0 million. Applying a 7 percent rate, these annualized losses are $7.2 million.

As shown in Table 6-15, EPA estimates that annual commercial harvest will increase by 5.7 million pounds under the final rule. Annualized benefits to commercial fishers under the final rule will be about $0.9 million using a 3 percent discount rate and $0.7 million using a 7 percent discount rate. For other options considered, the annual increase in commercial harvest ranges from 5.3 million pounds under Proposal Option 4 to 14.0 million pounds under Proposal Option 2. The associated annual benefits under other options considered range from $0.9 to $3.9 million using a 3 percent discount rate and $0.7 to $2.7 million using a 7 percent discount rate (Table 6-15). Appendix H presents species-specific results for the estimated annual increase in harvest and monetary benefits to commercial fishers for each region.

Table 6-15: National Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E Mortality Losses at Regulated Facilities, for the Final Rule and Options Considered (2011$)				
Regulatory Option	**Annual Increase in Commercial Harvest (1,000 lbs)**	**Annualized Benefits from Increase in Commercial Harvest (2011$, 1,000s)**		
		Undiscounted	**3% Discount Rate**	**7% Discount Rate**
Proposal Option 4	5,345	$1,379	$883	$652
Final Rule	5,669	$1,457	$934	$689
Proposal Option 2	14,019	$6,910	$3,935	$2,707
Baseline	17,349	$9,312	$7,953	$7,215
Source: U.S. EPA analysis for this report				

6.3 Limitations and Uncertainties

Table 6-16 summarizes the caveats, omissions, biases, and uncertainties known to affect the estimates that EPA developed for the benefits analysis.

Table 6-16: Caveats, Omissions, Biases, and Uncertainties in the Commercial Benefits Estimates		
Issue	**Impact on Benefits Estimate**	**Comments**
Change in commercial landings due to IM&E is uncertain	Uncertain	Projected changes in harvest may be underestimated because cumulative impacts of IM&E over time, interactions with other stressors, and population changes, are not considered.
Some estimates of commercial harvest losses due to IM&E under current conditions are not region/species-specific	Uncertain	EPA estimated the impact of IM&E in the case study analyses based on the most current data available data provided by the facilities. However, in some cases these data are 20 years old or older. Thus, they may not reflect current fish stock and waterbody conditions.
Effect of change in stocks on landings is not considered	Uncertain	EPA assumed a linear stock to harvest relationship, so that a 10 percent change in stock would have a 10 percent change in landings; this may be low or high, depending on the condition of the stocks. Region-specific fisheries regulations also will affect the validity of the linear assumption.
Effect of uncertainty in estimates of commercial landings and prices is unknown	Uncertain	EPA assumed that NMFS landings data are accurate and complete. In some cases prices and/or quantities may be reported incorrectly.

7 Recreational Fishing Benefits

7.1 Introduction

This chapter presents the estimated benefits to recreational anglers from improved recreational fishing opportunities due to reductions in IM&E under the final rule and regulatory options EPA considered for section 316(b). EPA used a benefit transfer approach based on a meta-analysis of economic studies of recreational fishing benefits from improved catch rates. Benefit transfer involves adapting research conducted for another purpose to address the policy questions at hand (Bergstrom and De Civita 1999). Benefit-cost analysis of environmental regulations rarely affords sufficient time to conduct original stated or revealed preference studies specific to policy effects. Benefit transfer is a widely used approach which provides information to inform policy decisions in benefit-cost analysis of environmental regulations. EPA notes that Smith *et al.* (2002, p.134) state that "…nearly all benefit cost analyses rely on benefit transfers…"

Boyle and Bergstrom (1992) define benefit transfer as "the transfer of existing estimates of nonmarket values to a new study which is different from the study for which the values were originally estimated." There are four types of benefit transfer studies: point estimate, benefit function, meta-analysis, and Bayesian techniques (USEPA 2010a). These types may be categorized into three fundamental classes: (1) transfer of an unadjusted fixed value estimate generated from a single study site; (2) the use of expert judgment to aggregate or otherwise alter benefits to be transferred from a site or set of sites; and (3) estimation of a value estimator model derived from study site data, often from multiple sites (Bergstrom and De Civita 1999). Recent studies have shown little support for the accuracy or validity of the first method, leading to increased attention to, and use of, *adjusted values* estimated by one of the remaining two approaches (Bergstrom and De Civita 1999). The third class of benefit transfer approaches includes meta-analysis techniques, which economists have explored increasingly as a potential basis of policy analysis conducted by various government agencies charged with the stewardship of natural resources.[33]

Section 7.2 provides a brief overview of the benefit transfer methodology EPA used for estimating the recreational fishing benefits. Chapter A5 of EPA's Regional Benefits Analysis of the Final Section 316(b) Phase III Existing Facilities Rule (USEPA 2006b) provides a detailed description of the benefit transfer methodology that EPA employed in this analysis. Section 7.2 also highlights updates to the Phase III methodology. Section 7.3 presents the recreational fishing benefits by region, and Section 7.4 summarizes the limitations and uncertainties inherent in EPA's analysis of recreational fishing benefits.

7.2 Methodology

EPA's analysis of recreational fishing benefits from reducing IM&E at CWIS at regulated facilities includes the following general steps:

[33] Meta-analysis is "the statistical analysis of a large collection of results from individual studies for the purposes of integrating the findings" (Glass 1976).

1. **Estimate the forgone catch of recreational fish (in number of fish) due to baseline IM&E and increases in recreational harvest under regulatory options.** EPA modeled these losses using the methods presented in Chapter 3. EPA's estimates of recreational fish losses are expressed as the number of harvestable adults because this is the measure to which recreational values are attributed.[34] Many of the fish species affected by IM&E at CWIS sites are harvested both recreationally and commercially. EPA used the proportion of total species landings attributable to recreational fishing to estimate baseline losses in recreational harvest due to baseline (current) levels of IM&E and reductions in recreational harvest losses under the final rule and other options considered.
2. **Estimate the marginal value per fish.** EPA used the estimated meta-regression described in Chapter A5 of Regional Benefits Analysis of the Final Section 316(b) Phase III Rule (USEPA 2006b) to estimate marginal values per fish for the species affected by IM&E at all regulated existing facilities. To calculate the marginal value per fish for the affected species, EPA chose input values for the independent variables based on the affected species characteristics, study regions, and demographic characteristics of the affected angling populations. The study design variables were selected based on current economic literature. This step is described in more detail in Section 7.2.1.
3. **Estimate the value of forgone recreational catch lost to baseline IM&E benefits under regulatory options.** EPA multiplied the marginal value per fish by the number of recreational fish currently lost to baseline IM&E that would otherwise be caught by recreational anglers and increases in recreational fishing harvest under policy options, respectively.

7.2.1 Estimating Marginal Value per Fish

EPA used a benefit transfer function based on meta-analysis of recreational fishing studies from the Section 316(b) Phase III Final Rule to estimate marginal values per fish for the species affected by IM&E at regulated facilities. The general approach follows standard methods illustrated by Johnston *et al.* (2006) and Shrestha *et al.* (2007), among many others (e.g., Rosenberger and Phipps 2007). This function allows EPA to forecast willingness to pay (WTP) based on assigned values for model variables, chosen to best represent a resource change in the 316(b) policy context. EPA's meta-analysis results imply a simple benefit function of the following general form:

$$\ln(WTP) = \text{intercept} + \sum(\text{coefficient}_i)(\text{Independent Variable Values}_i) \qquad (7\text{-}1)$$

Here, ln*(WTP)* is the dependent variable in the meta-analysis—the natural log of WTP for catching an additional fish. The independent variables included in the meta-analysis characterize the species being valued, study location, baseline catch rate, elicitation and survey methods, demographics of survey respondents, and other specific characteristics of each study.

To calculate the marginal value per fish for the species affected by regulated facilities, EPA chose input values for the independent variables based on the characteristics of the affected species, study regions, and demographic characteristics of the affected angling populations. The study design variables were selected based on current economic literature. Table 7-1 provides the

[34] Adult fish of harvestable age means that they are the age at which they can legally be harvested.

independent variable names, the estimated variable coefficients ($coefficient_i$), and the assigned input values for each of the independent variables in the model.

EPA followed Johnston et al. (2006) in assigning values for methodological attributes (i.e., variables characterizing the study methodology used in the original source studies), which are set at mean values from the metadata except in cases where theoretical considerations dictate particular assignments. This approach follows general guidance from Bergstrom and Taylor (2006) that meta-analysis benefit transfer should incorporate theoretical expectations and structures, at least in a weak form. In this instance, two of the methodology variables, *RUM_nest* and *high_resp_rate*, are included with an assigned value of one. *RUM_year* represents the year in which the study was conducted, converted to an index by subtracting 1976. It was given the value of 9.37, corresponding to average study year of 1985, because there was no clear justification for selecting a specific year based on the meta-data. In their detailed analysis of methodological variable specifications for this meta-analysis model, Stapler and Johnston (2009) found that "the additional error associated with an empirical, mean value treatment of methodological covariates is relatively modest, on average."

EPA decided not to include the error term when using the regression equation to predict marginal values per fish. Bockstael and Strand (1987) argue that if the econometric error in an equation is due primarily to omitted variables, the error term should be included, but if the error is due primarily to random preferences or measurement error, it should be excluded. Because the error term is positive, the empirical effect of including this term is to increase the predicted marginal values. The authors warned against the practice of assuming that all error is associated with omitted variables. If the error is due to random preferences or measurement errors, the estimated WTP values are likely to be upward biased if the error term is included. EPA decided not to include the error term in the estimation of WTP per fish because the source of error in the underlying meta-data is unknown. EPA notes that when the error term is excluded, the values predicted by the regression equation are more consistent with those from the underlying studies.

Table 7-2 presents region- and species-specific values for the input variables that vary across regions. Table 7-3 presents the estimated marginal value per fish for all species affected by IM&E in each region.

Table 7-1: Independent Variable Assignments for Regression Equation

Variable	Coefficient	Assigned Value	Explanation
Intercept	-1.4568	1	The equation intercept was set to one by default.
SP_conjoint	-1.1672	0	Binary variables denoting the type of stated preference, travel cost, or random utility used for the study. Current academic literature suggests that nested RUM models produce the most accurate valuation results, so *RUM_nest* was set to one, and the other study methodology variables were set to zero.
SP_dichot	-0.9958	0	
TC_individual	1.1091	0	
TC_zonal	2.0480	0	
RUM_nest	1.3324	1	
RUM_nonnest	1.7892	0	
SP_year	0.08754	0	Variables denoting the year that the study was conducted by study type (stated preference, travel cost, or random utility model). *SP_year* and *TC_year* were set to zero because EPA selected RUM, above. *RUM_year* was set equal to the average value across the studies in the analysis, 9.37.
TC_year	-0.03965	0	
RUM_year	-0.00291	9.37	
SP_mail	0.5440	0	Sp_mail and sp_phone correspond to mail and phone survey methods for stated preference studies, Since *RUM_nest* was the model specified above rather than stated preference (i.e, *SP_conjoint*, *SP_dichot*), *SP_mail* and *SP_phone* were set to zero.
SP_phone	1.0859	0	
high_resp_rate	-0.6539	1	Binary variable indicating that the survey response rate exceeded 50 percent. EPA set *high_response_rate* to one because high response rates may provide more accurate estimates.
inc_thou	0.003872	Varies	Household income of survey respondents in thousands of dollars. *Inc_thou* was set to the median household income for each study region evaluated, based on U.S. Census data.
age42_down	0.9206	0.0972	Binary variables indicating whether the average age of respondents was less than 43 or 43 and greater. *Age42_down* and *age43_up* were set to their sample means.
age43_up	1.2221	0.2711	
trips19_down	0.8392	0.1100	Binary variables indicating whether the mean number of fishing trips taken each year by sample respondents was less than 20 or 20 and greater. *Trips19_down* and *trips20_up* were set to their sample means.
trips20_up	-1.0112	0.3350	
nonlocal	3.2355	0	Binary variable indicating that respondents in the sample were not local residents. Because the default (zero) value for the *nonlocal* dummy variable represents a combination of local and nonlocal anglers, *nonlocal* was set to zero.

Table 7-1: Independent Variable Assignments for Regression Equation

Variable	Coefficient	Assigned Value	Explanation
big_game_pac	2.2530	Varies	Binary variables indicating the targeted species. Species-targeted variables were assigned input values based on characteristics of the species affected by IM&E and the study region. In general, the match between the affected species and the variables in the meta-analysis equation was good.
big_game_natl	1.5323	Varies	
big_game_satl	2.3821	Varies	
small_game_pac	1.6227	Varies	
small_game_atl	1.4099	Varies	
flatfish_pac	1.8909	Varies	
flatfish_atl	1.3797	Varies	
other_sw	0.7339	Varies	
musky	3.8671	Varies	
pike_walleye	1.0412	Varies	
bass_fw	1.7780	Varies	
trout_GL	1.8723	Varies	
trout_nonGL	0.8632	Varies	
salmon_pacific	2.3570	Varies	
salmon_atl_morey	5.2689	Varies	
salmon_GL	2.2135	Varies	
steelhead_pac	2.1904	Varies	
steelhead_GL	2.3393	Varies	
cr_nonyear	-0.08135	Varies	Variables describing catch rates. *Cr_nonyear* indicates the catch rate for studies presenting catch rate per hour, per day, or per trip. It was assigned species and region-specific values for the coastal and Great Lakes regions based on catch rates data provided by the National Marine Fisheries Service (NMFS 2002, 2003) and the Michigan Department of Natural Resources (MDNR 2002). For the Inland region, EPA assigned values to the *cr_nonyear* variable based on the average values for each species from the studies. *Spec_cr* is a binary variable indicating that the study presents information on the baseline catch rate. EPA set *spec_cr* to one. *Catch_year* is a binary variable indicating that the study presented catch rates on a per year basis and *cr_year* is the annual catch rate from the study. *Cr_year* and *catch_year* were set to zero because catch per trip and catch per day are more common measures of angling quality.
cr_year	-0.05208	0	
catch_year	1.2693	0	
spec_cr	0.6862	1	
shore	-0.1129	Varies	
cr_year	-0.05208	0	
catch_year	1.2693	0	
spec_cr	0.6862	1	
shore	-0.1129	Varies	Binary variable indicating that all respondents in the sample fished from shore. *Shore* was assigned values based on NMFS (2002, 2003) and U.S. Fish and Wildlife Service (USDOI and USDOC 2002) survey data indicating the average percentage of anglers who fish from shore in each region.

Source: U.S. EPA (2006)

Table 7-2: Region- and Species-specific Variable Assignments for the Regression Equation[a]

Variable		Region						
		California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland
inc_thou		54.385	55.000	51.846	40.730	36.641	44.519	58.240
Shore		24.0	24.0	23.1	30.0	25.0	48.0	57.0
Species[b]	**Species Type Dummy Variable[c]**	**Baseline Catch Rate, Expressed in Fish per Day (*cr_nonyear*)[d]**						
Small game[e]	*small_game_atl*, *small_game_pac*	2.7	1.6	1.6	2.2	2.2		2.1
Flatfish[f]	*flatfish_atl*, *flatfish_pac*	1.3	1.0	1.0	1.5			
Other saltwater	*other_sw*	1.7	1.7	1.7	1.7	1.7		
Salmon	*Salmon_GL*						0.2	0.2
Walleye/pike	*pike_walleye*						0.8	0.8
Bass	*bass_fw*						0.2	0.2
Panfish[g]				4.7			4.7	4.7
Trout							3.2	3.2
Unidentified		1.7	1.7	1.7	1.7	1.9	1.9	3.8

[a] See Table 7-1 for information regarding the specification of variables that EPA held fixed across regions.
[b] The table is restricted to species groups which correspond to species impacted by IM&E at regulated facilities.
[c] This column indicates which species type dummy variable was set to one to represent each species.
[d] Blank cells indicate that IM&E losses are not estimated for the species in that benefits region.
[e] For "small game" fish in the North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, and Inland regions, *small_game_atl* was set to one. For "small game" fish in the California region, *small_game_pac* was set to one.
[f] For "flatfish" in the North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, Great Lakes, and Inland regions, *flatfish_atl* was set to one. For flatfish in the California region, *flatfish_pac* was set to one.
[g] To indicate that the target species was "panfish," all species type dummy variables were set to zero.
Source: U.S. EPA (2006)

Table 7-3: Marginal Recreational Value per Fish, by Region and Species (2011$)[a]

Species	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland
Small game	$7.60	$6.22	$6.17	$5.99	$5.89		$5.61
Flatfish	$10.21	$6.24	$5.88	$5.87			
Other saltwater	$3.09	$3.12	$3.05	$2.98	$2.91		
Salmon						$13.88	$13.88
Walleye/pike						$4.30	$4.29
Bass						$8.95	$9.43
Panfish			$1.11			$1.39	$1.11
Trout						$9.87	$2.96
Unidentified	$3.25	$3.15	$3.39	$2.99	$3.83	$6.51	$2.33

[a] Blank cells indicate that recreational value per fish was not estimated because zero IM&E losses are estimated for the species in that benefits region.
Source: U.S. EPA (2006), converted to 2011$ using the Consumer Price Index (USBLS 2011)

7.2.2 Calculating Recreational Fishing Benefits

EPA estimated the recreational welfare gain from eliminating current IM&E and the recreational welfare gain from the final rule and other options considered by combining estimates of the marginal value per fish with the estimated recreational fishing losses under the baseline level of IM&E, and the reduction in recreational fishing losses attributable to the final rule and other options considered. To calculate the recreational welfare gain from eliminating baseline IM&E, EPA multiplied the marginal value per fish by the number of fish that are lost due to baseline IM&E that would otherwise be caught by recreational anglers. To calculate the recreational welfare gain from the final rule and other options considered, EPA multiplied the marginal value per fish by the estimated additional number of fish caught by recreational anglers that would have been impinged or entrained in the absence of the regulation. As explained in Chapter 3, these calculations express recreational fish losses as the number of harvestable adults.

7.2.3 Sensitivity Analysis Based on the Krinsky and Robb (1986) Approach

The meta-analysis model briefly described above can be used to predict mean WTP for catching an additional fish. However, estimates derived from regression models are subject to some degree of error and uncertainty. To better characterize the uncertainty or error bounds around predicted WTP, EPA adopted the statistical procedure described by Krinsky and Robb in their 1986 *Review of Economics and Statistics* paper, "Approximating the Statistical Property of Elasticities." The procedure involves sampling from the variance-covariance matrix and means of the estimated coefficients. WTP values are then calculated for each drawing from the variance covariance matrix, and constructing an empirical distribution of WTP values. By varying the number of drawings, it is possible to generate an empirical distribution with a desired degree of accuracy (Krinsky and Robb 1986). The lower or upper bound of WTP values can then be identified based on the 5th and 95th percentile of WTP values from the empirical distribution. These bounds may help decision-makers understand the uncertainty associated with the benefit results.

The results of EPA's calculations are shown in Table 7-4. The table presents 95th percentile upper confidence bounds and 5th percentile lower confidence bounds for the marginal value per fish for each species in each region. These bounds can be used to estimate upper and lower confidence bounds for the WTP for improvements in recreational catch rates from eliminating baseline IM&E or reducing IM&E under the final rule and other options considered. Refer to EPA (2006) for more detail on the specific calculations. The 5th percentile values shown in Table 7-4 show that, with the exception of panfish, even the lowest estimates of recreational value are well above $1.00 per fish. Certainly, all are above zero.

Table 7-4: Confidence Bounds on Marginal Recreational Value per Fish, Based on the Krinsky and Robb Approach (2011$)[a]

Species	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland
5th Percentile Lower Confidence Bounds[b]							
Small game	$4.40	$2.23	$2.37	$2.84	$3.00		$1.68
Flatfish	$5.35	$3.98	$3.92	$4.05			
Other saltwater	$1.87	$1.87	$1.94	$2.24	$2.23		
Salmon						$8.53	$8.53
Walleye/pike						$2.28	$2.07
Bass						$4.63	$4.48
Panfish			$0.55			$0.73	$0.55
Trout						$6.39	$1.59
Unidentified	$1.95	$1.88	$2.00	$2.25	$2.47	$3.49	$1.13
95th Percentile Upper Confidence Bounds							
Small game	$13.01	$17.53	$16.23	$12.59	$1.55		$18.90
Flatfish	$19.49	$9.86	$8.92	$8.66			
Other saltwater	$5.11	$5.20	$4.82	$3.95	$3.78		
Salmon						$22.61	$22.61
Walleye/pike						$8.16	$8.92
Bass						$17.38	$19.96
Panfish			$2.20			$2.61	$2.20
Trout						$15.34	$5.53
Unidentified	$5.42	$5.26	$6.00	$3.99	$6.18	$12.25	$4.81

[a] Blank cells indicate that recreational value per fish was not estimated because IM&E losses are not estimated for the species in that benefits region.
[b] Upper and lower confidence bounds based on results of the Krinsky and Robb (1986) approach.
Source: U.S. EPA (2006), converted to 20011$ using the Consumer Price Index (USBLS 2011).

7.3 Benefits Estimates for Recreational Fishing by Region

7.3.1 California Region

Table 7-5 presents the estimated increase in recreational fishing harvest and associated welfare gains from the elimination of baseline IM&E in the California region. EPA estimates an annual harvest increase of 1.4 million fish from the elimination of baseline IM&E, the majority attributable to reduced entrainment of rockfish and sea bass. The associated mean annual welfare gain is $4.0 million and $3.6 million, evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline IM&E is attributable to entrainment of "other saltwater" fish.[35]

[35] The "other saltwater" species group includes banded drum, black drum, chubby, cod family, cow cod, croaker, grouper, grunion, grunt, high-hat, kingfish, lingcod, other drum, perch, porgy, rockfish, sablefish, sand drum, sculpin, sea bass, smelt, snapper, spot, spotted drum, star drum, white sea bass, wreckfish, other bottom species, other coastal pelagics, and "no target" saltwater species.

Table 7-5 also presents the annual recreational harvest increases and welfare gains to California anglers under the final rule and other options considered. EPA estimates that the final rule will increase annual harvest by 0.04 million fish. The mean annualized welfare gain under final rule will be less than $0.1 million using both 3 percent and 7 percent discount rates. Annual harvest increases under other options considered range from 0.04 million fish under Proposal Option 4 to 0.88 million fish under Proposal Option 2. Mean annualized benefits under other options considered range from less than $0.1 to $1.5 million using a 3 percent discount rate and less than $0.1 to $1.0 million using a 7 percent discount rate. Appendix I presents additional species-specific results for final file rule, other options considered, and the elimination of baseline IM&E.

Table 7-5: Recreational Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the California Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2011$, 1,000s)[a]					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Proposal Option 4	35,420	$42	$69	$114	$30	$50	$83
Final Rule	38,159	$45	$74	$123	$33	$54	$89
Proposal Option 2	877,174	$919	$1,543	$2,595	$592	$994	$1,673
Baseline	1,431,170	$2,408	$4,044	$6,803	$2,153	$3,616	$6,084

[a] 5th and 95th are the 5th and 95th percentiles based on the results of the Krinsky and Robb (1986) approach.

Source: U.S. EPA analysis for this report

7.3.2 North Atlantic Region

Table 7-6 presents the estimated increase in recreational fishing harvest and associated welfare gains from the elimination of baseline IM&E in the North Atlantic region. EPA estimates an annual harvest increase of 0.73 million fish from the elimination of baseline IM&E, the majority attributable to reduced entrainment of winter flounder, cunner, and sculpin. The associated mean annual welfare gain is $2.7 million and $2.4 million, evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline IM&E is attributable to entrainment of “flatfish” and “other saltwater” fish.[36]

Table 7-6 also presents the annual recreational harvest increases and welfare gains to North Atlantic anglers under the final rule and other options considered. EPA estimates that the final rule will increase annual harvest by less than 0.01 million. The mean annualized welfare gain under final rule will be less than $0.1 million using both 3 percent and 7 percent discount rates. Annual harvest increases under other options considered range from less than 0.01 million fish under Proposal Option 4 to 0.56 million fish under Proposal Option 2. Mean annualized benefits under other options considered range from less than $0.1 to $1.4 million using a 3 percent discount rate and from less than $0.1 to $0.9 million using a 7 percent discount rate. Appendix I

36 The “other saltwater” species group includes banded drum, black drum, chubby, cod family, cow cod, croaker, grouper, grunion, grunt, high-hat, kingfish, lingcod, other drum, perch, porgy, rockfish, sablefish, sand drum, sculpin, sea bass, smelt, snapper, spot, spotted drum, star drum, white sea bass, wreckfish, other bottom species, other coastal pelagics, and “no target” saltwater species.

presents additional species-specific results for final file rule, other options considered, and the elimination of baseline IM&E.

Table 7-6: Recreational Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the North Atlantic Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2011$, 1,000s)[a]					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Proposal Option 4	1,367	$3	$4	$7	$2	$3	$5
Final Rule	7,975	$14	$23	$36	$10	$16	$27
Proposal Option 2	562,305	$852	$1,371	$2,219	$573	$921	$1,491
Baseline	733,985	$1,682	$2,705	$4,380	$1,504	$2,419	$3,917

[a] 5th and 95th are the 5th and 95th percentiles based on the results of the Krinsky and Robb (1986) approach.
Source: U.S. EPA analysis for this report

7.3.3 Mid-Atlantic Region

Table 7-7 presents the estimated increase in recreational fishing harvest and associated welfare gains from the elimination of baseline IM&E in the Mid-Atlantic region. EPA estimates an annual harvest increase of 5.82 million fish from the elimination of baseline IM&E, the majority attributable to reduced IM&E of spot and Atlantic croaker. The associated mean annual welfare gain is $16.2 million and $14.5 million, evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline IM&E is attributable to the entrainment of "other saltwater" fish.

Table 7-7 also presents the annual recreational harvest increases and welfare gains to Mid-Atlantic anglers under the final rule and other options considered. EPA estimates that the final rule will increase annual harvest by 0.46 million fish. The mean annualized welfare gain under final rule will be $1.1 million using a 3 percent rate and $0.8 million using a 7 percent discount rate. Annual harvest increases under other options considered range from 0.43 million fish under Proposal Option 4 to 5.10 million fish under Proposal Option 2. Mean annualized benefits under other options considered range from $1.0 to $8.6 million using a 3 percent discount rate and from $0.7 to $5.5 million using a 7 percent discount rate. Appendix I presents additional species-specific results for final file rule, other options considered, and the elimination of baseline IM&E.

Table 7-7: Recreational Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the Mid-Atlantic Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2011$, 1,000s)[a]					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Proposal Option 4	427,924	$531	$988	$1,961	$376	$700	$1,389
Final Rule	460,839	$572	$1,063	$2,108	$405	$753	$1,493
Proposal Option 2	5,103,595	$5,132	$8,634	$15,072	$3,273	$5,506	$9,612
Baseline	5,823,189	$9,665	$16,249	$28,341	$8,643	$14,531	$25,343

[a] 5th and 95th are the 5th and 95th percentiles based on the results of the Krinsky and Robb (1986) approach.
Source: U.S. EPA analysis for this report

7.3.4 South Atlantic Region

Table 7-8 presents the estimated increase in recreational fishing harvest and associated welfare gains from the elimination of baseline IM&E in the South Atlantic region. EPA estimates an annual harvest increase of 0.11 million fish from the elimination of baseline IM&E, the majority attributable to reduced IM&E of “other saltwater” fish, especially spot and croakers. The associated mean annual welfare gain is $0.3 million evaluated at both 3 percent and 7 percent discount rates. The majority of the monetized recreational benefits from eliminating baseline IM&E is attributable to entrainment of “other saltwater” fish.

Table 7-8 also presents the annual recreational harvest increases and welfare gains to South Atlantic anglers under the final rule and other options considered. EPA estimates that the final rule will increase annual harvest by 0.02 million fish. The mean annualized welfare gain under final rule will be less than $0.1 million using both 3 percent and 7 percent discount rates. Annual harvest increases under other options considered range from 0.01 million fish under Proposal Option 4 to 0.10 million fish under Proposal Option 2. Mean annualized benefits under other options considered range from less than $0.1 to $0.2 million using a 3 percent discount rate and from less than $0.1 to $0.1 million using a 7 percent discount rate. Appendix I presents additional species-specific results for final file rule, other options considered, and the elimination of baseline IM&E.

Table 7-8: Recreational Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the South Atlantic Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2011$, 1,000s)[a]					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Proposal Option 4	12,983	$18	$24	$33	$13	$17	$23
Final Rule	18,725	$26	$35	$47	$18	$24	$33
Proposal Option 2	104,943	$129	$173	$234	$86	$115	$156
Baseline	111,075	$211	$284	$385	$189	$254	$344

[a] 5th and 95th are the 5th and 95th percentiles based on the results of the Krinsky and Robb (1986) approach.

Source: U.S. EPA analysis for this report

7.3.5 Gulf of Mexico Region

Table 7-9 presents the estimated increase in recreational fishing harvest and associated welfare gains from the elimination of baseline IM&E in the Gulf of Mexico region. EPA estimates an annual harvest increase of 3.08 million fish from the elimination of baseline IM&E, the majority attributable the impingement of spotted seatrout and the entrainment of black drum and pinfish. The associated mean annual welfare gain is $9.6 million and $8.8 million, evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline IM&E is attributable to both the impingement of "small game" fish and the entrainment of "other saltwater" species.

Table 7-9 also presents the annual recreational harvest increases and welfare gains to Gulf of Mexico anglers under the final rule and other options considered. EPA estimates that the final rule will increase annual harvest by 0.78 million fish. The mean annualized welfare gain under final rule will be $2.3 million using a 3 percent discount rate and $1.6 million using a 7 percent discount rate. Annual harvest increases under other options considered range from 0.75 million fish under Proposal Option 4 to 2.14 million fish under Proposal Option 2. Mean annualized benefits under other options considered range from $2.2 to $5.1 million using a 3 percent discount rate and from $1.6 to $3.8 million using a 7 percent discount rate. Appendix I presents additional species-specific results for final file rule, other options considered, and the elimination of baseline IM&E.

Table 7-9: Recreational Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the Gulf of Mexico Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2011$, 1,000s)[a]					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Proposal Option 4	749,144	$1,260	$2,183	$3,904	$914	$1,583	$2,831
Final Rule	777,488	$1,308	$2,265	$4,051	$948	$1,643	$2,938
Proposal Option 2	2,137,861	$3,357	$5,116	$8,122	$2,476	$3,774	$5,991
Baseline	3,077,617	$6,457	$9,575	$14,756	$5,955	$8,831	$13,610

[a] 5th and 95th are the 5th and 95th percentiles based on the results of the Krinsky and Robb (1986) approach.
Source: U.S. EPA analysis for this report

7.3.6 Great Lakes Region

Table 7-10 presents the estimated increase in recreational fishing harvest and associated welfare gains from the elimination of baseline IM&E in the Great Lakes region. EPA estimates an annual harvest increase of 2.23 million fish from the elimination of baseline IM&E, the majority attributable to IM&E of white bass and “unidentified” species. The associated mean annual welfare gain is $13.8 million and $12.8 million, evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline IM&E is attributable to the impingement of bass and “unidentified” fish.

Table 7-10 also presents the annual recreational harvest increases and welfare gains to Great Lakes anglers under the final rule and other options considered. EPA estimates that the final rule will increase annual harvest by 1.47 million fish. The mean annualized welfare gain under final rule will be $7.2 million using a 3 percent discount rate and $5.3 million using a 7 percent discount rate. Annual harvest increases under other options considered range from 1.33 million fish under Proposal Option 4 to 2.04 million fish under Proposal Option 2. Mean annualized benefits under other options considered range from $6.5 to $8.9 million using a 3 percent discount rate and from $4.8 to $6.4 million using a 7 percent discount rate. Appendix I presents additional species-specific results for final file rule, other options considered, and the elimination of baseline IM&E.

Table 7-10: Recreational Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the Great Lakes Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2011$, 1,000s)[a]					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Proposal Option 4	1,331,956	$3,446	$6,509	$12,385	$2,562	$4,839	$9,208
Final Rule	1,466,650	$3,793	$7,166	$13,636	$2,820	$5,328	$10,138
Proposal Option 2	2,044,018	$4,717	$8,922	$16,993	$3,359	$6,354	$12,102
Baseline	2,232,409	$7,306	$13,825	$26,338	$6,738	$12,751	$24,292

[a] 5th and 95th are the 5th and 95th percentiles based on the results of the Krinsky and Robb (1986) approach.
Source: U.S. EPA analysis for this report

7.3.7 Inland Region

Table 7-11 presents the estimated increase in recreational fishing harvest and associated welfare gains from the elimination of baseline IM&E in the Inland region. EPA estimates an annual harvest increase of 11.90 million fish from the elimination of baseline IM&E, the majority attributable to IM&E of "bass," "panfish," and "unidentified" species groups. The associated mean annual welfare gain is $32.1 million and $29.6 million, evaluated at 3 percent and 7 percent discount rates, respectively. The majority of the monetized recreational benefits from eliminating baseline IM&E is attributable to IM&E of "bass," "panfish," and "unidentified" fish.

Table 7-11 also presents the annual recreational harvest increases and welfare gains to Inland anglers under the final rule and other options considered. EPA estimates the final rule will increase annual harvest by 3.73 million fish. The mean annualized welfare gain under the final rule will be $7.6 million using a 3 percent discount rate and $5.7 million using a 7 percent discount rate. Annual harvest increases under other options considered range from 3.57 million fish under Proposal Option 4 to 9.70 million fish under Proposal Option 2. Mean annualized benefits under other options considered range from $7.3 to $17.2 million using a 3 percent discount rate and $5.4 to $11.9 million using a 7 percent discount rate. Appendix I presents additional species-specific results for final file rule, other options considered, and the elimination of baseline IM&E.

Table 7-11: Recreational Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the Inland Region, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2011$, 1,000s)[a]					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Proposal Option 4	3,570,053	$3,503	$7,284	$15,231	$2,616	$5,440	$11,375
Final Rule	3,731,608	$3,661	$7,613	$15,918	$2,735	$5,686	$11,889
Proposal Option 2	9,704,334	$8,290	$17,204	$35,865	$5,726	$11,883	$24,773
Baseline	11,900,351	$15,471	$32,105	$66,919	$14,270	$29,611	$61,722

[a] 5th and 95th are the 5th and 95th percentiles based on the results of the Krinsky and Robb (1986) approach.
Source: U.S. EPA analysis for this report

7.3.8 National Estimates

Table 7-12 presents the estimated national increase in recreational fishing harvest and associated welfare gains to anglers from eliminating baseline IM&E. EPA estimates an annual harvest increase of 25.31 million fish from eliminating baseline IM&E. The associated mean annual welfare gain is $78.8 million and $72.0 million, evaluated at 3 percent and 7 percent discount rates, respectively.

Table 7-12 also presents the national recreational harvest increases and welfare gains to anglers under the final rule and other options considered. EPA estimates the final rule will increase annual harvest by 6.50 million fish. The mean annualized welfare gain under final rule will be $18.2 million using a 3 percent discount rate and $13.5 million using a 7 percent discount rate. Annual harvest increases under other options considered range from 6.13 million fish under Proposal Option 4 to 20.53 million fish under Proposal Option 2. Mean annualized benefits under other options considered range from $17.1 to $43.0 million using a 3 percent discount rate and $12.6 to $29.5 million using a 7 percent discount rate. Appendix I presents additional species-specific results for the final rule, other options considered, and the elimination of baseline IM&E.

Table 7-12: National Recreational Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities, for the Final Rule and Options Considered (2011$)

Regulatory Option	Annual Increase in Recreational Harvest (harvestable adult fish)	Annualized Benefits from Increase in Recreational Harvest (2011$, 1,000s)[a]					
		3 % Discount Rate			7 % Discount Rate		
		5th	Mean	95th	5th	Mean	95th
Proposal Option 4	6,128,847	$8,803	$17,061	$33,635	$6,513	$12,632	$24,914
Final Rule	6,501,444	$9,419	$18,239	$35,919	$6,969	$13,504	$26,607
Proposal Option 2	20,534,230	$23,396	$42,963	$81,100	$16,085	$29,547	$55,798
Baseline	25,309,796	$43,200	$78,787	$147,922	$39,452	$72,013	$135,312

[a] 5th and 95th are the 5th and 95th percentiles based on the results of the Krinsky and Robb (1986) approach.
Source: U.S. EPA analysis for this report

7.4 Limitations and Uncertainties

A number of limitations and uncertainties are common in application of benefit transfer approaches to valuing benefits of environmental policies and programs. To better characterize the uncertainty or error bounds around predicted WTP, EPA adopted the statistical procedure described by Krinsky and Robb in their 1986 *Review of Economics and Statistics* paper "Approximating the Statistical Property of Elasticities," to generate lower and upper bound WTP values identified as the 5th and 95th percentile of values from the empirical distribution. Additional detail regarding the Krinsky and Robb approach is provided in Section 7.2.3. These bounds may help decision-makers understand the uncertainty associated with the benefit results for eliminating baseline IM&E and the 316(b) final rule and regulatory options considered.

Specific limitations and uncertainties associated with the estimated regression model and the underlying studies are discussed in Section A5-3.3e of EPA (2006). Additional limitations and uncertainties associated with the calculation of per-fish values from the model, and with the use of those values to estimate the welfare gain resulting from the final section 316(b) regulation and regulatory options considered, are addressed below in Table 7-13.

Table 7-13: Other Caveats, Omissions, Biases, and Uncertainties in the Recreational Benefits Estimates

Issue	Impact on Benefits Estimate	Comments
Exclusion of error term from regression equation to predict marginal values	Estimates understated	Because the source of error in the underlying meta-data is unknown EPA decided not to include the error term in estimating marginal values per fish. EPA notes that if the source of error is due primarily to the omitted variables the estimated WTP may be biased downward. See Section 7.2.1 for more a detailed discussion regarding EPA's treatment of the error term.
Validity and reliability of benefit transfer	Uncertain	The validity and reliability of benefit transfer—including that based on meta-analysis—depend on a variety of factors. While benefit transfer can provide valid measures of use benefits, tests of its performance have had mixed results (e.g. Desvousges et al. 1998; Smith et al. 2002; Vandenberg et al. 2001) . Nonetheless, benefit transfers are increasingly applied as a core component of benefit-cost analyses conducted by EPA and other government agencies (Bergstrom and De Civita 1999; Griffiths undated). Smith et al. (2002, p.134) state that "nearly all benefit cost analyses rely on benefit transfers, whether they acknowledge it or not." An important factor in any benefit transfer is the ability of the study site or estimated valuation equation to approximate the resource and context for which benefit estimates are desired. As is common, the meta-analysis model presented here provides a close but not perfect match to the context in which values are desired.
IM&E estimates	Uncertain	Recreational losses due to IM&E may be higher or lower than expected for a number of reasons. Projected changes in recreational catch may be underestimated because cumulative impacts of IM&E over time are not considered. In particular, IM&E estimates include only individuals directly lost to IM&E, not their progeny. Additionally, the interaction of IM&E with other stressors may have either a positive or negative effect on recreational catch. Finally, in estimating recreational fishing losses, EPA used the most current IM&E data available provided by facilities, which in some cases may not reflect current conditions.

8 Nonuse Benefit Transfer Approach

8.1 Introduction

Comprehensive estimates of total social value include both use and nonuse values, and may be compared to total social cost. "Non-use values, like use values, have their basis in the theory of individual preferences and the measurement of welfare changes. According to theory, use values and non-use values are additive" (Freeman III 1993). Consequently, excluding nonuse values from consideration is likely to substantially understate total social values. Recent economic literature provides strong support for the hypothesis that nonuse values are greater than zero for many types of environmental improvements. Moreover, when a substantial fraction of the population holds even small per capita nonuse values, these nonuse values can be very large in the aggregate. As stated by Freeman (1993), "there is a real possibility that ignoring non-use values could result in serious misallocation of resources." Both EPA's own Guidelines for Preparing Economic Analysis and OMB's Circular A-4, governing regulatory analysis, support the need to assess nonuse values (USEPA 2010a; USOMB 2003).

The vast majority (97 percent) of current (i.e., baseline) IM&E at CWIS consist of forage species and unlanded individuals of recreational and commercial species (Chapter 3). Although these forage and unlanded fish do not have direct use values, they may be valued by nonusers of fisheries resources (whose value for such fish is by definition a nonuse value) and by users separate from their use value. The nonuse values are likely to be substantial because fish and other species found within aquatic habitats impacted directly and indirectly by CWIS provide other valuable ecosystem goods and services, including nutrient cycling and ecosystem stability. Therefore, a comprehensive estimate of the welfare gain from reducing IM&E must include an estimate of nonuse benefits. The following sections present EPA's qualitative assessment of nonuse benefits and partial monetized nonuse benefits based on benefit transfer from an existing stated preference study. EPA evaluated the public's nonuse values for aquatic habitats qualitatively by considering evidence from existing aquatic restoration and protection programs (Section 8.2). EPA also provides a quantitative estimate of the numbers of A1E whose benefits are likely to be mainly associated with nonuse (Table 3-15; reproduced as Table 8-1). Finally, EPA used benefit transfer to generate a partially monetized estimate of nonuse benefits associated with reductions in IM&E of fish, shellfish, and other aquatic organisms under the final rule and other options considered in the North Atlantic and Mid-Atlantic Regions. The methodology is described in Section 8.3 and Section 8.4 presents the results.

Table 8-1: Baseline IM&E and IM&E Reductions at All Regulated Facilities (Manufacturing and Generating) Nationally, and Reductions under the Final Rule and Other Options Considered

IM&E Loss Metric (per year)	Reductions in Losses			Baseline Losses
	Proposal Option 4	Final Rule	Proposal Option 2	
All Species (million A1E)	614.16	652.00	1637.49	1930.97
Forage Species (million A1E)	528.22	560.80	1258.67	1459.70
Commercial & Recreational Species (million A1E)	85.94	91.20	378.82	471.28
Commercial & Recreational Harvest (million fish)	16.13	17.11	44.66	54.02
A1E Losses with Direct Use Value (%)	2.6%	2.6%	2.7%	2.8%

Source: U.S. EPA analysis for this report

8.2 Public Policy Significance of Ecological Improvements from the Final Rule

EPA expects that changes to CWIS design and operation resulting from the final existing facilities rule will reduce IM&E of fish, shellfish, and other aquatic organisms and lead to increases in local and regional fishery populations and ecosystem stability. In addition to those direct effects, many indirect ecosystem goods and services are affected by IM&E, thermal effects, and flow alteration. Due to the wide-ranging nature of these indirect effects, the existing facilities rule is likely to enhance the value of ecosystem goods and services provided by aquatic habitats, and will help reduce the overall impact of anthropogenic effects on aquatic systems affected by CWIS. Chapter 2 provides a detailed list of ecosystem services potentially affected by the rule.

EPA assessed the potential magnitude of nonuse benefits using information regarding government spending on the protection, restoration, and regulation of various aquatic habitats. These habitats include Marine Protected Areas (Section 8.2.2) and a subset of freshwater ecosystems undergoing large-scale restoration efforts (Section 8.2.3). Although not estimates of benefits of improving aquatic ecosystems, these expenditures are still an indication of significant social values for the protection of aquatic resources.

8.2.1 Effects on Depleted Fish Populations

Reducing IM&E will contribute to the health and sustainability of the affected fish populations by lowering the overall level of mortality for these populations. Fish populations suffer from numerous sources of mortality, both natural and anthropogenic. Natural sources include weather, predation by other fish, and the availability of food. Human activities besides IM&E include fishing, pollution, and habitat alteration. Fish populations decline when they are unable to compensate sufficiently for their overall level of mortality. Although it is difficult to measure, the compensatory ability of an aquatic population—the capacity for a species to increase survival, growth, or reproduction rates in response to decreased population —is likely compromised by IM&E and the cumulative impact of other stressors in the environment over extended periods of time (USEPA 2006a).

Lowering the overall mortality level increases the probability that a population will be able to compensate for mortality at a level sufficient to maintain long-term health. In some cases, impingement and entrainment may be significant source of mortality to already-depleted stocks of commercially targeted species (see Chapter 2). Depleted saltwater fish stocks affected by IM&E include winter flounder, Atlantic Cod, and rockfish, for example (NMFS 2012). As discussed in Chapter 2, IM&E also increases the pressure on freshwater species native to the Great Lakes, such as lake whitefish and yellow perch, the populations of which have declined dramatically in recent years (USDOI 2008; Wisconsin DNR 2003).

The federal government and the states have recognized the public importance of maintaining sustainable fisheries, achieving recovery of depleted fish stocks, and ensuring that functioning ecosystems are passed to future generations. Federal and state government actions have included buying fishing licenses and fishing vessels from individual fishers when stocks appear depressed, imposing restrictions on commercial and recreational harvests, conducting large-scale ecosystem restoration projects (USDOI 2008), and President George W. Bush's executive order creating a national system of marine protected areas (Executive Order No. 13158 2001).Together, these governmental actions suggest that the public holds substantial nonuse values for aquatic habitats.

8.2.2 Marine Protected Areas

A Marine Protected Area (MPA) is "any area of the marine environment that has been reserved by federal, state, tribal, territorial, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein" (Executive Order No. 13158 2001). In some states, the majority of coastal waters are found within MPAs (e.g., Massachusetts, Hawaii). The ecological importance of MPAs varies widely because of the broad focus on the preservation and maintenance of cultural and natural resources, and/or sustainable production (NMPAC 2006). Consequently, evaluating the impact of CWIS on the entire universe of MPAs may overstate the nonuse values for the ecological benefits associated with reductions in IM&E: because some MPAs are focused on the preservation of cultural resources (including historic shipwrecks, aircraft and other structures, submerged prehistoric remains, and sites with traditional cultural properties), they are likely to be less ecologically important than others.

For this reason, EPA focused on facilities in MPAs within the National Estuary Program (NEP). The NEP was established in the 1987 amendments to the CWA because the "Nation's estuaries are of great importance to fish and wildlife resources and recreation and economic opportunity [and because maintaining] the health and ecological integrity of these estuaries is in the national interest" (Water Quality Act 1987). In addition to the 28 estuaries designated under the NEP (USEPA 2010b), EPA included facilities found in Chesapeake Bay (which is protected by the Chesapeake Bay Program [CBP]).

Substantial federal and state resources have been directed to the NEP and CBP to enhance conservation of and knowledge about estuaries. Including funds received from federal, state, local and private sources, from 2005 to 2013, the NEP spent $3.5 billion to protect and restore aquatic habitat, support land acquisitions, conduct outreach and research, upgrade wastewater and stormwater infrastructure, and implement other priority actions to benefit the health of the 28 estuaries designated under the NEP. Approximately 11.1 percent, or $389 million, was designated for restoration programs (USEPA 2014). Between fiscal years 1995 and 2004, direct funding by federal and State governments to restore the Chesapeake Bay averaged $366 million annually (GAO 2005), with an additional $131 million in direct spending fiscal year 2005 (CBP 2007).. Moreover, recent governmental action is likely to increase restoration efforts in the future (Executive Order No. 13508 2009), These expenditures reflect high public values for restoring (or protecting) the biological integrity of these ecosystems.

A total of 44 regulated facilities are located on 32 waterbodies within MPAs designed to preserve natural resources and/or to ensure sustainable production (NOAA 2012) (Figure 8-1; Table 8-2). Although these facilities are located in fresh, brackish, and marine waters, the vast majority located within MPAs are in coastal waters and are most highly concentrated in the Northeastern U.S. (i.e. both coastal and inland facilities) (Figure 8-1; Table 8-2). Under the final rule, EPA estimates that 60 percent of regulated facilities (15 out of 25 facilities for which data are available) found within MPAs obtain reductions in impingement mortality. This estimate is based upon facilities for which sufficient data exist for EPA to estimate technology currently in-place. Additionally, although entrainment may be reduced at some facilities as a consequence of the final rule, EPA was not able to estimate reductions in entrainment likely to occur due to site-specific determination of entrainment BTA for facilities with CWIS inside of MPAs.

Figure 8-1: Regulated Facilities with CWIS Located in Marine Protected Areas

Table 8-2: 316(b) Facilities in Marine Protected Areas and Improvements in IM&E Tech for the Final Rule and Other Options Considered

Region	Number of Facilities with Improved Technologies by Option[a,b]						Baseline		
	Proposal Option 4		Final Rule		Proposal Option 2				
	IM	E	IM	E	IM	E	Number of Facilities	Affected Waterbodies	Facilities With Tech Data[b]
California	1	0	1	0	1	1	2	2	1
North Atlantic	2	0	2	0	2	2	7	6	6
Mid-Atlantic	8	0	8	0	8	6	24	15	12
South Atlantic	0	0	0	0	0	0	2	1	1
Gulf of Mexico	2	0	2	0	3	3	3	3	3
Great Lakes	0	0	0	0	0	0	0	0	0
Inland	2	0	2	0	2	2	6	5	2
Total	**15**	**0**	**15**	**0**	**16**	**14**	**44**	**32**	**25**

[a] IM is impingement mortality and E is entrainment.
[b] EPA does not have adequate data for all facilities to estimate current compliance with, or the number of facilities installing improved technologies because of, the final rule.
Source: U.S. EPA analysis for this report

8.2.3 Restoration of Freshwater Ecosystems

Reducing the effect of CWIS at regulated facilities is likely to benefit aquatic ecosystems nationwide. Due to a high density of facilities, and the potential for cumulative impacts associated with facilities in close proximity to each other (see Chapter 2 for additional details), the greatest improvements may occur in areas of the Great Lakes Basin and Mississippi River. There are large-scale ecosystem restoration efforts for these freshwater bodies that indicate public support for restoring the ecological health of these ecosystems (Northeast Midwest Institute 2010; USDOI 2008; USFWS 2011; Upper Mississippi River Basin Association 2004).

Nationally, ecosystem restoration efforts focus on many issues, including coastal habitat restoration, protection of fish species, and conservation of migratory birds. For example, the federal government provided in excess of $1.7 billion for sport fish restoration between fiscal years 2005 and 2009 (USFWS 2010c), and has initiated a 5-year multi-agency initiative to restore the ecosystems of the Great Lakes, for which $1.05 billion of federal funds were appropriated in fiscal years 2010 through 2012 (Great Lakes Restoration Initiative 2012). Additionally, the restoration of major inland river ecosystems has been recognized as a worthwhile goal, with more than $100 million spent on restoring ecosystems along the Mississippi River (Brescia 2002; USEPA 2004b).

Overall, the federal government spent more than $600 million on major restoration projects in aquatic ecosystems in FY2012 (Behrens 2012; USACE 2013). These projects include, but are not limited to, the construction of fish ladders, restoration of wetland nursery habitat, and the reduction of pollution. These expenditures indicate a high value placed on the maintenance and restoration of ecosystem function and the integrity of freshwater ecosystems.

8.2.4 Summary of Evidence for Nonuse Values of Ecosystems Affected by CWIS

Overall, the public appears to hold substantial nonuse values for ecosystems and species impacted by CWIS. For example, governments at various levels have committed to the designation of MPAs covering large areas. Governments also have committed substantial resources to the restoration of degraded aquatic ecosystems.

EPA notes that funding amounts for the protection and restoration of aquatic ecosystems is not an appropriate measure of benefits (i.e., willingness to pay (WTP)). As described by Brown (1993) "economic efficiency involves a balance between demand and supply, whereas restoration cost has nothing to do with demand or value" (p.88). Moreover, these costs do not necessarily reflect a cost-effective allocation of resources (Kopp and Smith 1993). High costs of restoration or protection may overstate benefits, and likewise, while low costs may under-state benefits.

Although not estimates of benefits of improving aquatic ecosystems, these expenditures are still an indication of significant social values for the protection and resource of aquatic resources affected under the final rule and options considered. Chapter 2 provides additional qualitative discussion of adverse environmental impacts from regulated facilities for which society is like to hold significant nonuse values.

8.3 Benefit Transfer for Nonuse Values in the North Atlantic and Mid-Atlantic Regions

Stated preference (SP) methods and benefit transfers based on SP studies are the generally accepted techniques for estimating total social values (including use and nonuse) values. SP methods rely on surveys that ask people to state their WTP for particular ecological improvements, such as increased protection of aquatic species or habitats with particular attributes. EPA searched the literature for SP studies that estimated WTP for ecological improvements similar to those impacted by CWIS of regulated facilities. EPA identified a SP survey of Rhode Island residents that is a relatively good match to the 316(b) policy context and used this study to develop a benefit transfer approach to estimate nonuse benefits associated with reduction in IM&E under the final rule and other options considered. EPA was only able to use this approach for the North Atlantic and Mid-Atlantic regions.

The study developed a Bioindicator-Based Stated Preference Valuation (BSPV) method specifically for applications to ecological systems,[37] and used it to address Rhode Island residents' preferences for the restoration of migratory fish passage over dams in a watershed within Rhode Island (Johnston et al. 2012). The study results have been published in multiple scientific journals and books including Johnston et al. (2012), Johnston et al. (2011a), Johnston et al. (2011b), and Zhao et al. (2013). EPA applied a model presented by Zhao et al. (2013).

Similar to the 316(b) regulatory context, the study addressed policy changes affecting individuals of forage species but for which ultimate population effects are unknown. The authors estimated total values by asking respondents to consider changes in ecological indicators reflecting quantity of habitat, abundance of wildlife, ecological condition, and abundance of migratory fish species. The study's choice experiment allows direct estimation of households' WTP for policies that increase the number of fish in watersheds. The benefits transfer involves a translation from reintroducing fish to aquatic habitats to reducing IM&E. Within the benefit transfer application, EPA is able to focus on nonuse values by holding constant all effects related to identifiable human uses.

[37] The stated preference survey was funded by the EPA's Science to Achieve Results (STAR) competitive grant program.

Section 8.3.1 describes the transfer study and BSPV methods in greater detail. This is followed by a description of EPA's benefit transfer methods (Section 8.3.2) and estimated benefits for the 316(b) final rule and other options considered in Section 8.4. EPA also developed an original SP survey to assess public values for reductions in IM&E and ecosystem improvements under the final rule. The 316(b) SP survey is discussed separately in Chapter 11. However, EPA notes that it would be inappropriate to add the benefits from the benefits transfer approach to benefits based on the SP survey, as this would result in double-counting of benefits.

8.3.1 Description of the Benefit Transfer Study and BSPV Methods

As described by Johnston et al. (2012), the Rhode Island study developed the BSPV method to promote ecological clarity, and closer integration of ecological and economic information within SP studies. The study focus on improved ecological valuation is an EPA priority as described in findings of EPA's Science Advisory Board's Committee on Valuing the Protection of Ecological System and Services (USEPA 2009b). In contrast to traditional SP valuation, BSPV employs a more structured and formal use of ecological indicators to characterize and communicate welfare-relevant changes. The method begins with a formal basis in ecological science, and extends to relationships between attributes in respondents' preference functions and those used to characterize policy outcomes.

Specific BSPV guidelines ensure that survey scenarios and resulting welfare estimates are characterized by (1) a formal basis in established and measurable ecological indicators, (2) a clear structure linking these indicators to attributes influencing individuals' well-being, (3) consistent and meaningful interpretation of ecological information, and (4) a consequent ability to link welfare measures to measurable and unambiguous policy outcomes. The welfare measures provided by the BSPV method can be linked unambiguously to models and indicators of ecosystem function, are based on measurable ecological outcomes, and are more easily incorporated into benefit-cost analysis than traditional SP valuation studies. The BSPV method also provides a means to estimate values for ecological outcomes that individuals might value, even though they may not fully understand all relevant ecological science.

The study developed the BSPV methods for a case study addressing public preferences for the restoration of migratory fish passage in the Pawtuxet Watershed. The BSPV survey (*Rhode Island River: Migratory Fishes and Dams*) was designed to estimate WTP of Rhode Island residents for options that would provide fish passage over dams, and access to between 225 and 900 acres of historical habitat within the Pawtuxet Watershed for which there is currently no fish passage (Johnston et al. 2011a; Johnston et al. 2011b; Johnston et al. 2012; Zhao et al. 2013). The watershed currently provides no spawning habitat for migratory fish; access to all 4,347 acres of potential habitat is blocked by 22 dams and other obstructions (Erkan 2002).

The survey was developed and tested over 2½ years through a collaborative process involving interactions of economists and ecologists; meetings with resource managers, natural scientists, and stakeholder groups. This included 12 focus groups with 105 total participants. In addition to survey development and testing in focus groups, individual interviews were conducted with both ecological experts and non-experts. Tests included cognitive interviews (Kaplowitz et al. 2004), verbal protocols (Schkade and Payne 1994), and other pretests in order to gain additional insight into respondents' understanding and interpretation of the survey. Careful attention to development and testing helped ensure that the survey language and format would be easily understood by respondents, that respondents would have similar interpretations of survey terminology and scenarios, and that the survey scenarios captured restoration outcomes viewed as relevant and realistic by both respondents and natural scientists. In all cases, the authors paid particular attention to the use and interpretation of ecological indicators and related information in the survey.

The choice scenarios and restoration options presented within the survey were informed in part by data and restoration priorities in the *Strategic Plan for the Restoration of Anadromous Fishes to Rhode Island Coastal Streams* (Erkan 2002). The study authors drew additional information from the ecological literature on fish passage restoration, interviews with ecologists and policy experts, and other sources described below. Consistent with the strategic plan, the choice experiment within the survey addressed restoration methods that neither require dam removal nor would cause appreciable changes in river flows; considered options included fish ladders, bypass channels, and fish lifts. The choice experiment addresses forage species such as alewife and blueback herring that are neither subject to current recreational or commercial harvest in Rhode Island nor are charismatic species. Hence, the species affected are a close analog to the forage fish affected in the 316(b) policy context. Moreover, the study's policy context involves changes to technologies used within in-water structures (i.e., the use of fish ladders or fish lifts at dams), providing another parallel to the 316(b) context, which also involves the use of new technologies within in-water structures to mitigate harm to aquatic organisms.

The choice experiment asked respondents to consider alternative options for the restoration of migratory fish passage in the Pawtuxet Watershed. Respondents were provided with two multi-attribute restoration options, "Restoration Project A" and "Restoration Project B," as well as a status quo option that would result in no policy change and zero household cost. An example of a choice question is presented in Figure 8-2. Prior to administration of the choice experiment questions, the survey provided information that: (1) described the current status of Rhode Island river ecology and migratory fish compared to historical baselines, (2) characterized affected ecological systems and linkages, (3) described the methods and details of fish passage restoration, and (4) provided the definitions, derivations, and interpretations of ecological indicators used in the survey scenarios, including the reason for their inclusion. All survey language and graphics were pretested carefully to ensure respondent comprehension.

Within each choice experiment question, the restoration options are characterized by seven attributes, including five ecological indicators, one attribute characterizing public access, and one attribute characterizing unavoidable household cost. The study fielded multiple versions of the survey, including variations in the definition or set of included ecological indicators. The versions differ in the metric used to characterize the impacts of restoration on migratory fish.

The first uses a *Population Viability Analysis* (*PVA*) score that indicates "the probability (in percentage terms) that migratory species will still migrate the river in 50 years, as calculated by scientists" (Zhao et al. 2013, p.10). The second, uses a migratory fish score, *migrants*, that indicates "the expected number of adults fish that will swim upstream each year", "[p]resented as a percentage of the reference values for the watershed" (Zhao e l. 2013, p.10). Respondents were either sent the *PVA* or *migrants* version. The other four ecological indicators presented include (1) the quantity of river habitat accessible to migratory fishes (*acres*), (2) the abundance of fish suitable for recreational harvest (*catch*), (4) the abundance of fish-dependent wildlife (*wildlife*), and (4) overall ecological condition measured by an index of biotic integrity score (*IBI*). EPA used a model variant published by Zhao et al. (2013) which was estimated based on combined responses to both survey versions (*PVA* and *migrants*). The model specification allows EPA to isolate WTP for *migrants*, which provides a good match to the policy variable (i.e., the number of fish saved).

EPA estimated the number of fish saved under the final rule and other options considered using the methods described in Chapter 3. Although the PVA score is likely to be affected by the number of fish saved, estimating expected changes in population viability in the 316(b) context is not feasible due to the lack of data allowing EPA to relate changes in individual species losses to populations, which is particularly the case for forage species.

8.3.2 Benefit Transfer Methodology

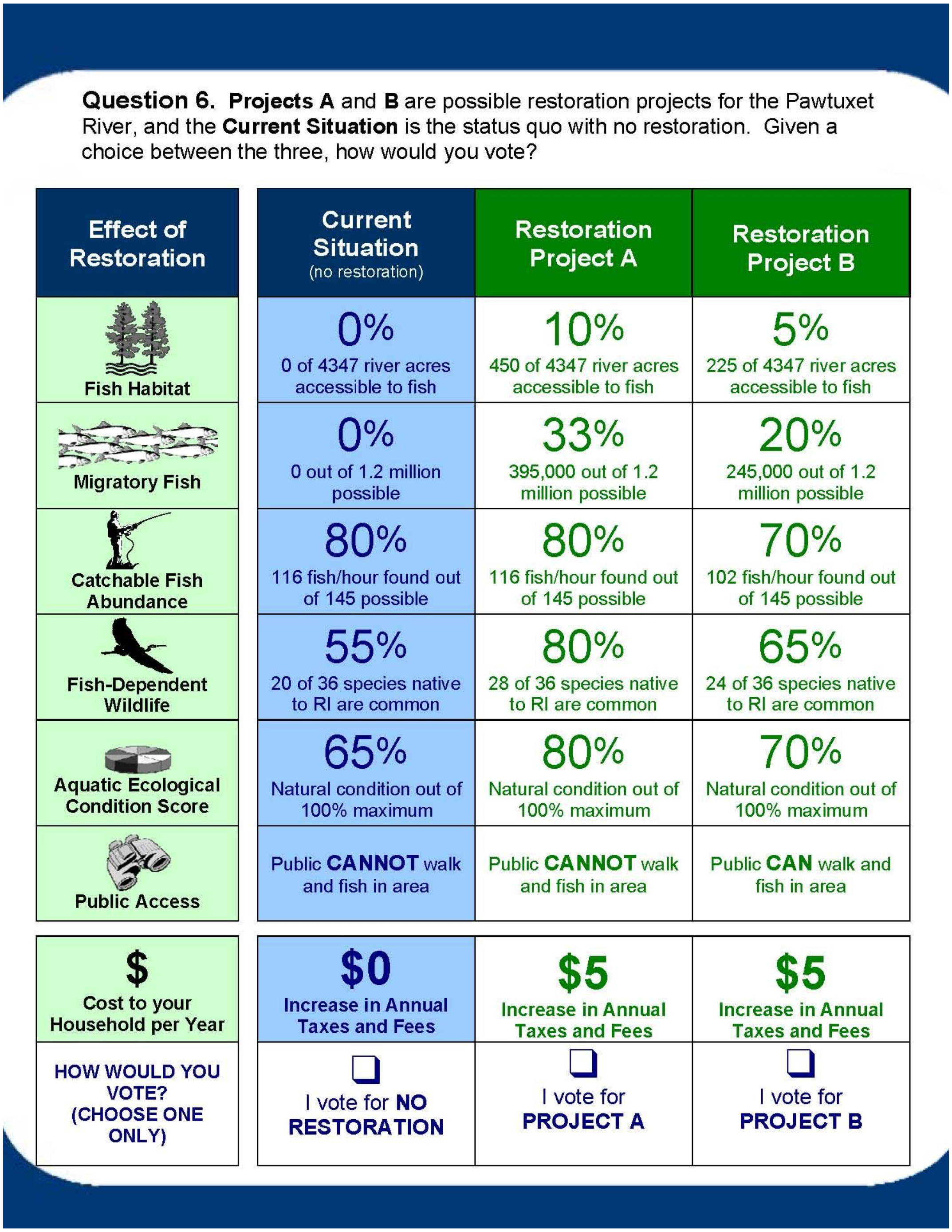
The following subsections describe EPA's benefit transfer methods using the BSPV study. Section 8.3.2.1 describes the estimation of WTP for a percentage increase in fish numbers and Section 8.3.2.2 describes the application of BSPV WTP values to IM&E reductions under the final rule and other options considered.

8.3.2.1 Estimating WTP for a Percentage Increase in Fish Numbers

Figure 8-2 is a sample choice experiment question from the *migrants* version of the study as presented in Zhao et al. (2013).[38] The five ecological attributes (*migrants*, *acres*, *catch*, *wildlife*, and *IBI*) are expressed as a percentage relative to upper and lower reference conditions (i.e., best and worst possible in the Pawtuxet) as defined in the survey information. Relative scores represent percent progress towards the upper reference condition (100 percent), starting from the lower reference condition (0 percent). This implies bounds on the potential attribute levels that might occur in the choice questions, following guidance in the literature to provide visible choice sets (Bateman et al. 2004). Because the survey used lower and upper bounds on a percentage point scale, it can be used for benefits transfer if IM&E reductions can be translated to the same scale. Hence, EPA based its benefit transfer on estimated WTP per percentage increase in fish numbers (*migrants*, "migratory fish" in Figure 8-2) relative to reference conditions.

EPA notes that the choice experiment question in the survey instrument also presented the increased number of fish and the total possible increase in the number of fish (the upper reference condition) directly below the percent improvement in migratory fish,. The number of fish affected by the existing facilities rule is many times larger than the number of fish corresponding to the maximum reference condition within the survey materials, because the Rhode Island survey covers a single watershed, rather than a large region. Because of this difference in scale, directly applying values per fish from the study to the 316(b) fish reduction estimates would likely overstate benefits of the final rule. Basing the benefit transfer on percentage improvement ameliorates this difference in scale, at least partially, because improvements are bounded by the 100 percent upper reference condition in all cases. The remainder of this section describes EPA's approach for using the implicit price, or WTP per percentage improvement, in migratory fish based on the Rhode Island study. Additional discussion of scale of fisheries improvements and the affected population is provided in Section 8.6.

[38] In the *PVA* version, the "migratory fish" (i.e., *migrants*) attribute is replaced with the *PVA* attribute.



Question 6. **Projects A** and **B** are possible restoration projects for the Pawtuxet River, and the **Current Situation** is the status quo with no restoration. Given a choice between the three, how would you vote?

Effect of Restoration	Current Situation (no restoration)	Restoration Project A	Restoration Project B
Fish Habitat	0% 0 of 4347 river acres accessible to fish	10% 450 of 4347 river acres accessible to fish	5% 225 of 4347 river acres accessible to fish
Migratory Fish	0% 0 out of 1.2 million possible	33% 395,000 out of 1.2 million possible	20% 245,000 out of 1.2 million possible
Catchable Fish Abundance	80% 116 fish/hour found out of 145 possible	80% 116 fish/hour found out of 145 possible	70% 102 fish/hour found out of 145 possible
Fish-Dependent Wildlife	55% 20 of 36 species native to RI are common	80% 28 of 36 species native to RI are common	65% 24 of 36 species native to RI are common
Aquatic Ecological Condition Score	65% Natural condition out of 100% maximum	80% Natural condition out of 100% maximum	70% Natural condition out of 100% maximum
Public Access	Public **CANNOT** walk and fish in area	Public **CANNOT** walk and fish in area	Public **CAN** walk and fish in area
$ Cost to your Household per Year	**$0** Increase in Annual Taxes and Fees	**$5** Increase in Annual Taxes and Fees	**$5** Increase in Annual Taxes and Fees
HOW WOULD YOU VOTE? (CHOOSE ONE ONLY)	❑ I vote for **NO RESTORATION**	❑ I vote for **PROJECT A**	❑ I vote for **PROJECT B**

Figure 8-2: Example Choice Experiment Question from the Zhao et al. (2013) Study including the Migratory Fish Score

Zhao et al. (2013) estimated a random utility model using simulated likelihood mixed logit accounting for correlations in choices from the same respondent.[39] Zhao et al. (2013) specified coefficients on all non-cost attributes, except *catch*, as random with a normal distribution within the mixed logit model. The study specified the coefficient on annual household cost (*cost*) with sign-reversed as random with a bounded triangular distribution. This *cost* specification ensures positive marginal utility of income. The likelihood simulations use Halton draws, or "intelligent draws", from the parameter distributions during model estimation. Halton draws are "generated number theoretically rather than randomly and so successive points at any stage 'know' how to fill in the gaps left by earlier points" (Bhat 2001, p. 684). This can improve model estimation compared to using purely random draws.

Table 8-3 presents the Zhao et al. (2013) unrestricted mixed logit model. The model was estimated based on both the *PVA* and *migrants* choice experiments including multiplicative interactions between each non-cost attribute and *d_mig*, a dummy variable identifying observations from the migrants choice experiment.[40] The model is significant at $p<0.0001$ with a pseudo-R^2 of 0.31. The coefficients of all environmental attributes, expect *catch*, are significant at $p<0.01$. The interactions allow for coefficient estimates to vary systematically between the *PVA* and *migrants* choice experiments. Using this specification, the marginal utility of non-cost attribute k is given by $\left(\hat{\beta}_{k,u} + \hat{\beta}_{k\times d_{mig},u}\right)$ for the *migrants* choice experiment.

[39] Mixed logit is an approach for modeling discrete choices subject to preference heterogeneity, based on the assumption that individual's preferences are randomly distributed and that heterogeneity in population preferences can be captured by estimating the mean and variance of the random parameter distributions (Holmes & Adamowicz 2003). As described by Hensher and Greene (2003, p. 170), "the mixed logit model offers an extended framework within which to capture a greater amount of behavioral choice making. Broadly speaking, the mixed logit model aligns itself much more with reality than most discrete choice models with every individual having their own inter-related systematic and random components for each alternative in their perceptual choice set(s)."

[40] Zhao et al. (2013) present an additional pooled model without interactions. That model is not presented here because it does allow for the isolation of WTP for changes in *migrants* and thus not well suited for benefits transfer to the 316(b) context.

Table 8-3: Results of the Unrestricted Model from Zhao et al. (2013)

Variable	Coefficient	Standard Error
Random Parameters		
acres	0.0463***	0.0117
fish (*PVA* and *migrants* pooled)	0.0169***	0.0043
IBI	0.0497***	0.0168
access	1.1577***	0.2056
wildlife	0.0267***	0.0083
neither	-4.2235***	0.4522
cost (bounded triangular, sign reversed)	0.0533***	0.0058
Non-random Parameters		
catch	0.0011	0.0082
acres × *d_mig*	0.0010	0.0161
fish × *d_mig*	0.0093	0.0087
IBI × *d_mig*	-0.0345	0.0229
access × *d_mig*	0.2170	0.2643
wildlife × *d_mig*	-0.0038	0.0113
neither × *d_mig*	-0.1865	0.8233
catch × *d_mig*	-0.0052	0.0114
Random Parameter Distributions		
std. dev. acres	0.0679***	0.0216
std. dev. fish	0.0154	0.0115
std. dev. IBI	0.0816***	0.0294
std. dev. access	1.5873***	0.2544
std. dev. wildlife	0.0174	0.0257
std. dev. neither	4.8330***	0.7627
spread cost (bounded triangular)	0.0533***	0.0058
Model Statistics		
-2 Log likelihood χ	1,127.26***	-
Pseudo-R^2	0.31	-
Observations (*N*)	1,634	-

Notes:
***, **, * indicates significance at 1%, 5%, 10% levels, respectively.
Parameter Descriptions:
acres – The number of acres of river habitat accessible to migratory fish.
fish – Variable that pools observations on *PVA* and *migrants* across the two choice experiments.
PVA – Population viability analysis (PVA) score. This was described to respondents as "the probability (in percentage terms) that migratory species will still migrate the river in 50 years, as calculated by scientists."
migrants - The percentage point increase in the number of migratory fish able to reach watershed habitat.
catch – The number of catchable-size fish in restored areas.
wildlife – Number of fish-eating wildlife species that are common in restored areas.
IBI – Index of biotic integrity (IBI) score reflecting the similarity of the restored area to the most undisturbed watershed in Rhode Island.
access – Indicates whether the restored area is accessible to the public for walking and fishing.
cost – The household annual cost required to implement the restoration program.
neither – Alternative specific constant (ASC) associated with the status quo, or a choice of neither plan.
d-mig – Binary (dummy) variable identifying observations from the choice experiment including *migrants* to represent effects on migratory fish.
Sources: U.S. EPA Analysis for this report, Zhao et al. (2013)

Implicit prices for each attribute are calculated based on the ratio of marginal utility and cost as $\left(\hat{\beta}_{k,u} + \hat{\beta}_{k\times d_{mig},u}\right)/\hat{\beta}_{cost,u}$. Because the betas are random for some attributes, simulations are used to estimate WTP per percentage improvement for each of the environmental attributes. Zhao et al. (2013) estimated WTP using the welfare simulation approach of Johnston and Duke (2007) following Hensher and Greene (2003). "The procedure begins with a parameter simulation following the parametric bootstrap of Krinsky and Robb (1986), with R=1000 random draws taken from the mean parameter vector and associated covariance matrix. For each draw, the resulting parameters are used to characterize asymptotically normal empirical densities for fixed and random coefficients. For each of these R draws, a coefficient simulation is then conducted for each random coefficient, with S=1000 draws taken from simulated empirical densities (either normal or bounded triangular, depending on the distribution for each coefficient). Welfare measures are calculated for each draw, resulting in a combined empirical distribution of $R \times S$ observations from which summary statistics are derived" (Zhao et al. 2013, p.17-18). The resulting empirical distributions accommodate both the sampling variance of parameter estimates and the estimated distribution of random parameters.

The welfare simulation approach provides a mean WTP estimate of $0.69 per percentage point increase in migratory fish in 2008$ $\left(\left(\hat{\beta}_{fish,u} + \hat{\beta}_{fish \times d_{mig},u}\right)/\hat{\beta}_{cost,u}\right)$, and $0.72 when adjusted to 2011$.[41] Results for total household WTP for a series of percentage improvements in fish numbers are shown below in Table 8-4. A zero percent improvement would mean no additional fish and 100 percent represents the maximum possible number of fish that may be supported by the ecosystem.[42] These percentage improvements do not represent population increases; rather, they reflect new fish within a specific habitat area that may be counted. In context of the 316(b) benefit transfer, the new fish are A1E saved under regulatory options.

EPA transferred the estimate of $0.72 per percentage improvement to estimate nonuse benefits of 316(b) regulatory options as described in the next section. The model makes it possible to distinguish benefits associated with resource uses from those associated primarily with nonuse motives. Because EPA used the implicit price for migratory fish changes for the benefit transfer application, WTP is estimated for increases in non-harvested fish alone. The transfer holds constant all effects related to identifiable human uses (e.g., effects on catchable fish, public access, observable wildlife, etc.). The remaining welfare effects—derived purely from effects on fish with little or no direct human use—may therefore be most accurately characterized as a nonuse benefit realized by households for the protection of all fish (including forage fish).

Table 8-4: WTP per Percentage Increase in the Number of Fish (2011$)

Percentage Point Increase in Number of Fish	WTP per % Increase in the Number of Fish	Total WTP per Household
1	$0.72	$0.72
12	$0.72	$1.44
20	$0.72	$14.41
33	$0.72	$23.78
100	$0.72	$72.06

Source: U.S. EPA analysis for this report

41 Within the Pawtuxet Watershed study area (the original study location), each percentage point increase in is equivalent to 12,250 individual fish migrating upstream.

42 EPA converted the implicit price from 2008$ to 2011$ using the consumer price index.

8.3.2.2 Estimating Total WTP for Eliminating or Reducing IM&E

The BSPV study was developed as a case study for a watershed-level policy in Rhode Island. While it provides parameterized benefit functions that require the fewest assumptions to implement for extrapolation to the 316(b) case, estimates are more likely to be representative of nonuse values held by individuals residing in the Northeast United States. EPA expects that it would provide less accurate estimates of nonuse values for residents of other U.S. regions outside the Northeast. EPA was unable to identify existing valuation studies conducted in other regions that would provide benefit functions of comparable quality and applicability to the 316(b) regulatory context. Although other studies in the literature value changes in aquatic resources, they do not provide a good match to the 316(b) policy scenario in terms of the expected resource change. The large number of assumptions required for developing benefit transfer based on these studies would result in greater uncertainties compared to application of the BSPV study. Therefore, EPA restricted the benefit transfer to the North Atlantic and Mid-Atlantic EPA 316(b) study regions.

The structure of the transfer study dictates that WTP should be evaluated based on the single species that would experience the greatest relative increase in abundance from restoration and that WTP estimates from multiple species impacted by IM&E should not be treated as strictly additive. This is related to the issue of independent valuation and summation. Species likely act as substitutes in people's utility. That is, if one species population has increased, WTP to increase a second species may be lower if the species are viewed as substitutes. If one values a set of species independently through separate application of the valuation function, then the individual species estimates do not account for substitution among the species in people's preferences and their summation could lead to misleading results. Johnston et al. (2002a) discusses this issue in the context of environmental management and states that "If interactions among multiple elements of environmental management programs exist, the use of survey methods such as contingent valuation to value single dimensions of these programs in isolation (i.e., relative to the same 'initial state of the world') may provide misleading results" (p. 4-1).

To match the original valuation scenario to the 316(b) policy scenario, EPA selected the single species in the Northeast United States that is most impacted among those species with sufficient stock information to conduct the analysis. The selected species is most likely to be a commercially or recreationally harvested species because of the availability of stock information. However, as discussed in the previous section, EPA is able to focus on nonuse values by using *migrants* attribute for the benefit transfer. The total baseline IM&E in the North-Atlantic and Mid-Atlantic regions were evaluated together to represent the Northeast United States. for consistency with the available stock assessments, which include waters from Maine to North Carolina. EPA selected winter flounder[43] as the species for the benefit transfer after considering multiple criteria:

- *Stock Assessment Data* – EPA defines biomass at maximum sustainable yield (B_{MSY}) as the baseline when estimating the percentage increase in fish abundance under the 316(b) regulatory options. An estimate of B_{MSY} must be available from a recent stock assessment. B_{MSY} was available for winter flounder from a recent stock assessment.
- *Current Stock Size* – Current biomass of the stock must be less than $B_{MSY;}$ otherwise, a percent improvement is not calculable. For example, striped bass and croaker stocks exceed B_{MSY} and were removed based on this criterion. The current biomass of winter flounder is less than B_{MSY}.

[43] Winter flounder are harvested commercially; however fish of commercial species may be forage during early life-stages and have nonuse values.

- *Magnitude of IM&E* – EPA selected the species with the highest relative magnitude of baseline IM&E on a percentage basis when compared to total age-one fish in the stock and B_{MSY}. Baseline IM&E for winter flounder (6.2 million) is high when compared total age-one fish in the winter flounder stock and B_{MSY}.[44] Various other species, such as butterfish and bluefish, suffer much lower baseline IM&E.

Winter flounder is the only species for which EPA conducts the benefits transfer, due to stock data availability and the aforementioned issues related independent valuation, summation, and substitution. EPA notes that baseline IM&E of winter flounder represents less than one percent of total baseline IM&E. It is difficult to ascertain the upper bound of nonuse benefits if the transfer were able to account for multiple species.

EPA expects that decreasing IM&E will lead to increased fish abundance in affected waterbodies. EPA assumed that the total number of fish introduced to local habitats throughout the Northeast under the final rule and regulatory options considered would be equivalent to the sum of A1E reductions for the North Atlantic and Mid-Atlantic regions. Application of the BSPV model results requires that the increases be expressed as a percentage increase over current conditions relative to a maximum number of fish that could be supported by the ecosystem. For the benefit transfer, EPA measured IM&E on a normalized yardstick based on fishery managed to the maximum sustainable yield. This measure should not be interpreted as a population impact.

To calculate improvements under the final rule and regulatory options considered, EPA compared the reduction in A1E lost to IM&E to an estimate of the number of age-1 fish in the winter flounder population at B_{MSY}. Available fish stock assessments of winter flounder did not estimate the number of eggs or larvae in the population; instead, the youngest fish modeled were of age 1. Additionally, EPA used the number of age-1 fish in the population as the basis for comparison in recognition of the fact that winter flounder adults migrate seasonally from estuaries to offshore shelf areas. Accordingly, adults are less likely to suffer IM&E than young fish. The most recent stock assessment for the Southern New England winter flounder conducted by the Northeast Fisheries Science Center (NEFSC 2011) indicates that spawning stock biomass (SSB_{MSY}[45]) at maximum sustainable yield is 43,661 metric tons. EPA calculated the approximate number of age-1 fish per metric ton of spawning stock biomass to be 2,624 using age-class data for 2005 (NEFSC 2008).[46] EPA multiplied the current SSB_{MSY} of 43,661 metric tons by 2,624 to generate an estimate a maximum of 114.6 million age-one fish at maximum sustainable yield.[47]

44 EPA used the estimated number of age-one fish in the Southern New England winter flounder stock from Terceiro (2008). The most recent stock assessment, released in 2011 (NEFSC 2011), did not provide an estimate of the number of age-one fish.

45 $SSB_{MSY\ is}$ the standard measure of biomass used by fisheries biologists to set fishing quotas. It includes only fish capable of reproduction: for winter flounder, this includes fish age 3 or greater. Accordingly, winter flounder SSB_{MSY} will always be lower than B_{MSY} because it excludes fish younger than age 3.

46 This is based on 8.8 million age-one fish for 3,368 metric tons of spawning stock biomass.

47 EPA analysis used data for the Southeast New England winter flounder stock. The Gulf of Maine (GOM) winter flounder stock is also within the North Atlantic region, however, estimates of B_{MSY} for the GOM stock are highly variable and a consensus estimate is not provided by NMFC. The effect on estimated benefits is relatively minor because the range of B_{MSY} indicates that the stock would be relatively small (around 10 percent) compared to the Southern New England stock at maximum sustainable yield.

EPA's calculation of nonuse values from eliminating or reducing IM&E for each regulatory option involved the following steps:

1. Calculate the percent increase of winter flounder relative to total age-1 winter flounder at maximum sustainable yield in the Northeast U.S. (the North Atlantic and Mid-Atlantic regions combined) by comparing A1E reductions under each regulatory option relative to a baseline of 114.6 million fish.
2. Multiply the percentage point change by the household WTP of $0.72 per percentage point improvement (Table 8-4) to calculate the WTP per household per year for the relative increase in winter flounder resulting from the regulatory option.
3. Calculate annual regional WTP for each regulatory option by multiplying WTP per household per year by the total number of households within the North Atlantic and Mid-Atlantic regions, respectively.

The results from implementing these steps for the final rule and the other options considered are described in Section 8.4. Discussion of geographic scale and other uncertainties are provided in Section 8.6.

8.4 Benefit Transfer Results for the Final Rule and Options Considered

Table 8-5 summarizes EPA's estimates of WTP for increased fish numbers resulting from the 316(b) final rule and options considered in the North Atlantic and Mid-Atlantic regions. EPA estimated that elimination of all baseline IM&E would increase the number of winter flounder in the Northeast United States by more than 6.2 million fish. This is equivalent to a 5.4 percentage point increase relative to a maximum of 114.6 million fish (i.e., 6.2 million divided by 114.6 million). Multiplying the 5.4 percent increase by a value of $0.72 per percentage point increase (as presented in Table 8-4) yields a household WTP of $3.92 per year. Applying the household WTP values to the number of households in each region results in annualized WTP values of $20.2 million and $78.9 million for the North Atlantic and Mid-Atlantic regions, respectively, using a discount rate of 3 percent. Annualized WTP values are $19.8 million for the North Atlantic and $77.2 million for the Mid-Atlantic using a discount rate of 7 percent. These numbers represent the nonuse value of eliminating all baseline losses of IM&E based on the benefit transfer using the BSPV study. These are thus the maximum possible nonuse values based on this benefits transfer covering these two regions.

EPA estimated that the final rule will increase winter flounder numbers by 0.07 percent in the North Atlantic and Mid-Atlantic waters. Applying per household WTP to this percent increase in the number of winter flounder ($0.05) and to the number of households in each region yields the total WTP for improvements in winter flounder abundance. The estimated annualized WTP for the final rule in the North Atlantic region will be about $0.2 million using both 3 percent and 7 percent discount rates. For the Mid-Atlantic, annualized WTP will be $0.8 million using a 3 percent discount rate and $0.7 million using a 7 percent discount rate. Table 8-5 also presents household WTP and annualized WTP for Proposal Option 4 and Proposal Option 2.

Table 8-5: Nonuse Value of Eliminating or Reducing Baseline IM&E for the Final Rule and Options Considered for Regulated Facilities in the North Atlantic and Mid-Atlantic Regions

Step	Proposal Option 4	Final Rule	Proposal Option 2	Baseline
Reduction in Northeast IM&E (millions of A1E)	0.03	0.08	4.78	6.23
Percentage increase in age-1 fish in Northeast waters relative to age-1 stock at MSY	0.02%	0.07%	4.18%	5.44%
Household WTP per Household (2011$)	$0.02	$0.05	$3.01	$3.92
North Atlantic[a]				
Annual WTP (millions of 2011$)	$0.09	$0.28	$16.35	$21.29
Annualized WTP (3% discount rate; millions of 2011$)	$0.06	$0.21	$10.43	$20.21
Annualized WTP (7% discount rate; millions of 2011$)	$0.05	$0.17	$7.61	$19.77
Mid-Atlantic[b]				
Annual WTP (millions of 2011$)	$0.34	$1.09	$63.80	$83.10
Annualized WTP (3% discount rate; millions of 2011$)	$0.25	$0.81	$40.70	$78.89
Annualized WTP (7% discount rate; millions of 2011$)	$0.20	$0.65	$29.69	$77.17
Total Northeast (North Atlantic plus Mid-Atlantic)				
Annual WTP (millions of 2011$)	$0.42	$1.37	$80.14	$104.39
Annualized WTP (3% discount rate; millions of 2011$)	$0.31	$1.01	$51.13	$99.10
Annualized WTP (7% discount rate; millions of 2011$)	$0.25	$0.82	$37.30	$96.95

[a] Based on 5.41 million households.
[b] Based on 21.11 million households.
Source: U.S. EPA analysis for this report

8.5 Habitat-Based Methodology for Estimating Nonuse Values for Fish Production Lost to IM&E

EPA also developed a habitat-based method for estimating nonuse values for fish lost to IM&E for the proposed rule (USEPA 2011b).[48] The purpose of the method was to estimate the value of fish losses due to IM&E by approximating the area of habitat required to produce and support the number of organisms lost to IM&E. Provision of fish habitat and nursery for aquatic species is one of the ecosystem services provided by wetlands and submerged aquatic vegetation (SAV). Thus, WTP for fish production services associated with wetlands and SAV can provide an indirect basis for estimating the nonuse values of increased number of fish. These values may be transferred from available wetlands and SAV valuation studies.[49] These studies found that survey respondents were aware of the fish production services provided by eelgrass (submerged aquatic vegetation, SAV) and wetlands; individuals expressed support

[48] EPAfocused on nonuse value of fish production services because use values were estimated using other valuation methods described in Chapter 5 through 7.The nonuse values are estimated as the total WTP for fish production services by nonusers of these resources.

[49] Refer to Chapter 9 of the Environmental and Economic Benefits Analysis (EEBA) for the proposed rule for the list of valuation studies used in EPA’s analysis (USEPA 2011b).

for programs that include increasing SAV and wetland areas with the expressed goal of restoring depleted fish and shellfish populations (Johnston et al. 2002b; Mazzotta 1996; Opaluch et al. 1995; 1998). EPA's habitat-based approach involved estimating the area of habitat required to replace fish and shellfish lost to IM&E and calculating public WTP for the estimated habitat area. When combined, these data yield an estimate of household values for an increase in fish and shellfish abundance which in turn provides an indirect estimate of the benefits of reducing or eliminating IM&E.

The habitat-based benefit transfer approach for the proposed rule involved four general steps:

1. Estimate the area of habitat necessary to produce and support the number of organisms lost to IM&E.
2. Develop per acre WTP values for fish production services that support fish species affected by IM&E (i.e., SAV and wetlands).
3. Estimate the total nonuse value of baseline IM&E by multiplying WTP values for fish and shellfish services by the estimated area of habitat required to offset baseline IM&E.
4. Estimate the nonuse benefits of reduced IM&E by multiplying WTP values for fish and shellfish services by the area of habitat required to offset IM&E reduced by regulatory options.

The WTP values used for fish and shellfish habitat services were based on an in-depth search of the economic literature to identify valuation studies that estimate WTP for aquatic habitat services using methods which are inclusive of nonuse values (e.g., contingent values, conjoint analysis). EPA used additional information to isolate the proportion of WTP associated with fish habitat services from other services such as bird habitat and mosquito control. The habitat-based benefit transfer method estimates only those values related to IM&E of organisms, not any indirect ecosystem effects of IM&E, or chemical effects of CWIS (Chapter 2).

For the proposed rule, EPA estimated national WTP to compensate for baseline IM&E losses under the habitat-based approach to be about $3.6 billion and $3.7 billion using 3 percent and 7 percent discount rates, respectively. For Proposal Option 1, EPA estimated total national WTP of $513.3 million using a 3 percent discount rate and $477.2 million using a 7 percent discount rate. National WTP for Proposal Options 4 and 2 ranged from $509.9 million to $2.1 billion using a 3 percent discount rate and $474.0 million to $1.5 billion using a 7 percent discount rate. Refer to Chapter 9 of the EEBA for the proposed rule (USEPA 2011b) for additional detail on the habitat-based benefit transfer method, results for the proposed regulatory options, and limitations and uncertainties associated with the approach.

EPA did not consider the habitat-based approach appropriate for primary analysis of nonuse benefits and thus did not include habitat-based estimates in the total benefits of eliminating or reducing IM&E under the proposed regulatory options. Likewise, EPA does not re-estimate the habitat-based approach for the final rule or include benefits based on the habitat-based approach within the comparison of benefits and costs for the final rule. Since the proposed rule, EPA has revised its estimates of baseline IM&E, IM&E reductions under regulatory options, and revised the compliance schedule. However, if EPA were to re-estimate the habitat-based analysis for the final rule, EPA expects that the results for the final rule would generally be similar to results described above for Proposal Option 1.[50] The habitat-based approach helps to illustrate the potential magnitude of nonuse values from the final rule, and provides additional support

[50] As described in the Chapter 1, the final rule is Option 1 from EPA's analysis for the proposed rule (U.S. EPA 2011) with some modifications. Proposal Options 4 and Proposal Option 2 correspond to Options 4 and 2 from EPA's analysis for the proposed rule (U.S. EPA 2011) with some modifications.

for the benefit transfer results presented in Section 8.4, and the results of EPA's SP survey described in Chapter 10.

8.6 Limitations and Uncertainties

By designing a survey instrument directly for the context at hand, EPA could use the stated preference survey results without the need to transfer benefits. However, EPA did not complete its stated preference study in time to have it fully peer reviewed for this analysis. Thus, EPA is relying on this benefits transfer to estimate, in part, nonuse values.

A number of issues are common to all benefit transfers. The technique involves adapting research found in the available literature and conducted for one purpose, to another purpose, to address the policy questions at hand. Some of the limitations and uncertainties associated with implementing a benefit transfer using Johnston et al.(2012) are addressed below. Broader limitations and uncertainties associated with benefit transfer in general are discussed by Johnston and Rosenberger (2010).

8.6.1 Scale of Fishery Improvements

Given the scope of the survey upon which benefit transfer results are based (Johnston et al. 2012; Zhao et al. 2013), the most reliable results apply within the range of the attributes presented to the respondents in the choice experiment. As shown in Figure 8-2, the percentage point increases in the number of fish for all analyzed 316(b) regulatory options are less than 33 percent, which is within the range of the fish migrants attribute changes presented in the survey instrument.).

8.6.2 Scale and Characteristics of the Affected Population

The results of the Rhode Island study (Johnston et al. 2012; Zhao et al. 2013) reflect WTP for improvements in nearby watersheds. WTP may decline as policy areas become more distant. The most reliable application of these results would be to calculate WTP for IM&E reductions in a single local watershed. However, the final rule will reduce IM&E and improve fish populations in multiple watersheds within some states. Although it is not unreasonable that households would hold values for multiple watersheds, this is a departure from the transfer study context. As noted, EPA assumed that households have consistent values for improvements in multiple watersheds within their state or region.

Moreover, for transfers based on absolute fish numbers, EPA assumed that the per household WTP for changes in the numbers of fish for all watersheds located within the state, including watersheds that are shared by multiple States, would be at least equal to the WTP value for improvements in a single watershed. Hence, EPA estimated per household WTP based on the average watershed improvement within the state. The transfer study context was a single watershed in Rhode Island (Johnston et al. 2012; Zhao et al. 2013). Using the benefit transfer approaches outlined here, the benefit function is applied to all states in the North Atlantic and Mid-Atlantic regions without adjustment, based on mean household income or local watershed characteristics. Some heterogeneity in WTP would be expected across states and regions due to diversity in species and public values. EPA did not extend the benefit transfer beyond the North Atlantic and Mid-Atlantic regions because of the potential for substantial differences in preferences, demographics, and species characteristics in other regions compared to the original context of the transfer study. This likely results in the underestimation of nonuse benefits.

8.6.3 Fish Population Size, Type and Improvement from the Elimination of IM&E

To conduct the benefit transfer, EPA assumed that the gain in fish abundance would be equal to IM&E reductions under the final rule and options considered. These gains are not intended to represent changes in fish population, but are merely normalized as percentages of age-one fish at maximum sustainable yield.

While both the transfer study and policy contexts involve forage fish, the specific species compositions involved differ between transfer study (Johnston et al. 2012; Zhao et al. 2013) and the 316(b) context. For example, most of the fish affected within the transfer study are migratory fish such as river herring, while such species may account for a smaller proportion of those affected by CWIS subject to the final rule. If WTP is sensitive to the specific type of forage fish involved, this could be a potential source of generalization error.

9 Assessment of Social Cost of Carbon

Benefits of regulatory actions include potential effects from estimated changes in greenhouse gas (GHG) emissions associated with energy requirements of compliance technology and installation downtime under the final rule and other options considered. Decreases in GHG emissions, measured as CO_2 equivalents, may reduce the burden of global climate change to society in future years, and thus may create a positive benefit to society, while increases in GHG emissions can impose a negative benefit, or cost, to society. EPA refers to the costs from increased emissions as the social cost of carbon (SCC). EPA estimated the benefit, or cost, to society from changes in GHG emissions expected to result from the final rule and other options considered. EPA based this estimate on the SCC concept, which reflects the cost (or benefit) to society associated with an incremental change in CO_2-equivalent emissions in a given year. This chapter presents EPA's analysis for existing units at Electric Generators and Manufacturers (Section 9.1). See Chapter 12 for EPA's analysis for new units.

EPA estimated the change in CO_2 emissions resulting from the energy penalty associated with closed-cycle recirculating system technology, auxiliary energy requirements for operating compliance technology, and technology installation downtime for Electric Generators. Energy penalty effects result from reduced energy conversion efficiency of the power generating system. EPA estimated the change in CO_2 emissions resulting only from the energy penalty and increase in the auxiliary energy requirement for Manufacturers. EPA assumed no change in CO_2 emissions for compliance technology installation downtime at Manufacturers because the short-term replacement of energy by electric power generating facilities that would otherwise be produced at Manufacturers could either increase or decrease emissions. Refer to Appendix I of the Economic Analysis (EA) for the final rule (USEPA 2014a) for additional detail on compliance technology effects that impose costs via impact on revenue or energy requirements.

9.1 Analysis Approach and Data Inputs

9.1.1 Electric Generators

As discussed in Chapter 3 and Appendix I of the EA, EPA expects Electric Generators to temporarily suspend electricity generation activities to install compliance technology, and to incur annual generation losses due to energy penalty and auxiliary energy requirements. In the case of downtime, other electric power facilities will have to compensate for these generation losses by generating more electricity to meet electricity demand. This may require an increased or decreased energy input, which may lead to increased or decreased CO_2 emissions, depending on the energy input and generation profile of the generating units used to compensate for the generation losses. In the case of the energy penalty and auxiliary energy requirements, either the affected Electric Generators or other electric power facilities or both will have to compensate for these generation losses by generating more electricity to meet electricity demand. As with downtime, this may require an increased or decreased energy input, which may lead to increased or decreased CO_2 emissions..

EPA estimated the potential increase in CO_2 emissions, based on results from the electricity market analysis using the Integrated Planning Model (IPM®). For the existing unit provision of the final rule, EPA used results for the Electricity Market Analysis - Final Rule option from the IPM analysis (for details on that analysis, see Chapter 6 of the EA for the final rule) to estimate changes in CO_2 emissions. As discussed in Chapter 6 of the EA for the final rule, the IPM analysis accounted only partially for the new unit provision of the final rule. Consequently, to avoid underestimating the effect on CO_2 emissions, EPA assumed that the IPM-based CO_2 emissions effects of the final rule reflect the existing unit provision only, and assessed the impact on CO_2 emissions from the new unit provision of the final rule in a separate analysis discussed in Chapter 12. To the extent that changes in CO_2 emissions estimated in IPM also reflect the impact of the new unit provision of the final rule, the estimated reductions in CO_2 effects and associated SCC benefit, which are assigned to the existing unit provision of the final rule, may be unders-estimated.

As described in Chapter 6 of the EA for the final rule, EPA did not conduct a separate electricity market analysis to assess the regulatory impacts of Proposal Option 2 as analyzed in support of the final rule. Instead, the Agency used results from the IPM analysis of Proposal Option 2 (referred to as Market Model Analysis Option 2 in the context of IPM analysis) conducted in support of the proposed rule. As described in the Chapter 6 of the Economic and Benefits Analysis (EBA) for the proposed rule, that IPM analysis used an older IPM platform – IPM V3.02_EISA. [51] For details on that analysis, see the EBA for the proposed rule.

EPA calculated the difference in CO_2 emissions reported in the baseline (i.e., pre-policy) case and policy case of the IPM analysis. Because EPA did not analyze Proposal Option 4 in IPM in support of either the proposed rule or the final rule, EPA could not estimate CO_2 emissions specifically for that option. However, Proposal Option 4 is similar to the existing unit provision of the final rule in that both set performance standards based on IM technology. Moreover, compliance costs for Proposal Option 4 are slightly lower than those of the existing unit provision of the final rule (see Chapter 3 of the EA for the final rule). Therefore, the change in CO_2 emissions for Proposal Option 4 is likely to be no larger than the emission changes calculated for the Electricity Market Analysis – Final Rule.

To estimate the change in CO_2 emissions for the 46-year analysis period of 2014 through 2059, EPA first calculated the change in CO_2 emissions from baseline to policy option, as estimated in the IPM electricity market analyses. As described in Chapter 6 of the EA for the final rule, the IPM V4.10_MATS platform embeds three run years – 2015, 2020, and 2030. These run years represent multiple years and specific technology-installation years as shown in Table 9-1.

Table 9-1: IPM V4.10_MATS Run-Year Specification – Final Rule[a,b]

Run Year	Represented Years	Regulatory Effects Captured – Final Rule
2015	2014-2016	Operations and financial changes in anticipation of future compliance[a]
2020	2017-2024	IM technology installation
2030	2025-2034	Steady-state post-compliance period; captures potential permanent changes.

[a] As discussed in Appendix P of the EA for the final rule, IPM reflects an assumption of perfect foresight.
[b] V4.10_MATS is the IPM version that EPA used to analyze the Final Mercury and Air Toxics Standards (MATS).

[51] Although Proposal Option 2 analyzed in support of the final rule set impingement mortality and entrainment performance standards similar to those analyzed under Market Model Analysis Option 2, the expected compliance responses differ in terms of technologies that some facilities will install and the associated costs. In addition, administrative requirements considered for Proposal Option 2 differ from those analyzed in IPM for the proposed rule. Also, the current universe of regulated facilities is slightly smaller than the universe of regulated facilities analyzed for the proposed rule. Finally, compared to Market Model Analysis Option 2, Proposal Option 2 provides facilities with more flexibility and a longer window to comply with the regulatory requirements. EPA judges that despite these differences, the electricity market analysis results from the proposed rule are sufficient to assess the change in CO_2 emissions under Proposal Option 2.

As described in Chapter 6 of the economic and benefits analysis for the proposed rule (USEPA 2011a), EPA specified four run years for the IPM analysis in accordance with the compliance-technology installation schedule considered at that time: 2015, 2020, 2025, and 2028. These run years represent multiple years and specific technology-installation years as follows:

Table 9-2: IPM V3.02_EISA Run-Year Specification – Proposal Option 2[a]

Run Year	Represented Years	Regulatory Effects Captured – Proposed Rule
2015	2013-2017	IM technology installation
2020	2018-2022	Entrainment control technology installation – non-nuclear facilities
2025	2023-2027	Entrainment control technology installation – nuclear facilities
2028	2028	Steady-state post-compliance period; captures potential permanent changes.

[a] V3.02_EISA is the IPM version that EPA used to model electric generation for the proposed Transport Rule.

EPA assumed that any observed changes in CO_2 emissions between the baseline case and the policy case are attributable to the analyzed 316(b) regulatory requirements. For the final rule, EPA assumed that the difference in CO_2 emissions reported for 2015 is the same as the difference in the other three years represented by 2015, i.e., 2014 through 2016. EPA applied the same methodology to the remaining two run years, thereby generating the change in CO_2 emissions for the 21-year period of 2014 through 2034.[52] EPA used the same methodology for Proposal Option 2, generating a time profile of changes in CO_2 emissions for the 16-year period of 2013 through 2028.

In reviewing the estimated changes in CO_2 emissions from the IPM runs, EPA observed that for some regulatory options and some analysis years, CO_2 emissions decline even though EPA would expect the options to have effects of replacing and/or providing additional electricity generation, as described above. On closer inspection, in these cases, the generation mix between the baseline and the regulatory option case changes in such a way that a CO_2 emissions decrease is plausible – e.g., increased generation from nuclear facilities (which are non-CO_2 emitting) and reduced generation from coal or other fossil fuel facilities.

The run-year configuration embedded in the IPM V4.10_MATS platform used for the analysis of the final rule was set independent of the 316(b) compliance and technology installation schedule. Unlike the case with the IPM analysis done in support of the proposed rule, EPA did not change this configuration to better reflect the final rule requirements. EPA expects all regulated facilities to install compliance technologies during the 5-year period of 2018 through 2022, which is within the range of years represented by the 2020 IPM run year. To align year-specific changes in CO_2 emissions estimated for the Electricity Market Analysis - Final Rule as part of the IPM analysis with technology-installation schedule of the final rule and consequently, Proposal Option 4, EPA made the following assumptions:

- As discussed in Chapter 6 of the EA for the final rule, the three years (2014 through 2016) represented by the 2015 IPM run year, have the same characteristics as the 2015 year. These three years immediately precede the technology-installation period assumed in the IPM analysis. EPA assumed that the year-specific changes in CO_2 emissions estimated for Electricity Market

52 Even though no compliance technology is installed during the 3-year period represented by the 2015 IPM run year, any changes in the market behavior resulting in changes in CO_2 emissions are due to anticipated compliance with the 316(b) requirements. As discussed in Appendix P of the Final Rule EA report, IPM reflects an assumption of perfect foresight, which means that market players have complete knowledge of the nature and timing of the constraints, including those created by regulatory requirements that will be imposed in future years during the analysis period, and make decisions based on this knowledge.

Analysis - Final Rule for 2014 through 2016 are the same as those that will occur during 2015 through 2017, i.e., the 3-year period immediately preceding the technology-installation period anticipated under the final rule.

- Similar to the 2015 IPM run year , the eight years (2017 through 2024) that are represented by the 2020 IPM run year have the same characteristics as the 2020 run year. As a result, in the IPM analysis, downtime was applied as a single value for each of the eight years. EPA assumed that the resulting total difference in CO_2 emissions for this eight-year period (CO_2 emissions reported for the 2020 IPM run year times eight – the number of years that the 2020 run year represents) is the same as the total difference in CO_2 emissions that would have resulted if all facilities were to install IM technologies during the five-year period, 2018 through 2022, when compliance technology will be installed under the final rule. EPA converted the eight-year total of CO_2 emissions change to a yearly value for each of the five years, 2018 and 2022, by simply dividing the total emissions change over the eight years by five.
- Finally, using the same approach as that used for the 2015 IPM run year, EPA assumed that the year-specific changes in CO_2 emissions estimated for the 2030 IPM run year and consequently, for each of the 10 years it represents – 2025 through 2034 – are the same as those that would occur during the 10-year period of 2023 through 2032. In other words, the Agency "moved" the emissions changes in the 10-year IPM-analysis period of 2025 through 2034 to the 10-year period of 2023-2032, the years following expected completion of technology installation under the final rule. The change in CO_2 emissions reported for the final rule in 2030 is negative (i.e., CO_2 emissions in that year decline from the baseline to the policy case). To avoid understating the potential effect of regulatory requirements on CO_2 emissions, EPA applied this decrease only to the 10 years represented by 2030 and assumed zero change in CO_2 emissions during the remaining years in the social-cost analysis period, i.e., 2033 through 2059.

The technology-installation schedules EPA assumed for the IPM analysis in support of the proposed rule differ from those assumed for Proposal Option 2 analyzed in support of the final rule. As shown in Table 9-2, for the proposed rule, EPA assumed that facilities would install IM technologies during a 5-year window of 2013 through 2017. Further, EPA assumed that non-nuclear and nuclear facilities would install entrainment control technologies during 2018 through 2022, and 2023 through 2027, respectively. As discussed earlier in this chapter, for the existing unit provision of the final rule, these technology-installation periods are 2018 to 2022, 2021 to 2025, and 2026 to 2030, respectively. To align year-specific changes in CO_2 emissions estimated for Market Model Analysis Option 2 with technology-installation schedules EPA assumed for Proposal Option 2 analyzed in support of the final rule, EPA made the following assumptions:

- Proposal Option 2 and Market Model Analysis Option 2 require both IM and entrainment control technologies. To capture differences in energy requirements to install and operate these two sets of technologies, EPA aligned year-specific changes in CO_2 emissions estimated for Market Model Analysis Options 2 with technology-specific installation schedules currently assumed for Proposal Option 2. To capture changes in emissions associated with IM technology, EPA assumed that the year-specific changes in CO_2 emissions estimated for Market Model Analysis Option 2 during 2013 through 2017 are the same as those that EPA would have estimated for 2018 through 2022. For entrainment-control technology installation at non-nuclear facilities, the Agency assumed that the changes in emissions it estimated for 2018 through 2022 are the same as those it would have estimated for 2021 through 2025. For installation of entrainment control technology at non-nuclear facilities, the Agency assumed that the changes in emissions estimated for 2023 through 2027 are the same as those that EPA would have estimated for 2026 through 2030. Unlike the case of Electricity Market Analysis - Final Rule, under Market Model Analysis Option 2, the change in CO_2 emissions reported for the steady-state year (2028) is positive (i.e., CO_2 emissions in that year increase from the baseline to the post-policy case). To avoid understating the potential effect of regulatory requirements on CO_2 emissions, EPA applied this increase in emissions over the remaining years in the social-cost analysis period, i.e., 2031 through 2059.

To estimate the benefits of changes in CO_2 emissions due to the existing unit provision of the final rule and Proposal Option 2, EPA used SCC values from *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis-Under Executive Order 12866* developed by the United States Government Interagency Working Group on Social Cost of Carbon, 2013 (Interagency Working Group 2013). The Working Group estimated annual unit SCC values ($ per metric ton) for 2010 through 2050 (Table 9-3). Three of these four sets are based on the *average* unit SCC values across models, and socio-economic and emissions scenarios, for each of three SCC discount rates: 5.0, 3.0, and 2.5 percent. The Work Group developed a fourth set of unit SCC values as the 95th percentile value of the 3 percent discount rate-based SCC values; these values represent the potential for higher-than-expected impacts from temperature change farther out in the tails of the SCC distribution.[53]

Table 9-3: Unit Social Cost of Carbon, 2010-2050 ($ per metric ton of CO_2; 2011$)[a]

Year	Discount Rates			
	2.5%	3.0%		5.0%
	Average SCC Value	Average SCC Value	High SCC Value	Average SCC Value
2010	$55.42	$34.15	$94.98	$11.74
2015	$0.83	$39.48	$116.32	$11.74
2020	$68.30	$45.89	$136.59	$12.81
2025	$73.63	$50.16	$152.60	$14.94
2030	$80.04	$55.49	$169.68	$17.07
2035	$85.37	$59.76	$186.75	$20.28
2040	$91.77	$65.10	$203.82	$22.41
2045	$98.18	$70.43	$219.83	$25.61
2050	$103.51	$75.77	$234.77	$27.75

[a] SCC values were calculated for 2010 through 2050 and vary by year; this table reports SCC values only for every fifth year.

Sources: Interagency Working Group, 2013; updated to 2011$ for this analysis using the GDP deflator.

These unit SCC values represent the present value of the future stream of costs to society from a change in GHG emissions in a given year, recognizing that the impact of changes in CO_2 in the atmosphere occurs not only in the year in which the emissions are generated, but extends over a substantial period into the future.[54] In the 2013 Technical Support Document (TSD) (Interagency Working Group 2013),

53 For more information on the assumptions and methodology used to develop these SCC values see the 2013 TSD(Interagency Working Group 2013) available online at: http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf.

54 The unit SCC values reported in the 2013 TSD and used in the current analysis are *global* SCC values. The Interagency Working Group determined that the use of global measures of benefits for greenhouse gas reductions is preferable to

these values are in 2007 dollars; EPA restated these values in 2011 dollars using the GDP deflator series. The SCC values published by the Working Group increase in real economic terms from year to year, reflecting the increasing marginal cost to society of additional GHG emissions and increasing cumulative burden of climate change over time. Because the Working Group published unit SCC values only through 2050, EPA extended the unit SCC values from 2050 to 2059, assuming that the annual real rate of change in the future SCC values remained the same as in the period 2049 to 2050.

EPA calculated the benefits of the year-to-year changes in CO_2 emissions as a product of the year-by-year unit SCC values and the estimated year-by-year changes in CO_2 emissions. The Agency then discounted the resulting year-by-year benefit values, summed the discounted values, and annualized them using discounts rate of 3 percent and 7 percent.[55]

9.1.2 Manufacturers

To estimate the change in CO_2 emissions due to compliance for Manufacturers, EPA estimated the replacement energy required during downtime and as a result of the energy penalty and auxiliary energy requirements. For downtime, electricity otherwise produced by Manufacturers will instead be produced by the electric power industry. Therefore, electricity generation and associated CO_2 emissions of Manufacturers decrease during downtime while generation and emissions from the electric power industry increase. Depending upon the carbon intensity of generation by the electric power industry relative to that of generation by Manufacturers, CO_2 emissions may increase or decrease during downtime. Given this uncertainty, EPA assumed no net change in CO_2 emissions during downtime. If the carbon intensity of generation for the electric power industry is greater than that for Manufacturers', this assumption will underestimate the increase in CO_2 emissions, and vice versa.

For a given quantity of energy input[56], energy penalty and auxiliary energy requirements reduce the amount of electricity that is available to the facility to meet baseline consumption needs and/or for sale.[57] EPA assumed that Manufacturers will not be able to increase energy input to offset this loss, with the net effect that a facility will need to purchase more electricity from other electric power generators or will deliver less electricity for external consumption. EPA assumed that these electricity losses, whether due to energy penalty or to auxiliary energy requirements, will be replaced by the electric power industry. This means that the facility's own CO_2 emissions will be unchanged but that CO_2 emissions may increase as other electric power generators make up this loss. EPA calculated the increase in CO_2 emissions from the generation of replacement electricity by the power industry based on the average CO_2 emissions intensity for United States.

EPA first calculated the replacement electricity required to offset the electricity loss from energy penalty and auxiliary energy requirements, assuming Manufacturers would incur the these effects from 2010

domestic measures. Refer to the 2013 TSD (Interagency Working Group 2013), and the earlier 2010 TSD (Interagency Working Group 2010) for additional discussion of global versus domestic measures.

55 This discounting approach diverges from the discount rate concepts used to develop the SCC values. However, the 3 percent and 7 percent discount rates are appropriate given that the alternative year-by-year SCC values reflect a range of factors including not only discount rates, but also different impact/socio-economic evolution scenarios, modeling approach/framework, and damage functions.

56 The energy that is consumed to generate electricity.

57 See Appendix I of the EA for detailed discussion of how energy penalty and auxiliary energy requirements affect electric power generation and the supply of electricity otherwise available for consumption at facilities installing compliance technology.

through 2059 (see Appendix I of the EA for the final rule). EPA then calculated the CO_2 emissions intensity based on projected total electricity generation (USDOE 2013b) and associated CO_2 emissions (USDOE 2013a) by year. EIA projects these values only to 2040, so EPA assumed no change in carbon intensity beyond 2040. EPA multiplied the carbon intensity in each year by the replacement electricity required in that year to calculate the CO_2 emissions due to the energy penalty of Manufacturers. EPA multiplied the estimated CO_2 emission values, by year, by the same unit SCC values as those used for Electric Generators (Table 9-3).

9.2 Key Findings for Regulatory Options

9.2.1 Electric Generators

Table 9-3 presents the total reduction in CO_2 emissions and associated values of SCC in 2013 for Electric Generators, by option and discount rate. The SCC values reported for Proposal Option 4 are the same as those reported for existing unit provision of the final rule because EPA assumed that CO_2 emissions for Proposal Option 4 would be the same as those calculated in the IPM analysis for Market Model Analysis 1, which aligns most closely with the existing unit provision of the final rule. To the extent that Proposal Option 4 is less stringent than Market Model Analysis 1 or the existing unit provision of the final rule, the SCC values reported for Proposal Option 4 are overstated.

As reported in Table 9-4, EPA estimates that the existing unit provision of the final rule (and Proposal Option 4) will result in a *total* reduction of 9.6 million tons of CO_2 equivalents (tCO2eq). As discussed above, EPA assesses that this reduction is likely the result of changes in generation mix that lead to more electricity generated by facilities with lower carbon emissions or none at all, such as nuclear facilities, and less electricity generated by coal or other fossil fuel facilities. Using the average SCC values calculated at a 3 percent discount rate, EPA estimates that this reduction in carbon emissions will result in average annual benefits of $12.4 million at the 3 percent discount rate and $13.4 million at the 7 percent discount rate. EPA estimates that under Proposal Option 4, *total* carbon emissions would increase by 1,471.9 million of tCO2eq. Using the average SCC values calculated at a 3 percent discount rate, EPA estimates the average annual (negative) benefit associated with this increase in carbon emissions to be -$1,613.6 million at the 3 percent discount rate and -$1,197.9 million at the 7 percent discount rate.

Table 9-4: Total Reduction in Carbon Emissions and Associated Benefits Under the Final Rule and Other Options Considered – Electric Generators (SCC Values in 2013; 2011$, millions)

Option	Total Reduction in Emissions (tCO2eq, millions)	Discount Rate for Calculating SCC Unit Values			
		2.5%	3.0%		5.0%
		Average SCC Value	Average SCC Value	High SCC Value	Average SCC Value
3% Discount Rate for Annualizing Benefits					
Proposal Option 4[a]	9.6	$18.1	$12.4	$37.7	$3.8
Final Rule – Existing Units[b]	9.6	$18.1	$12.4	$37.7	$3.8
Proposal Option 2	-1,471.9	-$2,281.0	-$1,613.6	-$4,988.0	-$536.2
7% Discount Rate for Annualizing Benefits					
Proposal Option 4[a]	9.6	$19.6	$13.4	$40.7	$4.1
Final Rule – Existing Units[b]	9.6	$19.6	$13.4	$40.7	$4.1
Proposal Option 2	-1,471.9	-$1,714.4	-$1,197.9	-$3,693.7	-$388.9

[a] To the extent that EPA used IPM results for Electricity Market Analysis – Final Rule as a proxy for Proposal Option 4, benefits for Proposal Option 4 are likely to be over-stated.
[b] To the extent that the change in CO_2 emissions estimated for the existing unit provision of the final rule partially accounts for the change in CO_2 emissions due to the new unit provision of the final rule, benefits reported for the existing unit provision of the final rule may be overstated.
Source: U.S. EPA analysis for this report

9.2.2 Manufacturers

Table 9-5 presents the total reduction in CO_2 emissions and associated benefit values for Manufacturers by option. Under the final rule and Proposal Option 4, EPA assessed no reduction in CO_2 emissions. Under Proposal Option 2, EPA calculated an increase of 25.4 million in tCO2eq. Using the average SCC values calculated at a 3 percent discount rate, EPA estimates the benefits associated with the estimated increase CO_2-equivalent emissions to be -$27.8 million at the 3 percent discount rate and $20.3 million at the 7 percent discount rate.

Table 9-5: Total Reduction in Carbon Emissions and Associated Benefits Under the Final Rule and Other Options Considered – Manufacturers (SCC Values in 2013; $2011, millions)

Option	Total Emissions (tCO2eq, millions)	Discount Rate for Calculating SCC Unit Values			
		2.5%	3.0%		5.0%
		Average SCC Value	Average SCC Value	High SCC Value	Average SCC Value
3% Discount Rate for Annualizing Benefits					
Proposal Option 4[a]	0.0	$0.0	$0.0	$0.0	$0.0
Final Rule – Existing Units	0.0	$0.0	$0.0	$0.0	$0.0
Proposal Option 2	-25.4	-$39.2	-$27.8	-$85.8	-$9.6
7% Discount Rate for Annualizing Benefits					
Proposal Option 4[a]	0.0	$0.0	$0.0	$0.0	$0.0
Final Rule – Existing Units	0.0	$0.0	$0.0	$0.0	$0.0
Proposal Option 2	-25.4	-$29.1	-$20.3	-$62.7	-$6.7

[a] To the extent that EPA used IPM results for Market Model Analysis 1 as a proxy for Proposal Option 4, benefits for Proposal Option 4 are likely to be over-stated.
Source: U.S. EPA analysis for this report

Table 9-6, Table 9-7, and Table 9-8 present the change in CO_2 emissions and associated undiscounted benefits for existing units for Electric Generators and Manufacturers by year for Proposal Option 4, the final rule, and Proposal Option 2, respectively.

Table 9-6: Social Cost of Carbon by Year for Electric Generators and Manufacturers – Proposal Option 4 ($2011, millions)

Year	Emissions (tCO2eq, millions)	Discount Rate for Calculating SCC Unit Values			
		2.5%	3.0%		5.0%
		Average SCC Value	Average SCC Value	High SCC Value	Average SCC Value
2013	0.0	$0.0	$0.0	$0.0	$0.0
2014	0.0	$0.0	$0.0	$0.0	$0.0
2015	0.2	$13.3	$8.6	$25.5	$2.6
2016	0.2	$13.8	$8.9	$26.2	$2.8
2017	0.2	$14.0	$9.1	$27.1	$2.8
2018	0.0	-$2.8	-$1.9	-$5.6	-$0.6
2019	0.0	-$2.9	-$1.9	-$5.7	-$0.6
2020	0.0	-$3.0	-$2.0	-$5.9	-$0.6
2021	0.0	-$3.0	-$2.0	-$6.1	-$0.6
2022	0.0	-$3.1	-$2.0	-$6.2	-$0.6
2023	0.9	$65.5	$44.0	$134.0	$12.7
2024	0.9	$66.5	$45.0	$137.0	$13.7
2025	0.9	$67.5	$46.0	$139.9	$13.7
2026	0.9	$68.5	$47.0	$142.8	$14.7
2027	0.9	$69.5	$47.9	$145.8	$14.7
2028	0.9	$70.4	$48.9	$148.7	$14.7
2029	0.9	$71.4	$49.9	$151.6	$15.7
2030	0.9	$73.4	$50.9	$155.5	$15.7
2031	0.9	$74.3	$50.9	$158.5	$16.6
2032	0.9	$75.3	$51.8	$161.4	$16.6
2033	0.0	$0.0	$0.0	$0.0	$0.0
2034	0.0	$0.0	$0.0	$0.0	$0.0
2035	0.0	$0.0	$0.0	$0.0	$0.0
2036	0.0	$0.0	$0.0	$0.0	$0.0
2037	0.0	$0.0	$0.0	$0.0	$0.0
2038	0.0	$0.0	$0.0	$0.0	$0.0
2039	0.0	$0.0	$0.0	$0.0	$0.0
2040	0.0	$0.0	$0.0	$0.0	$0.0
2041	0.0	$0.0	$0.0	$0.0	$0.0
2042	0.0	$0.0	$0.0	$0.0	$0.0
2043	0.0	$0.0	$0.0	$0.0	$0.0
2044	0.0	$0.0	$0.0	$0.0	$0.0
2045	0.0	$0.0	$0.0	$0.0	$0.0
2046	0.0	$0.0	$0.0	$0.0	$0.0
2047	0.0	$0.0	$0.0	$0.0	$0.0
2048	0.0	$0.0	$0.0	$0.0	$0.0
2049	0.0	$0.0	$0.0	$0.0	$0.0
2050	0.0	$0.0	$0.0	$0.0	$0.0
2051	0.0	$0.0	$0.0	$0.0	$0.0
2052	0.0	$0.0	$0.0	$0.0	$0.0
2053	0.0	$0.0	$0.0	$0.0	$0.0
2054	0.0	$0.0	$0.0	$0.0	$0.0
2055	0.0	$0.0	$0.0	$0.0	$0.0
2056	0.0	$0.0	$0.0	$0.0	$0.0
2057	0.0	$0.0	$0.0	$0.0	$0.0
2058	0.0	$0.0	$0.0	$0.0	$0.0
2059	0.0	$0.0	$0.0	$0.0	$0.0
2060	0.0	$0.0	$0.0	$0.0	$0.0
2061	0.0	$0.0	$0.0	$0.0	$0.0
2062	0.0	$0.0	$0.0	$0.0	$0.0
2063	0.0	$0.0	$0.0	$0.0	$0.0
2064	0.0	$0.0	$0.0	$0.0	$0.0
Present Value 3%	-	**$483.1**	**$330.3**	**$1,007.6**	**$101.7**
Annualized, 3%	-	**$18.1**	**$12.4**	**$37.7**	**$3.8**
Present Value 7%	-	**$290.4**	**$198.0**	**$603.0**	**$60.8**
Annualized 7%	-	**$19.6**	**$13.4**	**$40.7**	**$4.1**

Source: U.S. EPA analysis for this report

Table 9-7: Social Cost of Carbon by Year for Electric Generators and Manufacturers – Final Rule-Existing Units ($2011, millions)

Year	Emissions (tCO2eq, millions)	Discount Rate for Calculating SCC Unit Values			
		2.5%	3.0%		5.0%
		Average SCC Value	Average SCC Value	High SCC Value	Average SCC Value
2013	0.0	$0.0	$0.0	$0.0	$0.0
2014	0.0	$0.0	$0.0	$0.0	$0.0
2015	0.2	$13.3	$8.6	$25.5	$2.6
2016	0.2	$13.8	$8.9	$26.2	$2.8
2017	0.2	$14.0	$9.1	$27.1	$2.8
2018	0.0	-$2.8	-$1.9	-$5.6	-$0.6
2019	0.0	-$2.9	-$1.9	-$5.7	-$0.6
2020	0.0	-$3.0	-$2.0	-$5.9	-$0.6
2021	0.0	-$3.0	-$2.0	-$6.1	-$0.6
2022	0.0	-$3.1	-$2.0	-$6.2	-$0.6
2023	0.9	$65.5	$44.0	$134.0	$12.7
2024	0.9	$66.5	$45.0	$137.0	$13.7
2025	0.9	$67.5	$46.0	$139.9	$13.7
2026	0.9	$68.5	$47.0	$142.8	$14.7
2027	0.9	$69.5	$47.9	$145.8	$14.7
2028	0.9	$70.4	$48.9	$148.7	$14.7
2029	0.9	$71.4	$49.9	$151.6	$15.7
2030	0.9	$73.4	$50.9	$155.5	$15.7
2031	0.9	$74.3	$50.9	$158.5	$16.6
2032	0.9	$75.3	$51.8	$161.4	$16.6
2033	0.0	$0.0	$0.0	$0.0	$0.0
2034	0.0	$0.0	$0.0	$0.0	$0.0
2035	0.0	$0.0	$0.0	$0.0	$0.0
2036	0.0	$0.0	$0.0	$0.0	$0.0
2037	0.0	$0.0	$0.0	$0.0	$0.0
2038	0.0	$0.0	$0.0	$0.0	$0.0
2039	0.0	$0.0	$0.0	$0.0	$0.0
2040	0.0	$0.0	$0.0	$0.0	$0.0
2041	0.0	$0.0	$0.0	$0.0	$0.0
2042	0.0	$0.0	$0.0	$0.0	$0.0
2043	0.0	$0.0	$0.0	$0.0	$0.0
2044	0.0	$0.0	$0.0	$0.0	$0.0
2045	0.0	$0.0	$0.0	$0.0	$0.0
2046	0.0	$0.0	$0.0	$0.0	$0.0
2047	0.0	$0.0	$0.0	$0.0	$0.0
2048	0.0	$0.0	$0.0	$0.0	$0.0
2049	0.0	$0.0	$0.0	$0.0	$0.0
2050	0.0	$0.0	$0.0	$0.0	$0.0
2051	0.0	$0.0	$0.0	$0.0	$0.0
2052	0.0	$0.0	$0.0	$0.0	$0.0
2053	0.0	$0.0	$0.0	$0.0	$0.0
2054	0.0	$0.0	$0.0	$0.0	$0.0
2055	0.0	$0.0	$0.0	$0.0	$0.0
2056	0.0	$0.0	$0.0	$0.0	$0.0
2057	0.0	$0.0	$0.0	$0.0	$0.0
2058	0.0	$0.0	$0.0	$0.0	$0.0
2059	0.0	$0.0	$0.0	$0.0	$0.0
2060	0.0	$0.0	$0.0	$0.0	$0.0
2061	0.0	$0.0	$0.0	$0.0	$0.0
2062	0.0	$0.0	$0.0	$0.0	$0.0
2063	0.0	$0.0	$0.0	$0.0	$0.0
2064	0.0	$0.0	$0.0	$0.0	$0.0
Present Value 3%	-	**$483.1**	**$330.3**	**$1,007.6**	**$101.7**
Annualized, 3%	-	**$18.1**	**$12.4**	**$37.7**	**$3.8**
Present Value 7%	-	**$290.4**	**$198.0**	**$603.0**	**$60.8**
Annualized 7%	-	**$19.6**	**$13.4**	**$40.7**	**$4.1**

Source: U.S. EPA analysis for this report

Table 9-8: Social Cost of Carbon by Year for Electric Generators and Manufacturers – Proposal Option 2 ($2011, millions)

Year	Emissions (tCO2eq, millions)	Discount Rate for Calculating SCC Unit Values			
		2.5%	3.0%		5.0%
		Average SCC Value	Average SCC Value	High SCC Value	Average SCC Value
2013	0.0	$0.0	$0.0	$0.0	$0.0
2014	0.0	$0.0	$0.0	$0.0	$0.0
2015	0.0	$0.0	$0.0	$0.0	$0.0
2016	0.0	$0.0	$0.0	$0.0	$0.0
2017	0.0	$0.0	$0.0	$0.0	$0.0
2018	3.2	$210.3	$137.9	$413.7	$41.4
2019	3.2	$213.7	$144.8	$427.5	$41.4
2020	3.2	$220.6	$148.2	$441.3	$41.4
2021	-27.7	-$1,924.4	-$1,273.1	-$3,878.4	-$355.3
2022	-27.8	-$1,956.4	-$1,304.3	-$3,972.1	-$385.4
2023	-31.2	-$2,230.3	-$1,497.9	-$4,560.4	-$432.7
2024	-31.3	-$2,273.4	-$1,537.9	-$4,680.5	-$468.1
2025	-31.3	-$2,307.6	-$1,571.9	-$4,782.4	-$468.2
2026	-51.5	-$3,845.3	-$2,636.8	-$8,020.2	-$824.0
2027	-51.5	-$3,900.1	-$2,691.6	-$8,184.7	-$824.0
2028	-51.5	-$3,954.9	-$2,746.5	-$8,349.3	-$823.9
2029	-51.5	-$4,009.8	-$2,801.4	-$8,514.0	-$878.9
2030	-51.5	-$4,119.7	-$2,856.3	-$8,733.7	-$878.9
2031	-38.0	-$3,078.4	-$2,106.3	-$6,561.8	-$688.6
2032	-38.0	-$3,118.9	-$2,146.7	-$6,683.3	-$688.6
2033	-38.0	-$3,159.3	-$2,187.2	-$6,804.6	-$729.1
2034	-38.0	-$3,199.8	-$2,227.7	-$6,966.6	-$729.1
2035	-38.0	-$3,240.2	-$2,268.2	-$7,088.0	-$769.6
2036	-38.0	-$3,280.6	-$2,308.6	-$7,209.3	-$769.5
2037	-37.9	-$3,361.3	-$2,348.9	-$7,330.0	-$809.9
2038	-37.9	-$3,401.5	-$2,389.1	-$7,491.4	-$809.9
2039	-37.9	-$3,441.5	-$2,429.3	-$7,611.7	-$850.2
2040	-37.9	-$3,481.4	-$2,469.4	-$7,732.0	-$850.1
2041	-37.9	-$3,521.9	-$2,509.9	-$7,853.5	-$890.6
2042	-37.9	-$3,562.4	-$2,550.3	-$7,974.9	-$890.6
2043	-37.9	-$3,602.9	-$2,590.8	-$8,096.3	-$931.1
2044	-37.9	-$3,643.4	-$2,631.3	-$8,217.8	-$931.1
2045	-37.9	-$3,724.3	-$2,671.8	-$8,339.2	-$971.6
2046	-37.9	-$3,764.8	-$2,712.3	-$8,460.7	-$971.6
2047	-37.9	-$3,805.3	-$2,752.8	-$8,541.6	-$1,012.0
2048	-37.9	-$3,845.8	-$2,793.2	-$8,663.1	-$1,012.0
2049	-37.9	-$3,886.2	-$2,833.7	-$8,784.5	-$1,052.5
2050	-37.9	-$3,926.7	-$2,874.2	-$8,906.0	-$1,052.5
2051	-37.9	-$3,967.6	-$2,915.3	-$9,029.1	-$1,053.3
2052	-37.9	-$4,009.0	-$2,956.9	-$9,154.0	-$1,054.0
2053	-37.9	-$4,050.7	-$2,999.2	-$9,280.6	-$1,054.8
2054	-37.9	-$4,092.9	-$3,042.0	-$9,408.9	-$1,055.7
2055	-37.9	-$4,135.6	-$3,085.5	-$9,539.0	-$1,056.5
2056	-37.9	-$4,178.7	-$3,129.6	-$9,670.9	-$1,057.4
2057	-37.9	-$4,222.2	-$3,174.3	-$9,804.7	-$1,058.3
2058	-37.9	-$4,266.2	-$3,219.7	-$9,940.2	-$1,059.3
2059	-37.9	-$4,310.6	-$3,265.7	-$10,077.7	-$1,060.3
2060	0.0	$0.0	$0.0	$0.0	$0.0
2061	0.0	$0.0	$0.0	$0.0	$0.0
2062	0.0	$0.0	$0.0	$0.0	$0.0
2063	0.0	$0.0	$0.0	$0.0	$0.0
2064	0.0	$0.0	$0.0	$0.0	$0.0
Present Value 3%	-	**-$62,019.1**	**-$43,872.4**	**-$135,622.3**	**-$14,589.0**
Annualized, 3%	-	**-$2,320.2**	**-$1,641.3**	**-$5,073.8**	**-$545.8**
Present Value 7%	-	**-$25,804.9**	**-$18,030.6**	**-$55,597.3**	**-$5,855.4**
Annualized 7%	-	**-$1,743.5**	**-$1,218.2**	**-$3,756.4**	**-$395.6**

Source: U.S. EPA analysis for this report.

10 Summary of Monetized Benefits for Existing Units

10.1 Introduction

This chapter presents a summary of the monetized benefits for existing units under the final rule and options considered. Chapters 5 through 9 describe the methods and data EPA used to monetize benefits. Refer to Chapter 1 for a description of the requirements of the final rule and other options considered. The national benefits estimates presented in this chapter do not include benefits estimated using EPA's SP survey. Refer to Chapter 11 for detail on the SP survey and results.

10.2 Summary of Methods and Limitations

EPA based its estimates of national monetized benefits for IM&E reductions under the final rule and options considered on its regional estimates of monetized benefits by summing over the seven study regions. EPA estimated mean national use values, as well as values that include the 5th percentile lower bound and 95th percentile upper bound of the recreational benefits estimates.[58] EPA's estimates of changes in GHG emissions and associated benefits are at the national level. Monetizing the benefits resulting from IM&E reductions and GHG emissions reductions under the final rule and options considered is challenging. The preceding chapters discuss specific limitations and uncertainties associated with estimating reductions in IM&E and monetized benefits. The national benefits estimates presented in Section 10.3 are subject to the same uncertainties inherent in the valuation approaches EPA used for assessing regional benefits described in Chapter 5 through 9. The combined effect on estimated use values (threatened and endangered species, commercial fishing, and recreational fishing) is of unknown magnitude and direction (i.e., the estimates may over- or understate the anticipated national level of use benefits). Nevertheless, EPA has no data to indicate that the results for estimated use benefits are atypical or unreasonable. EPA was unable to estimate monetized nonuse benefits for IM&E in all regions using the benefit transfer approach described in Chapter 8. Therefore, the monetized benefits estimates presented in this section do not reflect total benefits associated with reducing IM&E at existing units at regulated facilities, and overall national benefits may accordingly be higher.

10.3 Summary of Baseline Losses and Monetized Benefits for the Final Rule and Options Considered for Existing Units

Table 10-1 shows that the total annual national value of IM&E losses due to CWIS at existing units of regulated facilities. Neither the final rule nor other options considered would eliminate all baseline IM&E losses. EPA presents the baseline values for illustration purposes. EPA did not estimate baseline impacts related to GHG emissions or associated values.

- Discounted at 3 percent, the total value of baseline IM&E losses is $187.1 million per year including $78.8 million in recreational fishing losses, $8.0 million in commercial fishing losses, $1.2 million in T&E species losses, and $99.1 million in forgone nonuse benefits. The total value

58 The lower estimates of value presented in this chapter are measured by the sum of the 5th percentile lower bound estimates of recreational values plus the mean value estimates for all other categories of value. The higher estimates of value presented in this chapter are measured by the sum of the 95th percentile upper bound estimates of recreational values plus the mean value estimates for all other categories of value.

of these fishery losses ranges from \$151.5 million and \$256.2 million based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, respectively.

- Discounted at 7 percent, the total value of baseline IM&E losses is \$177.3 million per year including \$72.0 million in recreational fishing losses, \$7.2 million in commercial fishing losses, \$1.1 million in T&E species losses, and \$96.9 million in forgone nonuse benefits. The total value of these fishery losses ranges from \$144.7 million and \$240.6 million based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, respectively.

More detailed discussions of the valuation of impacts under the baseline conditions in each region are provided in Chapters 5 through 8.

Table 10-2, Table 10-3, and Table 10-4 present EPA's estimates of benefits of reducing IM&E under the final rule and each of the regulatory options EPA considered for existing units (2011\$, discounted at 3 percent and 7 percent). Table 10-5 provides a summary of benefits including the avoided SCC. Monetized benefits of reductions in IM&E and reduction in GHG emissions based on 3 percent average SCC values, evaluated at a 3 percent discount rate, are as follows:

- Proposal Option 4 results in benefits of \$31.0 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling \$22.8 million and \$47.6 million.
- The final rule results in benefits of \$33.0 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling \$24.1 million and \$50.6 million.
- Proposal Option 2 results in benefits of -\$1,542.6 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling -\$1,562.2million and -\$1,504.5 million.

Evaluated at a 7 percent discount rate, the monetized benefits of the regulatory analysis options are somewhat smaller for Proposal Option 4 and the final rule, and greater for Proposal Option 2:

- Proposal Option 4 results in benefits of \$27.2 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling \$21.1 million and \$39.5 million.
- The final rule results in benefits of \$28.7 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling \$22.2 million and \$41.8 million.
- Proposal Option 2 results in benefits of -\$1,148.2 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling -\$1,161.7 million and -\$1,122.0 million.

More detailed discussions of benefits under each option are provided in Chapters 5 through 9.

Table 10-1: Summary of Annualized Benefits from the Elimination of Baseline IM&E at Existing Units of Regulated Facilities (2011$, millions)[a]

Region	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits[b]		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
California	$2.4	$4.0	$6.8	$1.7	-	-	$4.1	$5.7	$8.5
North Atlantic	$1.7	$2.7	$4.4	$0.4	-	$20.2	$22.3	$23.3	$25.0
Mid-Atlantic	$9.7	$16.2	$28.3	$2.2	-	$78.9	$90.7	$97.3	$109.4
South Atlantic	$0.2	$0.3	$0.4	$0.0	-	-	$0.2	$0.3	$0.4
Gulf of Mexico	$6.5	$9.6	$14.8	$3.4	-	-	$9.9	$13.0	$18.2
Great Lakes	$7.3	$13.8	$26.3	$0.2	-	-	$7.5	$14.1	$26.6
Inland	$15.5	$32.1	$66.9	-	$1.2	-	$16.7	$33.3	$68.1
Total	**$43.2**	**$78.8**	**$147.9**	**$8.0**	**$1.2**	**$99.1**	**$151.5**	**$187.1**	**$256.2**
7% Discount Rate									
California	$2.2	$3.6	$6.1	$1.5	-	-	$3.7	$5.1	$7.6
North Atlantic	$1.5	$2.4	$3.9	$0.4	-	$19.8	$21.6	$22.6	$24.0
Mid-Atlantic	$8.6	$14.5	$25.3	$1.9	-	$77.2	$87.8	$93.6	$104.5
South Atlantic	$0.2	$0.3	$0.3	$0.0	-	-	$0.2	$0.3	$0.4
Gulf of Mexico	$6.0	$8.8	$13.6	$3.2	-	-	$9.1	$12.0	$16.8
Great Lakes	$6.7	$12.8	$24.3	$0.2	-	-	$7.0	$13.0	$24.5
Inland	$14.3	$29.6	$61.7	-	$1.1	-	$15.4	$30.7	$62.8
Total	**$39.5**	**$72.0**	**$135.3**	**$7.2**	**$1.1**	**$96.9**	**$144.7**	**$177.3**	**$240.6**

"-" = not estimated

[a] All benefits presented in this table are annualized, i.e., represent the sum of the discounted stream of benefits annualized over 51 years (2014 to 2064). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region-and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.

[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] Zeros represent values less than 1,000.

Source: U.S. EPA analysis for this report.

Table 10-2: Summary of Annualized Benefits Associated with IM&E Reductions under Proposal Option 4 (2011$, millions)[a]

Region	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits[b]		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
California	$0.0	$0.1	$0.1	$0.0	-	-	$0.0	$0.1	$0.1
North Atlantic	$0.0	$0.0	$0.0	$0.0	-	$0.1	$0.1	$0.1	$0.1
Mid-Atlantic	$0.5	$1.0	$2.0	$0.2	-	$0.2	$1.0	$1.5	$2.5
South Atlantic	$0.0	$0.0	$0.0	$0.0	-	-	$0.0	$0.0	$0.0
Gulf of Mexico	$1.3	$2.2	$3.9	$0.5	-	-	$1.8	$2.7	$4.4
Great Lakes	$3.4	$6.5	$12.4	$0.1	-	-	$3.6	$6.6	$12.5
Inland	$3.5	$7.3	$15.2	-	$0.4	-	$3.9	$7.7	$15.6
Total	**$8.8**	**$17.1**	**$33.6**	**$0.9**	**$0.4**	**$0.3**	**$10.4**	**$18.7**	**$35.2**
7% Discount Rate									
California	$0.0	$0.1	$0.1	$0.0	-	-	$0.0	$0.1	$0.1
North Atlantic	$0.0	$0.0	$0.0	$0.0	-	$0.1	$0.1	$0.1	$0.1
Mid-Atlantic	$0.4	$0.7	$1.4	$0.2	-	$0.2	$0.8	$1.1	$1.8
South Atlantic	$0.0	$0.0	$0.0	$0.0	-	-	$0.0	$0.0	$0.0
Gulf of Mexico	$0.9	$1.6	$2.8	$0.4	-	-	$1.3	$1.9	$3.2
Great Lakes	$2.6	$4.8	$9.2	$0.1	-	-	$2.7	$4.9	$9.3
Inland	$2.6	$5.4	$11.4	-	$0.3	-	$2.9	$5.7	$11.7
Total	**$6.5**	**$12.6**	**$24.9**	**$0.7**	**$0.3**	**$0.3**	**$7.7**	**$13.8**	**$26.1**

"-" = not estimated

[a] All benefits presented in this table are annualized, i.e., represent the sum of the discounted stream of benefits annualized over 51 years (2014 to 2064). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region-and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.

[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] Zeros represent values less than 1,000.

Source: U.S. EPA analysis for this report.

Table 10-3: Summary of Annualized Benefits Associated with IM&E Reductions under the Final Rule for Existing Units (2011$, millions)[a]

Region	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits[b]		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
California	$0.0	$0.1	$0.1	$0.0	-	-	$0.0	$0.1	$0.1
North Atlantic	$0.0	$0.0	$0.0	$0.0	-	$0.2	$0.2	$0.2	$0.2
Mid-Atlantic	$0.6	$1.1	$2.1	$0.3	-	$0.8	$1.6	$2.1	$3.2
South Atlantic	$0.0	$0.0	$0.0	$0.0	-	-	$0.0	$0.0	$0.1
Gulf of Mexico	$1.3	$2.3	$4.1	$0.5	-	-	$1.8	$2.8	$4.6
Great Lakes	$3.8	$7.2	$13.6	$0.1	-	-	$3.9	$7.3	$13.8
Inland	$3.7	$7.6	$15.9	-	$0.4	-	$4.1	$8.0	$16.3
Total	**$9.4**	**$18.2**	**$35.9**	**$0.9**	**$0.4**	**$1.0**	**$11.8**	**$20.6**	**$38.3**
7% Discount Rate									
California	$0.0	$0.1	$0.1	$0.0	-	-	$0.0	$0.1	$0.1
North Atlantic	$0.0	$0.0	$0.0	$0.0	-	$0.2	$0.2	$0.2	$0.2
Mid-Atlantic	$0.4	$0.8	$1.5	$0.2	-	$0.7	$1.2	$1.6	$2.3
South Atlantic	$0.0	$0.0	$0.0	$0.0	-	-	$0.0	$0.0	$0.0
Gulf of Mexico	$0.9	$1.6	$2.9	$0.4	-	-	$1.3	$2.0	$3.3
Great Lakes	$2.8	$5.3	$10.1	$0.1	-	-	$2.9	$5.4	$10.2
Inland	$2.7	$5.7	$11.9	-	$0.3	-	$3.1	$6.0	$12.2
Total	**$7.0**	**$13.5**	**$26.6**	**$0.7**	**$0.3**	**$0.8**	**$8.8**	**$15.3**	**$28.4**

"-" = not estimated

[a] All benefits presented in this table are annualized, i.e., represent the sum of the discounted stream of benefits annualized over 51 years (2014 to 2064). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region-and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.

[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] Zeros represent values less than 1,000.

Source: U.S. EPA analysis for this report.

Table 10-4: Summary of Annualized Benefits Associated with IM&E Reductions under Proposal Option 2 (2011$, millions)[a]

Region	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	Total Benefits[b]		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
California	$0.9	$1.5	$2.6	$0.7	-	-	$1.6	$2.2	$3.2
North Atlantic	$0.9	$1.4	$2.2	$0.2	-	$10.4	$11.5	$12.0	$12.9
Mid-Atlantic	$5.1	$8.6	$15.1	$1.2	-	$40.7	$47.0	$50.5	$57.0
South Atlantic	$0.1	$0.2	$0.2	$0.0	-	-	$0.1	$0.2	$0.2
Gulf of Mexico	$3.4	$5.1	$8.1	$1.7	-	-	$5.1	$6.8	$9.8
Great Lakes	$4.7	$8.9	$17.0	$0.2	-	-	$4.9	$9.1	$17.2
Inland	$8.3	$17.2	$35.9	-	$0.7	-	$9.0	$17.9	$36.5
Total	**$23.4**	**$43.0**	**$81.1**	**$3.9**	**$0.7**	**$51.1**	**$79.1**	**$98.7**	**$136.8**
7% Discount Rate									
California	$0.6	$1.0	$1.7	$0.4	-	-	$1.0	$1.4	$2.1
North Atlantic	$0.6	$0.9	$1.5	$0.1	-	$7.6	$8.3	$8.7	$9.2
Mid-Atlantic	$3.3	$5.5	$9.6	$0.8	-	$29.7	$33.7	$36.0	$40.1
South Atlantic	$0.1	$0.1	$0.2	$0.0	-	-	$0.1	$0.1	$0.2
Gulf of Mexico	$2.5	$3.8	$6.0	$1.3	-	-	$3.7	$5.0	$7.2
Great Lakes	$3.4	$6.4	$12.1	$0.1	-	-	$3.5	$6.5	$12.2
Inland	$5.7	$11.9	$24.8	-	$0.5	-	$6.2	$12.3	$25.2
Total	**$16.1**	**$29.5**	**$55.8**	**$2.7**	**$0.5**	**$37.3**	**$56.6**	**$70.0**	**$96.3**

"-" = not estimated

[a] All benefits presented in this table are annualized, i.e., represent the sum of the discounted stream of benefits annualized over 51 years (2014 to 2064). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region-and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.

[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] Zeros represent values less than 1,000.

Source: U.S. EPA analysis for this report.

Table 10-5: Summary of Annualized Benefits by Regulatory Option for Existing Units (2011$, millions)[a]

Regulatory Option	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	SCC[e]	Total Benefits		
	Low	Mean	High					Low	Mean	High
3% Discount Rate										
Proposal Option 4	$8.8	$17.1	$33.6	$0.9	$0.4	$0.3	$12.4	$22.8	$31.0	$47.6
Final Rule	$9.4	$18.2	$35.9	$0.9	$0.4	$1.0	$12.4	$24.1	$33.0	$50.6
Proposal Option 2	$23.4	$43.0	$81.1	$3.9	$0.7	$51.1	-$1,641.3	-$1,562.2	-$1,542.6	-$1,504.5
7% Discount Rate										
Proposal Option 4	$6.5	$12.6	$24.9	$0.7	$0.3	$0.3	$13.4	$21.1	$27.2	$39.5
Final Rule	$7.0	$13.5	$26.6	$0.7	$0.3	$0.8	$13.4	$22.2	$28.7	$41.8
Proposal Option 2	$16.1	$29.5	$55.8	$2.7	$0.5	$37.3	-$1,218.2	-$1,161.7	-$1,148.2	-$1,122.0

[a] All benefits presented in this table are annualized, i.e., represent the sum of the discounted stream of benefits annualized over 51 years (2014 to 2064). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region- and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.

[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon).
See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] SCC results presented here are based on 3 percent average SCC values.

Source: U.S. EPA analysis for this report

11 Stated Preference Survey

11.1 Introduction

EPA developed a stated preference survey to estimate total values (use plus nonuse) for improvements to fishery resources and ecosystems affected by IM&E from regulated facilities.[59] Understanding total public WTP for resulting changes in fishery resources, including the more difficult to estimate nonuse values, is necessary to determine the full range of benefits associated with reductions in IM&E, and simplifies the determination of whether the benefits of government action to reduce IM&E at existing facilities are commensurate with the costs of such actions. Because potential nonuse values may be substantial, failure to recognize such values may lead to improper inferences regarding benefits and costs, and an inefficient allocation of society's resources. As discussed in Chapter 8, EPA was able to generate only a partial estimate of nonuse benefits using benefit transfer with existing SP data. Moreover, estimates from high quality primary valuation studies are generally considered superior to those from benefit transfer (Johnston & Rosenberger 2010) because primary studies are designed for the specific context of the policy case, whereas transferring results from other studies may require assumptions to facilitate transfer that may not be completely accurate. EPA developed and implemented the SP survey to fill this gap by providing data which could be used to estimate total benefits for all U.S. regions.

EPA plans to obtain SAB review of the SP survey EPA conducted. The SAB review would be in addition to the external peer review EPA already conducted on the survey. SAB review will provide high caliber, independent professional judgment concerning the quality of the survey done to date, including possible improvements EPA could make to the analysis. EPA also plans to seek SAB input on whether, how and in what circumstances this or similar surveys could be used as support for national rulemakings or 316(b) NPDES permitting. EPA expects that while this process will add time (it may take a year or more), given the importance of this issue for the evaluation of ecological benefits generally, it is worth taking the time to seek this additional input. Given the planned SAB review, using the SP survey results prior to completion of the review would be premature. EPA is committed to working with the states to support their site-specific permitting decisions with the benefit of the SAB review once it is completed.

EPA has not accounted for values estimated from the survey in the comparison of monetized costs and benefits. This chapter describes the design of the SP survey and presents current, but not necessarily final, model estimation results. EPA also describes a method for monetizing benefits for the final rule and presents a preliminary estimate of benefits for the final rule and options considered to illustrate the potential magnitude of regulatory benefits and demonstrate progress towards this effort. Discussion of peer reviewer comments related to their confidence in the study results and limitations for policy analysis is presented in Section 11.10.

[59] As discussed in Chapter 8, nonuse values are values people may hold for an environmental improvement that are not associated with use (e.g., recreation) of the resource.

11.2 Survey Design

SP surveys, in general, ask questions that elicit individuals' stated values for carefully specified changes in an environmental amenity. This value is typically estimated in terms of WTP, defined as the maximum amount of money (or some other commodity) that an individual or household would be willing to give up in exchange for a specified environmental change, rather than go without that change. EPA designed the SP survey as a choice experiment. Choice experiments, also called choice models, are an SP technique in which individuals' values are estimated based on their choices over a set of hypothetical but realistic multi-attribute policy options designed to mimic the consumer decision-making that occurs in actual markets, and span the range of possible policy options.[60] Choice experiments have been applied in many past studies to assess WTP for ecological resource improvements, which is also the context of the main improvement in the 316(b) policy case (e.g., Bennett and Blamey 2001; Hanley et al. 2006; Hoehn et al. 2004; Johnston et al. 2002a; Johnston et al. 2011b; Johnston et al. 2012; Milon and Scrogin 2006; Morrison et al. 2002; Morrison and Bennett 2004; Opaluch et al. 1999).

Advantages of these choice-based methods include similarity to familiar referenda or market choice contexts, in which individuals choose among alternative bundles of attributes or commodities (for example, attributes of consumer electronics) at different costs (Freeman 2003). Among other advantages, such methods are intended to reduce strategic and other survey biases that can be associated with alternative ways of using survey questions to elicit values, versus assessing WTP through market transactions or referenda. For example, some types of SP surveys ask respondents to express their WTP using open-ended questions, payment cards, or bidding games. Increasingly, however, these types of SP surveys have been replaced in the literature by choice-based methods.[61]

Choice experiments also allow survey respondents to express WTP for a wide range of different potential outcomes, differentiated by their attributes. This enables EPA to isolate the marginal effects of different potential policy outcomes on stated choices and hence, on estimated WTP. EPA can thereby estimate benefits for a wider range of potential policy outcomes than would be possible with alternative SP methods. This is a primary factor distinguishing choice experiments from older forms of SP analysis, in which stated WTP is typically contingent upon a single specification of ecological and other policy effects.

11.2.1 Survey Format

EPA followed established choice experiment methodology in the developing the format of the 316(b) SP survey (Adamowicz et al. 1998; Bateman et al. 2002; Bennett and Blamey 2001; Louviere et al. 2000). Respondents are presented with two alternative hypothetical policy options

[60] In addition to choice experiments, stated preference techniques include as contingent valuation (CV). CV surveys typically ask respondents, "What are you willing to pay?" for a particular environmental improvement, or in a dichotomous choice form as "are you willing to pay $X?" for a particular environmental improvement. In general, CV surveys focus on a comparison between the status quo and a particular environmental improvement (akin to a one-time offer). This is different from the consumer decision-making that occurs in actual markets and involves comparing status quo to multiple environmental outcomes. Therefore, EPA relied on the choice experiment technique that mimics common market situations in its study design.

[61] Choice-based methods are also increasingly employed in the marketing research literature to analyze consumer preferences. In particular, choice based experiments are a popular in modeling brand choice (Erdem and Keane 1996) and demand for new products (Brownstone and Train 1996).

described by multiple attributes. They are asked to choose (or vote for) the policy they prefer, much as one would choose a preferred option in a public referendum. Respondents may also choose to reject both policies and retain the status quo. The underpinning theoretical model is adapted from a standard random utility specification in which household *h* chooses among three choice options ($j=A,B,N$), including two multi-attribute policy options (*A, B*) and a fixed “No Policy” (the status quo) (*N*) that includes no policy changes and zero cost to the household. Each choice option reflects a hypothetical but feasible outcome under various 316(b) regulatory alternatives.

The effects of the policy options are described in terms of a household cost and four environmental endpoints, or attributes: (a) commercial fish populations, (b) fish populations (all fish), (c) fish saved per year, and (d) condition of aquatic ecosystems. The definition of each attribute is presented in Table 11-1. Ecological attributes are expressed relative to upper and lower reference conditions; i.e., best and worst possible conditions of the attribute, as defined in survey informational materials. Respondents were asked to evaluate changes in fish saved per year as a percentage of current estimated mortality, but those changes were also illustrated in terms of numbers of A1E fish.[62] Relative scores represent percent progress towards the upper reference condition (100 percent), starting from the lower reference condition (0 percent), both keyed to readily understood conditions. Presentation of all ecological attributes was informed by input from focus groups and cognitive interviews (Johnston et al. 1995; Kaplowitz et al. 2004) used to pretest the survey instrument.

Values for “fish saved” in the referendum questions are based on EPA’s estimate of A1E losses due to CWIS at baseline. Refer to Chapter 3 for additional description of the A1E metric. Introductory materials in the survey describe the age classes impacted due to cooling water intakes and the “fish saved” metric as “young adult fish (the equivalent of one year old).” Pre-testing during focus groups and cognitive interviews suggested that participants understood the “fish saved” attribute and the concept of “young fish” as reflecting initial IM&E of eggs and other juvenile life stages expressed as in terms of the A1E metric. Page three of the survey booklet includes introductory materials that specify the proportion of “fish saved” that are and are not commercial or recreational species.

Values are reflected in the survey by individuals’ willingness to “vote” for policies that would result in an increase in their cost of living, in exchange for specified changes in the four environmental attributes. Other questions in the survey elicit information including whether the respondent is a user of the affected aquatic resources, household income, and other respondent demographics.[63]

[62] A1E, in addition to providing a way to standardize organisms lost to IM&E so that it could be compared among species, years, facilities, and regions, is a convenient way to express losses of all life stages, including fish eggs and larvae, as numbers of individual age-one equivalent fish.

[63] The four environmental attributes were designed based on the Johnston et al. (2011a; 2011b; 2012) Bioindicator-Based Stated Preference Valuation (BSPV) method which was developed to promote ecological clarity and closer integration of ecological and economic information within SP studies. This methodology was developed in part to address the EPA Science Advisory Board’s call, in its May 2009 report, *Valuing the Protection of Ecological Systems and Services: A Report of the EPA Science Advisory Board* (USEPA 2009b), for improved quantitative linkages between ecological services and economic valuation of those services.

Table 11-1: Definitions of Policy Attributes and Baseline (No Policy) Values	
Attribute	**Definition**
Commercial Fish Populations	A score between 0 and 100 percent showing the overall health of commercial and recreational fishing populations. High scores mean more fish and greater fishing potential. A score of 100 means that these fish populations are at a size that maximizes long-term harvest: 0 means no harvest.
Fish Populations (All Fish)	A score between 0 and 100 percent showing the estimated size of all fish populations compared to natural levels without human influence. A score of 100 means that populations are the largest natural size possible; 0 means no fish.
Fish Saved (per Year)	A score between 0 and 100 percent showing the reduction in young fish lost compared to current levels. A score of 100 would mean that no fish are lost in cooling water intakes (all fish would be saved because of the new policy).
Condition of Aquatic Ecosystems	A score between 0 and 100 percent showing the ecological condition of affected areas, compared to the most natural waters in the region. The score is determined by many factors including water quality and temperature, the health of aquatic species, and habitat conditions.
Cost per Year	How much the policy will cost your household, in unavoidable ongoing price increases for products and services you buy, including electricity and common household products.
Source: U.S. EPA analysis for this report	

11.2.2 Experimental Design

The experimental design is the plan for varying attribute levels across questions within a survey and across survey versions, so that aggregated responses will provide enough data for efficient estimation of model parameters and WTP. Respondents were presented with three separate policy questions in the survey, each with a specific combination of policy options. The experimental design specifies how these attribute levels were "mixed and matched" within choice questions, thereby developing an empirical data framework with appropriate statistical properties to allow for analysis of respondent's choices (Louviere et al. 2000). It generates multiple unique combinations of policy options for different respondents to compare.

Table 11-2 presents the set of attribute levels that are used across the option pairs. Following guidance from the literature, EPA designed the attribute levels to illustrate realistic policy scenarios that "span the range over which we expect respondents to have preferences, and/or are practically achievable" (Bateman et al. 2002, p. 259; USEPA 2012a; USEPA 2012b).

In interpreting the results, it is useful to keep in mind that three of the attributes spanned a relatively narrow range of percentage values reflecting realistic ecological expectations (e.g., commercial fish populations differing by no more than six percentage points from the baseline), while the "fish saved per year" attribute, which was ultimately used to estimate household WTP for the policy options, spanned a much larger range (i.e., up to 95 percentage points). This reflects the expected range of potential reductions based on the performance of the technologies consider for the regulatory options. Given this realistic distinction in attribute spread, EPA expects that the WTP per percentage point will be lower for fish saved than for other attributes because respondents "see" most of the possible ranges of fish saved. Allowing the range of variables to vary according to realistic ecological and technological expectations is recommended practice in SP design (Bateman et al. 2002).

EPA applied a fractional factorial experimental design representing a subset of all possible combinations of environmental attributes and household cost. This allows efficient estimation of particular effects of interest with a relatively small number of choice questions (Louviere et al.

2000), thereby reducing the cognitive burden faced by respondents (i.e., by reducing the number of questions that each respondent must answer; Holmes and Adamowicz 2003). EPA generated the design using a D-efficiency criterion for main effects estimation (Kuhfeld and Tobias 2005; Kuhfeld 2010). This design enables model coefficients, and hence, estimated WTP, to be estimated with greater precision, i.e., lower standard errors or variability, for any given number of observations. It also minimizes correlation between attributes across survey questions (i.e., attributes do not "move together" across different survey questions), so that the unique effect of each attribute on respondents' choices, and ultimately, values, can be isolated.[64]

The experimental design for the 316(b) survey is characterized by 72 unique Option A vs. Option B pairs, each corresponding to a choice question defined by an orthogonal (independent) array of attribute levels for the two policy options. It is standard practice to include more than one choice question in each survey, thus increasing the information obtained from each respondent (Layton 2000; Poe et al. 1997). EPA randomly assigned the 72 option pairs to 24 distinct versions for each of the four regional surveys and the national survey, with three option pairs (i.e., choice questions) per survey booklet. See the ICR supporting statement (USEPA 2011C) for additional detail on the experimental design.

[64] EPA removed dominated pairs where one option is superior to the other in all attributes. Allowing such pairs would effectively limit respondents to selecting between the dominant choice option and the No Policy option. Focus groups showed that respondents react negatively and often protest when offered dominated pairs. Given that such choices provide negligible statistical information compared to choices involving non-dominated pairs, they are typically avoided in choice experiment statistical designs.

Table 11-2: Attribute Levels Assigned Across Policy Options and Survey Versions

Attribute	Baseline (No Policy)[a]	Max Change Assigned	Attribute Levels Assigned to Option A vs. Option B Pairs					
			1	2	3	4	5	6
Commercial Fish Populations (Score showing the overall health of commercial and recreational fish populations)								
Northeast	42%	6%	43%	45%	48%	-	-	-
Southeast	39%	6%	40%	42%	45%	-	-	-
Pacific	56%	6%	57%	59%	62%	-	-	-
Inland	39%	6%	40%	42%	45%	-	-	-
National	51%	6%	52%	54%	57%	-	-	-
Fish Populations (all fish) (Score showing the estimated size of all fish populations compared to natural levels without human influence)								
Northeast	26%	4%	27%	28%	30%	-	-	-
Southeast	24%	4%	25%	26%	28%	-	-	-
Pacific	32%	4%	33%	34%	36%	-	-	-
Inland	33%	4%	34%	35%	37%	-	-	-
National	30%	4%	31%	32%	34%	-	-	-
Fish Saved per Year (Score showing the reduction in young fish lost compared to current levels)								
Northeast	0%	95%	5%	50%	95%	-	-	-
Southeast	0%	90%	25%	55%	90%	-	-	-
Pacific	0%	95%	2%	50%	95%	-	-	-
Inland	0%	95%	55%	75%	95%	-	-	-
National	0%	95%	25%	55%	95%	-	-	-
Aquatic Ecosystem Condition (Score showing the ecological condition of affected areas, compared to the most natural waters in the region)								
Northeast	50%	4%	51%	52%	54%	-	-	-
Southeast	68%	4%	69%	70%	72%	-	-	-
Pacific	51%	4%	52%	53%	55%	-	-	-
Inland	42%	4%	43%	44%	46%	-	-	-
National	53%	4%	54%	55%	57%	-	-	-
Household Costs (The increase in annual household cost, in unavoidable price increases)								
Northeast	$0	$72	$12	$24	$36	$48	$60	$72
Southeast	$0	$72	$12	$24	$36	$48	$60	$72
Pacific	$0	$72	$12	$24	$36	$48	$60	$72
Inland	$0	$72	$12	$24	$36	$48	$60	$72
National	$0	$72	$12	$24	$36	$48	$60	$72

[a] Each question includes a "no policy" option, characterized by the baseline levels for each attribute and a household cost of $0.

Source: U.S. EPA analysis for this report

11.2.3 Pre-Tests

Following recommended methods for SP survey design, EPA used focus groups and cognitive interviews to test wording and attribute selection and ensure that respondents understand and are not cognitively burdened by the question format (cf. Arrow et al. 1993; Bateman et al. 2002; Bennett and Blamey 2001; Kaplowitz et al. 2004; Powe 2007). The survey instrument was pre-tested extensively in six focus groups, with eight to ten participants each, and a set of eight one-on-one cognitive interviews (USEPA 2010d). Each cognitive interview included only one participant. This allowed in-depth exploration of the cognitive processes respondents used to answer survey questions, without the potential for interpersonal dynamics to sway respondents' comments (Kaplowitz et al. 2004). These focus groups and cognitive interviews were in addition to ten focus groups and two series of cognitive interviews that were conducted previously by EPA in 2004 and 2005 to test an earlier version of the survey developed in anticipation of the Phase III benefits analysis. Focus groups and cognitive interviews also included questions following the verbal protocol format suggested by Schkade and Payne (1994), in which respondents were asked to talk through the process used to answer choice questions. Within focus group and cognitive interviews, the moderator first asked the participants to complete a draft survey questionnaire. The moderator then led a general conversation which led the group/individual through a series of debriefing questions. During debriefing, the moderator asked focus group and cognitive interview participants about their reactions to the survey format and content, their interpretations of survey materials (including questions and the information provided), whether the survey questions were clear, whether the background information presented in the survey or introductory materials was sufficient, whether respondents felt like the questions were leading, what went through participants' minds when they read survey information and questions, and response motivations. Debriefing questions also explored whether responses were influenced by hypothetical, strategic, symbolic and other biases noted in the stated preference literature.

The participants' comments and feedback provided important information on such concerns as whether (1) questions and survey information were readily understood, (2) respondents were interpreting questions similarly to how EPA interprets them, (3) responses or survey interpretations showed any evidence of heuristics or survey biases, including hypothetical bias, (4) respondents were addressing choice questions in a manner commensurate with utility maximization and neoclassical WTP estimation, and (5) respondents were following instructions provided in the survey instrument and responding to questions accordingly. Focus group participants' responses to the survey choice questions could not be included in model estimation because the draft surveys completed during pre-testing represent evolving versions and differed somewhat from the final survey. EPA modified the survey several times based on the results of these pre-tests to help minimize potential biases and ensure shared and accurate interpretation of survey language by the respondents. The amount of pre-testing conducted for SP surveys varies within the literature and tends to be related to the complexity of the survey instrument. However, the amount of time and number of focus groups the Agency used is significantly greater than many academic studies and matches the practice in developing SP surveys for natural resource damage assessments.

11.3 Sampling Frame

The sampling frame is the population from which the potential respondents are selected, in this case, at random. EPA designed the 316(b) SP study as a household mail survey, because the household is the fundamental economic decision-making unit for WTP studies. The mail survey approach avoids potential sampling biases in telephone surveys associated with the incomplete coverage of landline and cellphone databases. The mail address sample of households in the continental U.S. was from drawn from a database which covers 97 percent of residences in the United States including city-style addresses and PO boxes, and covers single-unit, multi-unit, and other types of housing structures.

EPA stratified households based on the geographic boundaries of four regions: Northeast, Southeast, Inland, and Pacific. The SP regions are based on state boundaries and include both coastal and freshwater facilities in the Northeast, Southeast, and Pacific regions. These regions differ from the 316(b) benefits regions used elsewhere in this Benefits Analysis which separate coastal and freshwater resources. During survey pretesting, EPA found that respondents more easily understood regional boundaries based on states than boundaries that distinguished between coastal and freshwater facilities.

Table 11-3 presents the States included in each SP region, the total number of households in each region, the target number of completed surveys, and the number of surveyed households for each survey region. EPA developed target sample sizes for each region to provide statistically robust results while minimizing the cost and burden of the survey to individual respondents.[65] The target sample sizes refer to *completed* mail surveys. A larger number of households must be mailed surveys because only a portion of households that receive a survey complete and return it.

EPA selected a total target sample of 2,000 completed surveys across all four regional surveys to provide estimates of population percentages with a margin of error ranging from 3.6 to 5.8 percentage points at the 95 percent confidence level.[66] These 2,000 surveys were allocated across the four regions based on the number of households in each region relative to the total number of household in the continental United States. In addition, a minimum number of completed surveys were required for each region to enable model estimation. Monte Carlo experiments indicate that approximately 6 to 12 completed responses are required for each profile (unique set of choice options) in order to achieve large sample statistical properties for choice experiments (Louviere et al. 2000, p. 104, citing Bunch and Batsell 1989). As described previously, the experimental design includes 72 option profiles. Following this guidance, the experiment design requires 12 completed surveys for each of the 72 profiles, for a total of 864 profile responses per region (72×12=864). A minimum of 288 completed surveys were hence required for each region because each survey version includes three profiles (864÷3=288).

The allocation of the 2,000 completed surveys across the four regions resulted in target sample sizes of 417 for the Northeast region, 562 for the Southeast region, 289 for the Pacific region, and 732 for the Inland region. EPA also conducted a national mail survey with a target sample size of 288 completed surveys. EPA mailed the survey to 7,840 households in total, anticipating a response rate of 30 percent. EPA assumed that it would take respondents an average of 30 minutes to complete and mail back the questionnaire.

65 EPA included three choice questions within each survey, to increase information obtained from each respondent. It is standard practice within choice experiment and dichotomous choice contingent valuation surveys to include more than one choice question in each survey (Layton 2000; Poe et al. 1997). Including more than three choice questions may have negatively affected the response rate by increasing burden on respondents and including fewer would have increased survey costs by requiring additional households to be sampled.

66 Margin of error was calculated assuming that the population percentage selecting a specific answer (e.g., “yes”) in a binary question is 50 percent (i.e., worst case scenario). This is the worst case scenario because it indicates that there is disagreement among people regarding the correct response (i.e., 50 percent select “yes” and 50 percent select “no”) and the standard error of the proportion is large (Orme 2010). The range of the margin of error (3.6 to 5.8 percent) is based on the sample sizes for each region. For example, the sample percentage selecting a specific response to a binary question based on a sample of 732 households has a margin of error of plus or minus 3.6 percent at a 95 percent confidence level whereas the sample percentage selecting a specific response based on a sample of 288 households will have a margin of error of plus or minus 5.8 percent.

Table 11-3: Target Sample Sizes and Number of Mailed Surveys by Survey Region

Survey Region	State Included	Number of Households[a]	Target Sample Size[b,c]	Number of Surveyed Households[d]
Northeast	CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT	23,281,296	417	1,440
Southeast	AL, FL, GA, LA, MS, NC, SC, TX, VA	31,378,122	562	1,920
Pacific	CA, OR, WA	40,852,983	289	1,040
Inland	AR, AZ, CO, ID, IA, IL, IN, KS, KY, MI, MN, MO, MT, ND, NE, NM,NV, OH,OK,SD,TN, UT, WI, WV, WY	16,158,206	732	2,480
Total for Regional Surveys	U.S. (excluding AK and HI)	111,670,607	2,000	6,880
National Survey	U.S. (excluding AK and HI)	111,670,607	288	960

[a] The number of households in each region was obtained based on the estimated population size and average household size from the 2006-2008 American Community Survey (U.S. Census Bureau 2009).
[b] Target sample sizes presented here refer to completed mail surveys.
[c] The sample is allocated to each region in proportion to the total number of households in that region, with at least 288 completed surveys required for each region to estimate the main effects and interactions under an experimental design model.
[d] The number of intended completed questionnaires for each survey region was rounded up so that the same number of households received each of the 24 survey versions.
Source: U.S. EPA analysis for this report

EPA used multiple preview and reminder mailings to promote a high response rate and minimize the potential for non-response bias. This approach follows Dillman et al. (2009), which is among the most commonly cited sources for survey logistics management. Households were selected from the U.S. Postal Service Digital Sequence File (DSF) of residences which, in total, covers 97 percent of residences in the United States. EPA also conducted a follow-up study of households that did not return a completed mail survey to determine whether survey non-respondents are fundamentally different than survey respondents. The follow-up survey included demographic and attitudinal questions.

11.4 Mail Survey Responses

Published guidance for SP survey design recommends conducting a pilot study to inform potential changes to other survey versions (Arrow et al. 1993; Bateman et al. 2002). Following this guidance, EPA undertook the Northeast region of the survey in advance of the other regions and national survey, as described in the ICR for the 316(b) SP survey (USEPA 2011c). After review of the Northeast survey responses, EPA received approval from the Office of Management and Budget (OMB) to implement the remaining survey regions (Inland, Southeast, and Pacific) and the national survey. EPA fielded the remaining survey versions in October 2011. EPA received a total of 2,313 completed mail surveys. Table 11-4 summarizes the number of completed surveys received and the response rate (responses as a percentage of mailed surveys minus undeliverable surveys). The average response rate was 32 percent. This response rate is comparable to various other recent mail surveys in the SP literature (e.g., Boyle and Özdemir 2009; Hanley et al. 2006; Johnston and Duke 2009; Johnston and Bergstrom 2011)

Table 11-4: Completed Survey Received and Response Rates by Survey Version

Survey Region	Households Surveyed	Completed Surveys Received	Response Rate[a]
Northeast	1,440	421	31%
Southeast	1,920	506	29%
Pacific	1,040	311	32%
Inland	2,480	787	35%
National Survey	960	288	34%
Total	**7,840**	**2,313**	**32%**

[a] The number of undeliverable surveys was subtracted from surveys mailed when calculating the response rate for each survey region. Undeliverable surveys are those surveys that were returned to sender.
Source: U.S. EPA analysis for this report

Analysis of the survey data across all four regions and the national survey indicates that respondents appear to have been evaluating tradeoffs between costs and benefits of policy options presented to them, and that WTP is responsive to scope (i.e., the quantity of environmental improvements across different attributes). Respondents appear to have understood and distinguished between different types of outcomes from 316(b) regulation. About 90 percent of respondents answered the choice experiment questions (questions 4, 5, and 6). Question 8 asked respondents to rate the statement that the survey material was easy to understand. Only 14 percent disagreed with that statement (see Figure 11-1). Seventy-one percent of respondents strongly agreed or agreed when asked in a 5-level Likert scale question whether they were confident in their responses to the survey questions. The vast majority indicated that they would answer the same way if parallel questions were asked in a binding referendum, with less than three percent of respondents indicating otherwise (see Figure 11-2).

About 75 percent of mail survey respondents were under age 65 and the majority of those completing the survey (63 percent) were male. About 87 percent of respondents selected “white” for racial category. For additional information on the demographic characteristics of respondents see EPA’s survey analysis memo to the 316(b) rulemaking record (USEPA 2012).

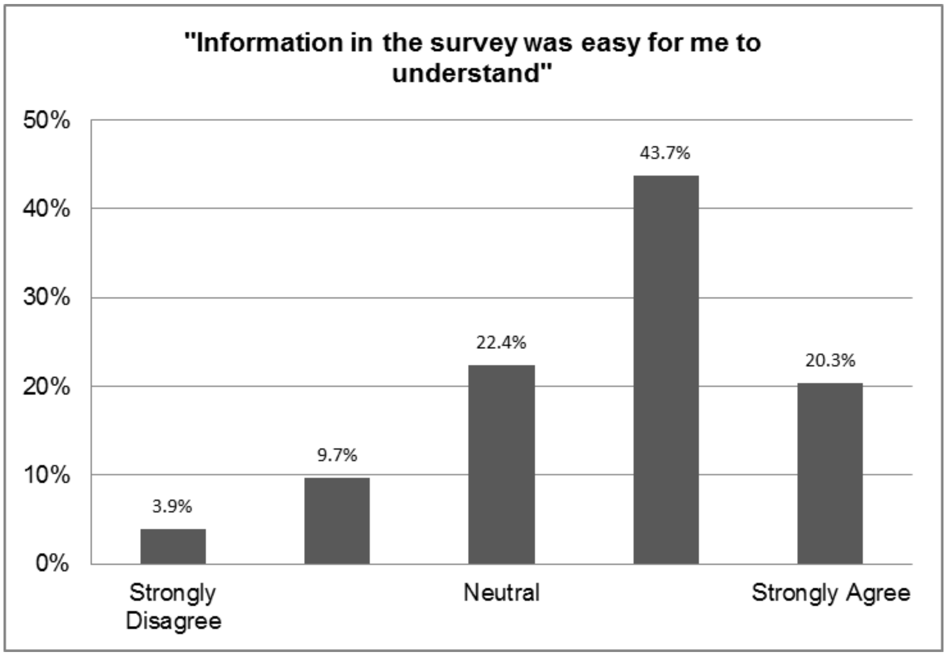


Figure 11-1: Summary of Responses to Regarding Respondent Understanding across All Surveys

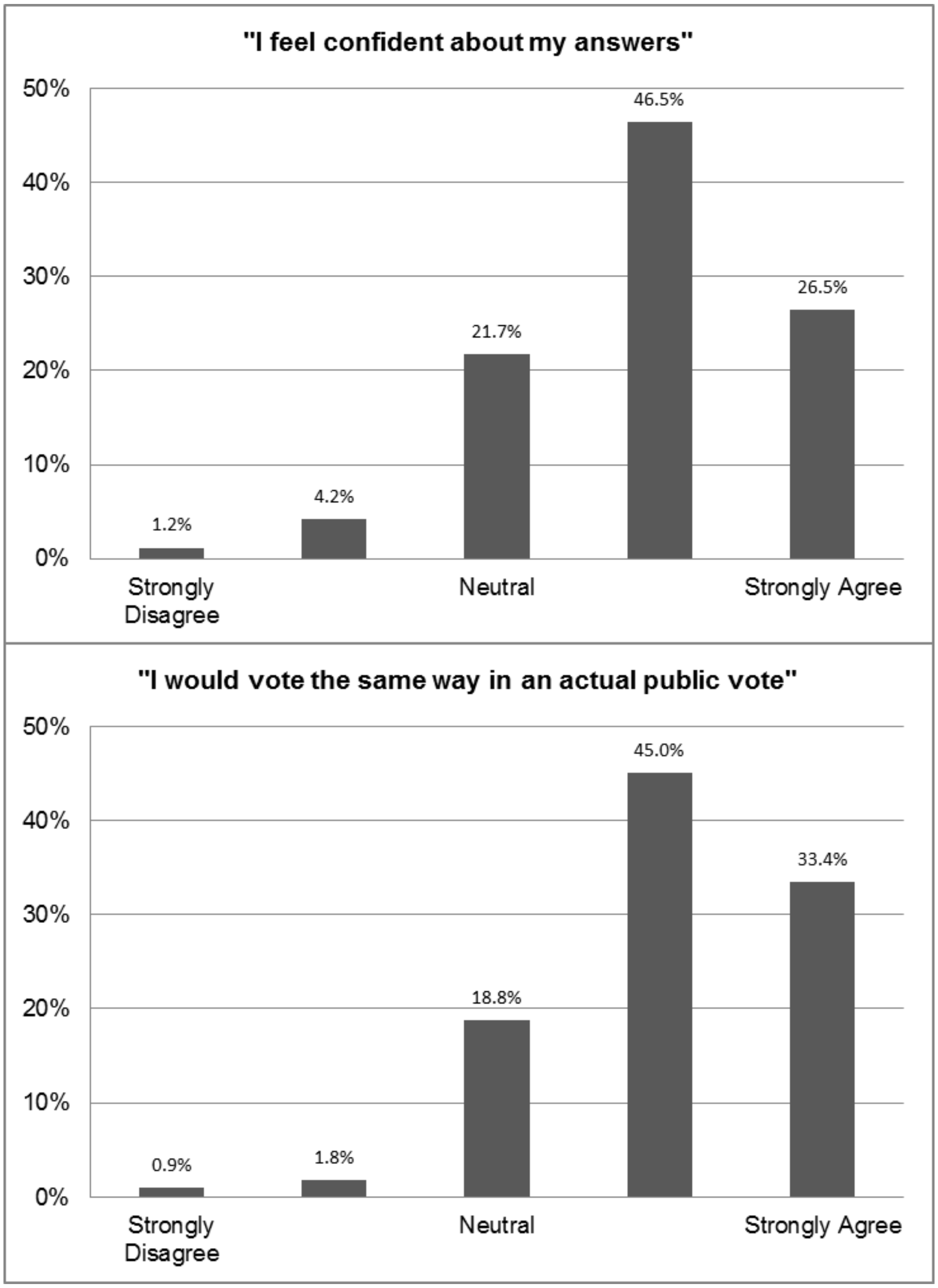


Figure 11-2: Summary of Responses Regarding Respondent Confidence across All Surveys

11.5 Non-Response Study

EPA conducted a follow-up study of households that did not return a completed mail survey to identify whether survey non-respondents are fundamentally different than survey respondents in certain attributes. The follow-up study included a set of key attitudinal questions and socio-demographic variables that are most likely to be associated with WTP for reducing fish mortality from CWISs and improvements in fish populations and conditions in the affected aquatic ecosystems. Section 11.5.1 describes the non-response sample and Section 11.5.2 describes statistical tests that EPA conducted comparing the main mail survey sample and the non-response sample.

11.5.1 Non-Response Sample

EPA implemented the follow-up study using two subsamples: the first subsample received a paper questionnaire via U.S. Postal Service Priority Mail®, and the second subsample was surveyed by telephone. Both non-response subsamples were asked the same set of attitudinal and demographic questions. It took participants approximately five minutes to complete the follow-up study.

EPA's target sample across all regions for the non-response study was 600 completed non-response surveys. This is the sample size required for a two-sided test showing a difference of 12 percentage points to be rejected with statistical power of 80 percent. In total, EPA planned to achieve 400 completed surveys in the Priority Mail subsample and 200 completed questionnaires in the telephone subsample. EPA allocated the initial target non-response completed surveys to each survey region in proportion to the mail survey sample size of each region. The priority mail subsample was conducted in advance of the telephone subsample. EPA conducted additional telephone calls to ensure that it reached targets for the total number of complete non-response surveys in each region, if the priority mail response fell short of the target. The number of completed non-response surveys is summarized in Table 11-5 by subsample. Overall response rates for the non-response study ranged from about 21.5 percent in the Southeast to 29.5 percent for the national survey.

Table 11-5: Completed Non-Response Surveys Received and Response Rates by Survey Region and Survey Mode

Survey Subsample/Survey Region	Sample Size	Completed Surveys	Response Rate
Priority Mail Subsample			
Northeast	146	48	32.9%
Southeast	297	71	23.9%
Inland	389	127	32.6%
Pacific	159	58	36.5%
National Survey	146	58	39.7%
Telephone Subsample			
Northeast	331	63	19.0%
Southeast	410	81	19.8%
Inland	356	71	19.9%
Pacific	160	20	12.5%
National Survey	125	22	17.6%
Total Non-Response Sample			
Northeast[a]	426	111	26.1%
Southeast	707	152	21.5%
Inland	745	198	26.6%
Pacific	319	78	24.5%
National Survey	271	80	29.5%

[a] For the Northeast region, EPA included 51 households which did not return the Priority Mail questionnaire within the telephone subsample in order to achieve the target number of completes. As a result, the total sample size for the Northeast is less than the sum of the Priority Mail and telephone subsamples.

Source: U.S. EPA analysis for this report

11.5.2 Statistical Testing of Mail Survey and Non-Response Data

EPA compared the respondent and non-respondent samples statistically according to eight characteristics to evaluate potential for non-response bias:

1. *Age*: age of the household member completing the survey
2. *Gender*: gender of the household member completing the survey
3. *Education*: highest level of education completed by the household member completing the survey
4. *Employment*: whether the survey participant is currently employed (yes/no)
5. *Hispanic or Latino origin*: whether the participant is of Hispanic or Latino ethnicity (yes/no)
6. *Race*: racial category of the participant
7. *Income*: annual household income
8. *Importance of protecting aquatic ecosystems:* attitudinal question asking the participant to rate how important he or she considers the protection of aquatic ecosystems.

Table 11-6 summarizes the characteristics of the respondents to the main surveys and non-response surveys.

Table 11-6: Characteristics of the Main and Non-Response Samples by Survey Region[a]

Statistic	Northeast		Southeast		Inland		Pacific		National Survey	
	Main	Non-Response	Main	Non-Response	Main	Non-Response	Main	Non-Response	Main	Non-Response
Age										
Average age	54.6	53.7	54.3	56.6	53.7	56.1	52.8	49.7	54.2	53.2
Percent under 65	74.6%	73.9%	74.1%	68.9%	76.3%	67.4%	76.1%	89.6%	72.7%	70.0%
Gender										
Percent male respondents	63.9%	44.5%	62.3%	46.7%	64.6%	51.3%	62.7%	55.1%	60.4%	45.6%
Employment										
Percent currently employed	63.6%	62.7%	59.2%	57.9%	64.4%	54.4%	65.0%	68.4%	60.2%	57.0%
Percent employed under age 65	76.9%	79.3%	75.0%	79.4%	76.9%	73.8%	80.3%	74.6%	72.5%	72.7%
Educational Attainment [b]										
Bachelor's Degree or Higher	45.9%	46.4%	44.1%	34.0%	43.1%	30.1%	50.8%	44.2%	46.9%	39.3%
Race and Ethnicity [c]										
Percent white respondents	86.6%	85.7%	82.3%	78.8%	91.0%	93.0%	84.7%	75.7%	83.4%	80.8%
Percent Hispanic or Latino Origin	5.1%	5.6%	9.9%	9.9%	3.4%	5.2%	13.3%	13.3%	7.0%	11.4%
Total Household Income [d]										
Average	$88,880	$81,480	$75,588	$74,179	$73,567	$59,598	$96,144	$79,306	$79,496	$63,681
Standard Deviation	$69,309	$68,486	$62,618	$66,760	$57,261	$54,966	$71,282	$67,757	$60,972	$57,415
Percent >$60,000	55.7%	49.0%	48.1%	44.8%	48.1%	31.0%	57.2%	50.0%	51.9%	37.5%
Importance of Aquatic Ecosystems [e]										
Average Ranking	4.0	4.0	3.9	4.0	3.8	3.9	4.0	4.1	3.9	3.9

[a] Respondents who did not answer a given demographic question were excluded when calculating percentages.
[b] The surveys included six categories for educational attainment: (1) less than high school, (2) high school or equivalent, (3) high school + technical school, (4) one or more years of college, (5) bachelor's degree, and (6) graduate degree.
[c] The surveys include six categories for education attainment: (1) American Indian or Alaskan Native, (2) Black or African American, (3) Native Hawaiian or Other Pacific Islander, (4) Asian, (5) White, and (6) Other. Respondents could select more than one racial category. The "Percent white respondents" presented above includes respondents that selected other racial categories in addition to white.
[d] The survey asked respondents to select one of eight categories for annual household income. The average and standard deviation reported here were calculated using the midpoint of each range. The amount of $250,000 was used for the highest income category included in the survey ("$250,000 or more").
[e] Respondents were asked to rate the "importance of protecting aquatic ecosystems" on a scale of 1 to 5, 1 being "not important" and 5 being "very important".
Source: U.S. EPA analysis for this report

For categorical or ordinal variables (i.e., all variables except age), EPA tested for statistical differences between respondents and non-respondents using both the Mann-Whitney U Test and χ^2 Test of Proportions. EPA used the Student's *t*-test for age, the only cardinal variable in the group. EPA considered a variable to be statistically different across the two populations if the null hypothesis of equality could be rejected at $p<0.10$. Table 11-7 presents the variables which were found to be statistically different for each survey region and the national survey.

Table 11-7: Variables Found to be Statistically Different Across Respondent and Non-Respondent Samples

Survey Region	Variables
Northeast	Gender, education
Southeast	Gender, education
Pacific	Importance of aquatic ecosystems, race
Inland	Age, gender, education, employment[a], and income
National Survey	Gender, income

[a] Employment was not statistically different for respondents under the age of 65.

Source: U.S. EPA analysis for this report

In general, attitudes towards the protection of aquatic ecosystems tended to be similar across samples for most survey regions, with a large majority of respondent rating it as important. No statistical difference was found in rating the protection of aquatic ecosystems among respondents and non-respondents, the only exception being the Pacific region. The average ranking was slightly higher for non-respondents than respondents in the Pacific region. The vast majority of participants in the non-response study also indicated that government should be at least somewhat involved in environmental protection.[67]

EPA developed for the weights for those demographic variables which were found to be statistically different in each region to account for over- and under- represented groups in the mail survey dataset used for model estimation. Section 11.6.3 describes weight development.

11.6 Random Utility Model

EPA's analysis of the 316(b) survey data is grounded in the random utility model presented by Hanemann (1984) and McConnell (1990). The use of the random utility model is standard in the SP literature for attribute-based SP data, such as that provided by choice experiments (Bateman et al. 2002; Bennett and Blamey 2001). Under the model, "utility is the sum of systematic [or observed] and random [or unobserved] components" (Holmes and Adamowicz 2003, p. 189). The individual choices are systematic (i.e., deterministic) from the perspective of the individual, while the random component reflects preferences which are unobservable to the researcher, among other things(Holmes and Adamowicz 2003). The model is applied extensively within SP research, and allows for the calculation of well-defined welfare measures (i.e., WTP) from choice experiment models (Bennett and Blamey 2001; Louviere et al. 2000). This section describes

[67] Multiple questions in the main mail survey asked respondents about their views toward government and environmental protection (e.g., questions 1-5 and 1-6 on page 3 of the mail survey). However, the wording of these questions differed from the question included in the non-response survey, such that they are not directly comparable.

EPA's model specification (Section 11.6.1), model estimation (Section 11.6.2), approach for estimating weights (Section 11.6.3), and model results (Section 11.6.4).

11.6.1 Model Specification

Table 11-8 lists and defines the variables included in the random utility models. For each choice option, the respondent may choose Option A, Option B, or No Policy, where No Policy is characterized by zero change in all attributes.

Table 11-8: Summary of Variables Included in the Random Utility Models for the Regional and National Surveys

Variable	Variable Definition
CONSTANT	Alternative specific constant (ASC) associated with No Policy, or choice of neither plan.
COM_FISH	Score showing the overall health of commercial and recreational fish populations.
FISH_POP	Score showing the estimated size of all fish populations compared to natural levels without human influence.
FISH_SAV	Score showing the percentage point reduction in young fish lost compared to current levels.
AQUATIC	Score showing the ecological condition of affected areas, compared to the most natural waters in the region.
COST	The increase in annual household cost, in unavoidable price increases for products and services, including electricity and common household products.

Source: U.S. EPA analysis for this report

The linear econometric specification of the model of the observable component of utility appears as:

$$v(\cdot) = \beta_0 + \beta_1(\Delta fish\_sav) + \beta_2(\Delta com\_fish) + \beta_3(\Delta fish\_pop) + \beta_4(\Delta aquatic) + \beta_5(cost) \quad (11\text{-}1)$$

This specification allows EPA to estimate the relative linear "main effects" of the four environmental attributes on utility. The estimated constant (β_0) represents utility associated with the relevant ASC (alternative specific constant). This is a fixed coefficient estimated within choice experiments that is designed to capture "systematic but unobserved information about why respondents chose a particular option (that is, unrelated to choice set attributes)" (Bennett and Blamey 2001). ASCs become statistically significant in choice experiment models when elements other than the independent variables, or choice attributes, in the model influence respondents' choices (Kerr and Sharp 2006). Here, EPA included an ASC for No Policy; this variable takes a value of 1 for the No Policy option and a value of 0 for either of the two available policy options. Hence, β_0 in this model represents the fixed utility associated with No Policy (maintaining the status quo), holding all other attribute changes at zero.

Economic theory provides guidance regarding some, but not all, aspects of model specification for mixed logit models within SP choice experiments. For example, the parameter on program cost is expected to have a negative sign, reflecting a positive marginal utility of income. Comparison of model output suggested that the greatest robustness of results is achieved when cost is modeled as fixed rather than random. This specification also avoids well-known challenges for welfare estimation associated with the specification of a random coefficient on program cost (Hensher and Greene 2003; Scarpa et al. 2008; Train and Weeks 2005). Coefficients on all variables except that on program cost (*cost*) are specified as random with a normal distribution.

11.6.2 Model Estimation

EPA estimated the random utility models for all four regions and the national survey using maximum likelihood mixed logit with Halton draws. As described in Chapter 8, Halton draws, or "intelligent draws", are "generated number theoretically rather than randomly and so successive points at any stage 'know' how to fill in the gaps left by earlier points" (Bhat 2001, p. 684). The mixed logit model is an approach for modeling preference heterogeneity based on the assumption that individuals' preferences are randomly distributed and that heterogeneity in population preferences can be captured by estimating the mean and variance of the random parameter distributions (Holmes and Adamowicz 2003). As described by Henscher and Greene (2003), "the mixed logit model offers an extended framework within which to capture a greater amount of behavioral choice making. Broadly speaking, the mixed logit model aligns itself much more closely with reality than most discrete choice models. This is because every individual has their own inter-related systematic and random components for each alternative in their perceptual choice set(s)" (p. 170). It is a highly flexible model that "obviates the three limitations of standard logit by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors over time" (Train 2009, p. 134).

The mixed logit model allows for the possibility of preference heterogeneity but cannot attach specific parameter values to particular individuals. That is, the model relaxes the assumption of respondents being identical, which is required for multinomial logit estimation, and replaces it with a less restrictive assumption that respondents' preferences follow distribution. The theory and methods of mixed logit modeling are well-established (Train 2009), and it has now become standard practice in many areas of research (Hensher and Greene 2003). These models allow for coefficients on attributes to be distributed across sampled individuals according to a set of estimated coefficients and researcher-imposed restrictions. The models are evaluated numerically using random draws because choice probabilities take the form of an integral over a mixing distribution that does not have a closed form (Train 2009). The likelihood simulation for the models estimated by EPA used 300 Halton (random) draws.[68] Coefficients on all variables except that on program cost (*cost*) are specified as random with a normal distribution. As discussed in the previous section, the greatest model robustness was achieved when cost was specified as fixed.

11.6.3 Approach for Estimating Weights

EPA developed weights for each region to account for the over- and under-representation of demographic groups in the mail survey data for each region. As described in Section 11.5.2, EPA statistically compared a set of key demographic characteristics across respondent and non-respondent samples. For those characteristics which were statistically different, EPA developed weights such that the weight given to particular subgroup of individuals within the analyzed sample (sample proportion) matches the weight for the same subgroup in the overall (population proportion).[69] EPA used data from Census 2010 and the American Community Survey (ACS) as the target for the desired population.

EPA applied one of two approaches to calculate the weights assigned to each respondent in the mail survey dataset: (1) subgroup weighting and (2) raking. The combination of demographic characteristics dictated which approach was applied for a given region:

- *Subgroup weighting* – Applied if the population proportions for each subgroup could be calculated directly based on data from ACS and Census 2010. For example, the 2010 ACS reports educational attainment by gender, the two characteristics which were statistically different in the Northeast and Southeast survey regions. Because separate proportions for males and females for educational attainment were available according to gender, EPA could calculate population proportions directly from the data for these regions. EPA also used subgroup weighting for race in the Pacific region.
- *Raking* – Used when the number and combination of variables are such that EPA could not calculate the grid of sample and population proportions directly using Census or ACS data. Raking uses an iterative process to match the subpopulations weights to the population statistics, using targets for the individual demographic characteristics of interest. Additional detail on raking is provided by (Izrael et al. 2004) This approach was

[68] EPA also ran the models with 200, 400, and 500 Halton draw to assess model robustness. They indicate that the models are relatively robust (stable) across different numbers of draws, for the "fish saved" attribute in particular.

[69] EPA could not develop weights for the importance of aquatic ecosystems in the Pacific region because a statistical target (e.g., Census for ACS data) was unavailable (adjusting would have increased WTP). EPA did not weight based on employment in the Inland region because employment was not statistically different for respondents under the age of 65 and EPA weighted for age.

used to weight for age, gender, education, and income in the Inland region and for gender and income for the national survey.

11.6.4 Model Results

Mixed logit model statistics suggest good statistical fit across the regional survey versions. Table 11-9 presents results for both linear and weighted linear models for each survey region. The following discussion, however, focuses on the weighted model since this model allows to correct for differences in demographic characteristics of respondents and general population. For the weighted linear models, the χ^2 values ranged from 483.07 to 1,119.22 (all with d.f. = 21, $p<0.0001$) and pseudo-R^2 ranged from 0.23 to 0.31 for the regional surveys. The national weighed linear model has a χ^2 value of 394.0 (d.f. = 21, $p<0.0001$) and pseudo-R^2 of 0.23.

The variable for fish saved (*fish_sav*) is significant in all four regional weighted linear models, commercial fish populations (*com_fish*) is significant in two of the four regional models, and aquatic ecological condition (*aquatic*) is statistically significant in two of the four regional models. The significance of these attributes suggests positive implicit prices; that is, positive WTP for changes in individual attributes. Analogous outcomes are common in choice experiments across the literature addressing aquatic ecological improvements, with the substantial majority of choice attributes found to have statistically significant impacts (Carlsson et al. 2003; Do and Bennett 2009; Johnston et al. 2011a; Johnston et al. 2011b). The ASC was significant in three of the five models.

As noted above, all variables except cost represent percent progress toward the upper ecological reference condition (100 percent). Hence, these coefficients may be directly interpreted as the relative marginal utility derived from a one percentage point change in each ecological attribute. In the estimated Southeast weighted linear model, for example, marginal utility is greatest (per percentage point) for increases in commercial fish populations (*com_fish*), with lower (but still statistically significant) impacts associated with changes in the number of fish saved (*fish_sav*). The percentage differences in environmental attributes across the options presented were much larger for the number of fish saved (*fish_sav*) than for the other variables. Therefore, the coefficients on *fish_sav* tend to be lower than on other environmental attributes. Following recommended practice in SP valuation, these variations correspond with realistic ecological and policy expectations for regulatory outcomes (Bateman et al. 2002). The lack of significance of *com_fish*, *all_fish* and *aquatic* in some models may be related to the relatively small changes in these attributes included in the survey, relative to effects on fish saved, which were much larger. There are only two coefficients of unexpected sign and neither is significant.

Direct comparisons of statistical fit measures across different choice experiments in the literature can be misleading and should be viewed with extreme caution. Many measures of model fit are not directly comparable across different datasets or models. Nonetheless, the overall statistical fit of the model appears broadly similar to choice experiments found in the published literature addressing environmental improvements both worldwide and in the United States. Johnston et al. (2011a,b), in a similar survey of ecological improvements, report a pseudo-R^2 of 0.30. By comparison, using a commonly reported measure of model fit (pseudo- or McFadden R^2), Campbell et al. (2009) report a pseudo-R^2 of 0.20; Carlsson et al. (2003) report pseudo-R^2 values between 0.12 and 0.27; Do and Bennett (2009) report pseudo-R^2 between 0.07 and 0.18; and Colombo and Hanley (2008) report values between 0.16 and 0.36. Other measures of fit are also similar, although again, caution must be exercised when drawing conclusions from any such comparisons across models.

EPA also tested alternative models and conducted various validity tests using the survey data and model results. This included investigation of non-linear functional forms, including stepwise models and inverse hyperbolic sine (IHS) models, as it is possible that there is diminishing marginal WTP for fish saved. However, EPA found that model results did not improve under non-linear specifications. For the stepwise models, EPA coded fish saved as a set of binary (dummy) variables instead of a continuous variable for each survey region and results are intuitive. Resulting WTP across steps seems to suggest a generally linear relationship. EPA designed the IHS model for each survey region to capture potential nonlinearities in WTP for fish saved. Review of IHS results indicate that the fit and intuitiveness varies somewhat across models, but in general, models do not improve upon linear specification. Results for these alternative models are included in the 316(b) rulemaking docket. Based on these results, EPA used the weighted linear specification as its primary models in this report for preliminary assessment of WTP. The Agency also notes that with only three attribute levels (per region), it would be difficult to capture non-linearities in the fish saved attribute.

Table 11-9: Linear and Weighted Linear Model Results

Variable	Coefficient [a,b] (Standard Error)									
	Northeast		Southeast		Inland		Pacific		National	
	Linear	Weighted Linear	Linear	Weighted Linear	Linear	Weighted Linear	Linear	Weighted Linear	Linear	Weighted Linear
Random parameters in utility functions										
CONSTANT	-0.56919 (0.42972)	-0.52259 (0.37095)	-0.19920 (0.30806)	-1.63728*** (0.33244)	-3.56478*** (0.58123)	-3.53149*** (0.56418)	0.18220 (0.45022)	0.18797 (0.49719)	-2.09328*** (0.45875)	-1.49361*** (0.48000)
COM_FISH	0.13145* (0.06765)	0.21316*** (0.05180)	0.12662*** (0.04660)	0.08871* (0.04991)	0.06082** (0.02946)	0.02335 (0.02773)	0.15056** (0.07282)	0.11072 (0.08606)	0.08925 (0.06077)	0.07350 (0.06015)
FISH_POP	0.13602 (0.10508)	0.06502 (0.09369)	0.14670** (0.06364)	-0.02800 (0.07830)	0.02175 (0.04405)	0.01007 (0.04182)	0.21176* (0.11078)	0.16039 (0.12739)	0.02838 (0.10735)	0.19524* (0.11069)
FISH_SAV	0.02852*** (0.00537)	0.02900*** (0.00464)	0.02183*** (0.00462)	0.02596*** (0.00507)	0.01483*** (0.00439)	0.01597*** (0.00393)	0.04389*** (0.00698)	0.03645*** (0.00683)	0.02241*** (0.00585)	0.02116*** (0.00665)
AQUATIC	0.17102 (0.10955)	0.20135* (0.10306)	0.24591*** (0.07741)	0.06163 (0.08284)	0.04630 (0.05036)	0.04864 (0.04478)	0.34171*** (0.11007)	0.31963** (0.13338)	-0.12105 (0.11085)	-0.10694 (0.17007)
Non-random parameters in utility functions										
COST	-0.02677*** (0.00513)	-0.02106*** (0.00453)	-0.03868*** (0.00417)	-0.04209*** (0.00502)	-0.03356*** (0.00298)	-0.03280*** (0.00284)	-0.02756*** (0.00518)	-0.02177 (0.00534)	-0.03739*** (0.00520)	-0.03294*** (0.00578)
Derived standard deviations for parameter distributions										
sdCONSTANT	0.37257 (1.01103)	0.19465 (1.01704)	0.00256 (4.10600)	0.29835 (1.20020)	5.91389*** (0.97758)	5.18984*** (0.89828)	0.09866 (1.0278)	0.01702 (6.00963)	0.18221 (2.51713)	0.08915 (1.29659)
sdCOM_FISH	0.43573*** (0.12740)	0.13635 (0.16831)	0.26774*** (0.09727)	0.17567 (0.12699)	0.12217* (0.06487)	0.12565** (0.06115)	0.30101 (0.30183)	0.32221* (0.18467)	0.27147 (0.41960)	0.30494* (0.17425)
sdFISH_POP	0.51160** (0.21996)	0.58902*** (0.18116)	0.04792 (0.39545)	0.34982 (0.21724)	0.07409 (0.07769)	0.12423 (0.08723)	0.22539 (0.41340)	0.23578 (0.25612)	0.54531 (1.33621)	0.64049** (0.30347)
sdFISH_SAV	0.05755** (0.02241)	0.04375*** (0.01269)	0.05697*** (0.01339)	0.06335** (0.02852)	0.04838*** (0.00615)	0.04359*** (0.00554)	0.05362 (0.04330)	0.05332*** (0.01546)	0.05514*** (0.01773)	0.08467*** (0.02698)
sdAQUATIC	0.61933*** (0.22791)	0.64976 (0.44299)	0.45656*** (0.12343)	0.77220 (0.60628)	0.44593*** (0.08826)	0.33881*** (0.08224)	0.35905 (0.57884)	0.29608 (0.26966)	0.81244 (0.53981)	1.19443* (0.72258)
Model significance										
Model χ^2	582.48 (d.f. = 21, p<0.0001)	538.59 (d.f. = 21, p<0.0001)	741.92 (d.f. = 21, p<0.0001)	700.17 (d.f. = 21, p<0.0001)	1,191.94 (d.f. = 21, p<0.0001)	1,119.22 (d.f. = 21, p<0.0001)	578.74 (d.f. = 21, p<0.0001)	483.07 (d.f. = 21, p<0.0001)	413.53 (d.f. = 21, p<0.0001)	394.00 (d.f. = 21, p<0.0001)
Pseudo-R^2	0.24	0.23	0.24	0.24	0.25	0.24	0.32	0.31	0.24	0.23

[a] For random parameters in utility functions, coefficients represent the estimated means of random parameter distributions.
[b] ***, **, * indicates significance at 1%, 5%, 10% levels, respectively.
Source: U.S. EPA analysis for this report

11.6.5 Validity Tests

Generally accepted economic thinking maintains that obtaining greater quantities of a desired economic good will lead to higher levels of consumer utility (Heberlein et al. 2005). A scope test looks at whether respondents' WTP is greater for (or not less than) a good that is somehow larger, either in a quantitative or qualitative sense. There are two types of scope tests. An internal scope (or within-sample) test involves comparing multiple WTP estimates from SP responses collected from the same respondents" while an external scope test "employs split-sample designs to compare WTP estimates across samples from the sample population" (Lew and Wallmo 2011). A major criticism of stated preference studies had been that this relationship – consumers preferring greater quantities of a good over lesser quantities of that same good– is sometimes violated when valuating environmental amenities. Evidence provided by these early findings prompted the 1993 NOAA Panel on Contingent Valuation to regard surveys that exhibit insensitivity to scope as "unreliable" (Arrow et al. 1993). Compared to tests of scope in contingent valuation, the role of external scope tests within choice modeling has received much less attention in the literature (cf., Heberlein et al. 2005).

Unlike open-ended contingent valuation questions, choice experiments provide a direct mechanism for respondents to react to the scope and scale of resource changes, by enabling respondents to compare policy options with different levels for each attribute. As noted by Bennett and Blamey (2001, p. 231), "internal scope tests are automatically available from the results of a [choice modeling] exercise." That is, choice experiments already include "internal" scope tests because respondents compare levels across Options A and B. Respondents express WTP for incremental improvements in environmental attributes through their selection of No Policy, Option A, or Option B within the choice questions and model results indicate that WTP is higher for an option with a greater level of goods. Within a choice modeling context, external scope tests may also be confounded by differences in the implied choice frame (Bennett and Blamey 2001). These caveats aside, an external scope test can provide some additional insight into response patterns, and some researchers view these tests as a "stronger" form of validation than internal scope tests. EPA therefore implemented a form of external scope tests to evaluate this form of validity using the mail survey data for each survey region. As the experimental design was not originally conceived to allow formal tests of external scope, the following test is illustrated as an alternative approach that is possible given the current experimental design and available data.[70]

EPA used a split sample to look at respondents' selections for Options A and B separately and obtain a more "external" perspective based on the concept that, if all else is orthogonal (effectively equal), a choice option with more fish saved should be chosen more often than a choice option with fewer fish saved. Splitting out Options A and B provides a more convincing test, because it shows that the same patterns apply to both Options A and B. EPA limited the test to the *fish saved* attribute because fish saved is the only attribute that EPA is using at this time to estimate WTP for regulatory options. To distinguish this test from the "internal" scope tests automatically performed by choice experiments, it is implemented using a split sample of choice options viewed in isolation. To implement the test, EPA first created a dataset *only* of

[70] External scope tests were recommended for contingent valuation studies (Arrow et al. 1993). Because scope tests are automatically available from the results of a choice modeling exercise (Bennett and Blamey (2001, p. 231), accounting for external scope tests in the experimental design was not necessary.

observations on Option A for all survey responses, along with a dummy (0-1) variable indicating whether that option was chosen.[71] EPA then further split this sample into three sub-samples based on the three levels of fish saved assigned to each region within the experimental design. Using the Pacific region as an example, the three sub-samples are: (1) observations on Option A when percent fish saved = 95 percent, (2) observations on Option A when percent fish saved = 50 percent, and (3) observations on Option A when percent fish saved =2 percent. Because of the near orthogonal nature of the experimental design, all other attribute levels should be approximately equal across each of these three sub-samples. Given this split sample, EPA expected to observe the greatest proportion of respondents choosing Option A in sub-sample (1), followed by sub-sample (2) and then (3). This order would establish external sensitivity to scope. EPA then repeated the same test for Option B.

The results of the scope sensitivity test are presented in Table 11-10. The results tables illustrate means and standard deviations for respondent choices for each observation of Option A and Option B. The external scope tests for split samples of both Options A and B demonstrate scope sensitivity for all survey regions, as indicated by economic theory. The values of other choice attributes (*com_fish*, *fish_pop*, *aquatic*, and *cost*) are approximately equal over the split samples, as one would expect given the experimental design. The proportion of respondents choosing Option A declines as the percentage of fish declines for all survey regions. Using the Inland region as an example, the proportion of respondents choosing Option A declines from 0.42 to 0.39 to 0.37 as the percentage of fish saved declines from 95 percent to 75 percent to 55 percent. Option B exhibits a similar decline in respondent choice with fish saved all survey regions. EPA used the χ^2 test of proportions to examine whether the proportions were statistically different across levels of fish saved for a given option. The null hypothesis of equality in proportions is rejected at $p<0.10$ for all regions and options. This shows that respondent choices were statistically different across levels of fish saved.

EPA also conducted further testing with the responses split by survey question as well as option to respond to the external peer review. Using this approach, each question/option sample includes only one choice from each respondent. The null hypothesis of equality in proportion is rejected at p<0,10 or better for 22 of the 30 cases (5 survey versions x 3 questions x 2 options = 30). EPA did not generate the survey experimental design with such tests in mind, so the combination of other choice attributes (*com_fish, fish_pop, aquatic,* and *cost*) vary somewhat across cases when split by question and option, which would affect the results of this scope test in a systematic fashion. Overall, results indicate sensitivity to scope for fish saved.

[71] Thus, each respondent is represented up to three times, once for each choice question in their survey booklet.

Table 11-10: Results of the Split-Sample External Validity Test for Each Survey Region

Region/ Percent Fish Saved	Option A		Option B	
	Mean	Std. Dev.	Mean	Std. Dev.
Northeast				
95%	0.4617	0.4992	0.4861	0.5004
50%	0.4274	0.4954	0.4415	0.4973
5%	0.2473	0.4320	0.2345	0.4243
χ^2 Test of Proportions[a]	42.43 (d.f.=2; p<0.001)		58.81 (d.f.=2; p<0.001)	
Southeast				
90%	0.4796	0.5001	0.4000	0.4904
55%	0.3593	0.4803	0.2939	0.4560
25%	0.2922	0.4553	0.2602	0.4392
χ^2 Test of Proportions[a]	35.58 (d.f.=2; p<0.001)		23.29 (d.f.=2; p<0.001)	
Inland				
95%	0.4225	0.4943	0.3679	0.4825
75%	0.3897	0.4880	0.3234	0.4681
55%	0.3652	0.4818	0.2712	0.4449
χ^2 Test of Proportions[a]	5.00 (d.f.=2; p<0.082)		15.77 (d.f.=2; p<0.001)	
Pacific				
95%	0.4929	0.5008	0.5993	0.4909
50%	0.3722	0.4843	0.4118	0.4931
2%	0.1932	0.3955	0.2333	0.4237
χ^2 Test of Proportions[a]	53.89 (d.f.=2; p<0.001)		76.63 (d.f.=2; p<0.001)	
National				
95%	0.4753	0.5003	0.4604	0.4994
55%	0.3571	0.4801	0.3013	0.4598
25%	0.3269	0.4700	0.2737	0.4466
χ^2 Test of Proportions[a]	13.60 (d.f.=2; p<0.001)		24.06 (d.f.=2; p<0.001)	

[a] The null hypothesis is that the proportion of respondents choosing an option is equal for all percentage fish saved.
Source: U.S. EPA analysis for this report

11.7 Estimation of Implicit Prices and WTP

EPA used the results of the random utility models presented in Table 11-9 to estimate the implicit price or marginal annual WTP for a one percentage point change in each of the four environmental attributes within each survey region. This represents WTP per household, per year, for a one percentage point change in the corresponding choice model attribute. For example, one could calculate the marginal WTP for each additional percentage increase in fish saved, holding all else constant. If utility is modeled as a linear function of attributes, implicit prices may be calculated as $IP_a = \beta_a/\beta_n$, where β_a is the estimated coefficient on an environmental attribute (e.g., change in fish saved), and β_n is the coefficient on program cost. Assuming a linear preference function as estimated above, compensating surplus (or household WTP) for any given policy option may be calculated as:[72]

$$\text{WTP} = (IP_{com_{fish}} * \Delta com\_fish) + (IP_{fish_{pop}} * \Delta fish\_pop) + (IP_{fish\_sav} * \Delta fish\_sav) + (IP_{aquatic} * \Delta aquatic) \quad (11\text{-}2)$$

where the delta (Δ) represents a change in the attribute in question. That is, total WTP for a policy change is calculated as the sum of the product of implicit prices and corresponding attribute changes. Once a preference function is estimated, the decision to include or exclude the ASC (*constant*) in subsequent welfare estimation must be made on a case-by-case basis; economic theory alone is insufficient to determine this choice.[73] In this case, EPA excludes the ASC when calculating compensating surplus, because by definition it reflects anticipated utility change unrelated to the included model attributes. Section 11.8 includes additional discussion of EPA's treatment of the ASC when analyzing regulatory benefits.

EPA notes that ecological systems are typically characterized by correlation among many processes and outcomes. In the context of IM&E, for example, a reduction in A1E losses (*fish_sav*) may be correlated with changes in fish populations (*fish_pop*), aquatic ecosystem condition (*aquatic*), and commercial fish populations (*com_fish*). It would have been difficult to determine which attribute(s) caused respondents to choose one scenario over another had the SP survey scenarios incorporated the same correlations. For example, if it were the case that large reductions in IM&E always accompany large positive effects on fish populations and large positive effects on ecosystem condition and these correlations were embedded within survey scenarios, it would have been difficult to estimate the specific influence of each attribute on respondents' choices.

The experimental design used in the SP survey breaks this correlation and allows different survey attributes to vary independently. This enables different respondents to view many different possible policy outcomes, each with different combinations of *fish_sav*, *fish_pop*, *aquatic* and *com_fish*. While some of the resulting scenarios might be unlikely in actual aquatic systems, they are not ecologically impossible. For example, the experimental design allows respondents to consider scenarios in which large reductions in fish losses accompany very small changes in fish populations and aquatic condition (positive changes in *fish_sav* in some questions are also paired with no change in the population or aquatic condition metrics). Because attributes vary independently across the 72 different choice questions presented to respondents in each survey region and national survey, it is possible to estimate the unique effects of each attribute on individuals' choices and therefore, values. By breaking the correlation between these attributes present in ecosystems, the choice experiment design allows estimation of the independent effect of each attribute on choices and WTP. The environmental attributes have almost zero correlation in the resulting experimental design. This allows WTP for each ecological effect to be estimated, independent from all other effects. Based on recommendations from external peer reviewers, EPA is currently conducting additional analysis to assess the robustness of fish saved under alternative treatments of the other environmental attributes.

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72 EPA excluded the ASC when estimating the benefits of regulatory options because there is no clear theoretical reason for inclusion. The magnitude and sign of the coefficient on ASC varies across regions.

73 The treatment of the ASC is discussed by Adamowicz et al. (1998) and Morrison et al. (2002), among others.

Because the mixed logit model includes random coefficients, EPA estimates implicit prices using the welfare simulation approach of Johnston and Duke (2007; 2009) following the framework outlined by Hensher and Greene (2003). The procedure begins with a parameter simulation following the parametric bootstrap of Krinsky and Robb (1986), with R=1,000 draws taken from the mean parameter vector and associated covariance matrix. For each draw, the resulting parameters are used to characterize asymptotically normal empirical densities for fixed and random coefficients. For each of these R draws, a coefficient simulation is then conducted for each random coefficient, with S=1000 draws taken from simulated empirical densities. Here, all coefficient simulations draw from a normal distribution except for that on *cost*, which is fixed. EPA calculated WTP measures for each draw, resulting in a combined empirical distribution of $R \times S$ observations from which summary statistics were derived. All implicit prices are modeled as the WTP for a one percentage point change in the ecological attribute, all else being constant.

The resulting mean implicit prices and 90 percent confidence intervals for the ASC (constant) and environmental attributes in each region are presented in Table 11-11. The point estimates for implicit prices tend to be larger for commercial fish populations, fish populations (all fish), and aquatic ecosystem condition than for fish saved, although the statistical significance of these point estimates varies. This is not surprising given the relatively narrow range over which these attributes vary. Hence, some point estimates that appear large may not be statistically significant, and vice versa. In the Pacific for example, households value a one percentage point increase in commercial fish populations or aquatic ecosystem condition about three or eight times, respectively, the value of a one percentage point increase in fish saved. The mean implicit prices for a 1 percent improvement in fish saved under the regional weighted linear models range from $0.50 in the Inland region to $1.77 in the Pacific region. The mean implicit price based on the national survey is $0.66. Peer reviewers indicated that EPA should focus on the regional over the national survey results because of concerns regarding the smaller size and representativeness of the national sample. EPA included implicit prices based on the national survey for illustrative purposes.

EPA did not use the national survey results in its analysis of regulatory options. EPA found that the implicit price for fish saved was relatively robust (stable) across mixed logit models with 200, 400, and 500 Halton draws. These additional model results are included in the 316(b) rulemaking docket. Although the discussion in this section refers to WTP for a percentage point increase in fish saved, it is important to note that this variable represents a one percentage point reduction relative to the level of baseline mortality (e.g., the Northeast survey booklet indicated a baseline loss of 1.1 billion fish). This relationship between the percentage point reduction and cardinal fish losses was specified clearly in survey questions, and the same relationship was maintained throughout each survey . WTP per percentage point reduction reflects a specific quantity of fish saved, rather than a general relative reduction of one percent from an unspecified level of IM&E. The regional and national surveys have different baseline fish losses. EPA expected survey responses to vary across the regions, because residents might have different values and baseline losses differ.

Table 11-11: Estimated Implicit Prices for a Once Percentage Point Change in Each Attribute, WTP per Household, per Year (2011$)[a]

Survey Version and Environmental Attribute	5th	Mean	95th
Northeast			
Commercial Fish Populations (*COM_FISH*)	$6.45	$10.30	$14.86
Fish Populations (all fish) (*FISH_POP*)	-$4.53	$3.09	$10.89
Fish Saved (*FISH_SAV*)	$0.95	$1.44	$2.07
Aquatic Ecosystem condition (*AQUATIC*)	$1.44	$9.76	$19.01
Southeast			
Commercial Fish Populations (*COM_FISH*)	$0.16	$2.10	$4.11
Fish Populations (all fish) (*FISH_POP*)	-$3.81	-$0.69	$2.48
Fish Saved (*FISH_SAV*)	$0.42	$0.62	$0.83
Aquatic Ecosystem condition (*AQUATIC*)	-$2.01	$1.43	$4.75
Inland			
Commercial Fish Populations (*COM_FISH*)	-$0.67	$0.69	$2.08
Fish Populations (all fish) (*FISH_POP*)	-$1.83	$0.28	$2.48
Fish Saved (*FISH_SAV*)	$0.28	$0.50	$0.70
Aquatic Ecosystem condition (*AQUATIC*)	-$0.78	$1.47	$3.68
Pacific			
Commercial Fish Populations (*COM_FISH*)	-$1.37	$5.37	$13.60
Fish Populations (all fish) (*FISH_POP*)	-$2.32	$7.71	$18.53
Fish Saved (*FISH_SAV*)	$1.07	$1.77	$2.62
Aquatic Ecosystem condition (*AQUATIC*)	$5.01	$15.32	$27.48
National			
Commercial Fish Populations (*COM_FISH*)	-$0.81	$2.22	$5.50
Fish Populations (all fish) (*FISH_POP*)	$0.41	$5.82	$11.28
Fish Saved (*FISH_SAV*)	$0.28	$0.66	$1.07
Aquatic Ecosystem condition (*AQUATIC*)	-$12.30	-$3.52	$5.20

[a] The implicit prices are per percentage point increase from the specified baseline (reference) levels for each survey.
Source: U.S. EPA analysis for this report

While 95 percent confidence intervals are rather large for *com_fish*, *fish_pop*, and *aquatic*, and sometimes include zero in the range, the confidence intervals are rather narrow for fish saved and do not include zero within the 95 percent confidence interval. This highlights a very specific result of the stated preference survey, which is that the WTP to protect fish and shellfish from impingement and entrainment, even when there are no effects on the other attributes, is greater than zero. This is the case despite the vociferous objections of some commenters opposed to the stated preference survey. To be clear, these benefit estimates represent an average WTP for protecting fish and shellfish from impingement and entrainment and incorporate the responses of all respondents, including those who expressed zero WTP .[74]

11.8 Method for Estimating Regional Benefits

EPA used the implicit prices, or WTP per percentage point change, for fish saved (*fish_sav*) to estimate annual monetized benefits for each survey region under the final rule and regulatory options considered. EPA did not estimate changes or potential benefits associated with changes in the other three environmental attributes. EPA's focus on the fish saved attribute for benefits estimation is consistent with recommendations from external peer reviewers. Peer reviewers

[74] About 17 percent of survey respondents selected No Policy (i.e., zero WTP) for all three choice questions.

indicated that using fish saved exclusively for benefits estimation helps to alleviate concerns regarding overlaps in the definitions of environmental attributes and potential interactions between environmental attributes which are not accounted for in the main effects experimental design. It also allays concerns with the degree of ecological uncertainty involved in the modeling and prediction of effects on fish populations and aquatic ecosystems.

For each survey region, EPA calculated annual household WTP under regulatory options by multiplying the estimating percentage change in fish saved by the regional implicit price for fish saved from Table 11-11. As noted above, EPA did not include the implicit price on the ASC within the benefits calculation. Once a preference function is estimated, the decision to include or exclude the ASC in subsequent welfare estimation must be made on a case-by-case basis; economic theory alone is insufficient to determine this choice (Adamowicz et al. 1998; Morrison et al. 2002). By excluding the ASC here (and other ecological attributes), EPA is presenting a clean estimate of WTP for fish saved alone, without other actual or possibly speculated benefits associated with reductions in IM&E. This approach is consistent with peer review comment that the exclusion of the ASC "…is not a problem for the annual household WTP estimated provided in the report for the regulatory options since these are calculated using only the marginal WTP for a one unit change in fish saved" (Applied Planning Corporation 2012, p. 34).

Total annual WTP for fish saved under each regulatory option is calculated by multiplying annual household WTP by the number of household in the region from Census 2010. EPA then discounted and annualized regional WTP using discount rates of 3 and 7 percent. Refer to Appendix D for additional regarding discounting and the compliance schedule. As stated previously, the boundaries of the SP survey regions differ slightly from the proposed rule regions. Because regional IM&E is a function of operational intake flow, EPA accounted for differences in regional boundaries by adjusting the proposed rule compliance schedule based on state-level AIF data by waterbody type (i.e., coastal/estuarine or freshwater).

11.9 Results for the Final Rule and Regulatory Options Considered

As noted previously, EPA considers it premature to include the SP survey results in the quantitative comparison of costs and benefits prior to completion of the SAB review. This section presents preliminary benefits for the final rule and options considered to illustrate the potential magnitude of regulatory benefits and demonstrate progress towards this effort.

Table 11-12 presents IM&E, percent fish saved, and WTP per household by regulatory option. Percent fish saved and mean household WTP for the final rule vary across regions, from less than one percent and less than $1 in the Pacific region to 56 percent and $28 in the Inland region. Percent fish saved and WTP per household are lower than the final rule under Proposal Option 4 and greater under Proposal Option 2.

Table 11-13 presents annualized benefits by regulatory option using both 3 percent and 7 percent discount rates. Total benefits under the final rule for all survey regions are $1.4 billion using a 3 percent discount rate and $1.1 billion using a 7 percent discount rate. Around half of the total benefits under the final rule are from the Inland Survey region. Total benefits under Proposal Option 4 are slightly less than the final rule using both 3 percent and 7 percent discount rates. Total benefits for Proposal Option 2 are $3.4 billion and $2.3 billion using 3 percent and 7 percent discount rates, respectively, and are greater than benefits under both Proposal Option 4 and the final rule.

Table 11-12: Reduction in A1E Losses, Percent Fish Saved and WTP per Household (2011$) by Survey Region for the Final Rule and Options Considered

Survey Version and Regulatory Option	IM&E		WTP per Household		
	Reduction in A1E Losses (in millions)	Fish Saved (%)[a]	5th	Mean	95th
Northeast					
Proposal Option 4	45.45	5.61%	$5.31	$8.06	$11.62
Final Rule	48.86	6.03%	$5.71	$8.66	$12.49
Proposal Option 2	512.53	63.23%	$59.91	$90.89	$130.99
Eliminating Baseline IM&E[b]	594.73	73.37%	$69.51	$105.47	$152.00
Southeast					
Proposal Option 4	218.96	29.92%	$12.49	$18.69	$24.96
Final Rule	228.54	31.23%	$13.04	$19.51	$26.06
Proposal Option 2	544.48	74.41%	$31.06	$46.47	$62.08
Eliminating Baseline IM&E[b]	663.79	90.72%	$37.87	$56.66	$75.68
Inland					
Proposal Option 4	348.47	51.98%	$14.53	$25.74	$36.46
Final Rule	373.25	55.68%	$15.56	$27.57	$39.05
Proposal Option 2	547.85	81.72%	$22.85	$40.46	$57.31
Eliminating Baseline IM&E[b]	619.58	92.42%	$25.84	$45.76	$64.82
Pacific[c]					
Proposal Option 4	1.28	0.37%	$0.40	$0.66	$0.97
Final Rule	1.36	0.39%	$0.42	$0.69	$1.03
Proposal Option 2	32.63	9.40%	$10.03	$16.65	$24.59
Eliminating Baseline IM&E[b]	52.87	15.23%	$16.25	$26.97	$39.84

[a] When calculating percent fish saved, EPA used a baseline which reflected current technology at regulated facilities including those facilities in CA and NY that are subject to state regulations. This differs from the rest of the benefits analysis, where EPA assigns these facilities baseline IM&E reductions commensurate with technologies required by the state regulations. This approach is consistent with the survey materials which were based on total IM&E. Fish saved under the elimination of baseline IM&E can be less than 100 percent because EPA does attribute IM&E reductions at facilities subject to state regulations to the existing facilities rule.
[b] This hypothetical scenario reflects the benefits that would be achieved if all IM&E were eliminated.
[c] The calculation of Fish Saved (%) for the Pacific survey region includes reductions in A1E losses at Hawaii facilities.
Source: U.S. EPA analysis for this report

Table 11-13: Annualized Monetized Benefits (millions of 2011$)						
Survey Version and Regulatory Option	3 % Discount Rate			7 % Discount Rate		
	5th	Mean	95th	5th	Mean	95th
Northeast						
Proposal Option 4	$90.6	$137.4	$198.1	$69.8	$105.9	$152.7
Final Rule	$97.4	$147.8	$212.9	$75.0	$113.9	$164.1
Proposal Option 2	$824.0	$1,250.1	$1,801.7	$535.6	$812.7	$1,171.2
Eliminating Baseline IM&E[a]	$1,545.1	$2,344.2	$3,378.6	$1,537.4	$2,332.5	$3,361.7
Southeast						
Proposal Option 4	$297.1	$444.5	$593.7	$229.6	$343.6	$458.9
Final Rule	$310.2	$464.0	$619.8	$239.7	$358.7	$479.1
Proposal Option 2	$634.4	$949.1	$1,267.8	$422.9	$632.8	$845.2
Eliminating Baseline IM&E[a]	$1,167.4	$1,746.6	$2,333.0	$1,161.6	$1,737.8	$2,321.3
Inland						
Proposal Option 4	$436.7	$773.4	$1,095.6	$339.5	$601.2	$851.7
Final Rule	$468.0	$828.8	$1,174.0	$363.8	$644.2	$912.6
Proposal Option 2	$603.1	$1,068.2	$1,513.1	$414.3	$733.7	$1,039.3
Eliminating Baseline IM&E[a]	$1,006.9	$1,783.3	$2,526.1	$1,001.9	$1,774.3	$2,513.5
Pacific[b]						
Proposal Option 4	$4.7	$7.8	$11.5	$3.7	$6.1	$9.0
Final Rule	$5.0	$8.2	$12.1	$3.9	$6.5	$9.5
Proposal Option 2	$98.3	$163.2	$241.0	$69.5	$115.4	$170.4
Eliminating Baseline IM&E[a]	$251.8	$418.0	$617.3	$250.6	$415.9	$614.2
Total for Regional Surveys						
Proposal Option 4	$829.1	$1,363.1	$1,898.8	$642.6	$1,056.8	$1,472.2
Final Rule	$880.5	$1,448.8	$2,019.0	$682.5	$1,123.2	$1,565.3
Proposal Option 2	$2,159.9	$3,430.7	$4,823.7	$1,442.4	$2,294.5	$3,226.1
Eliminating Baseline IM&E[a]	$3,971.3	$6,292.0	$8,854.9	$3,951.4	$6,260.5	$8,810.6

[a] This hypothetical scenario reflects the benefits that would be achieved if all IM&E were to be eliminated.
[b] The calculation of benefits for the Pacific survey region excludes households in Hawaii because Hawaii households were not included in the mail survey sample.
Source: U.S. EPA analysis for this report

11.10 Uncertainties

SP methods have "… been tested and validated through years of research and are widely accepted by … government agencies and the U.S. courts as reliable techniques for estimating non-market values" (Bergstrom and Ready 2009, p. 26). OMB's Circular A-4 notes that SP results "have also been widely used in regulatory analyses by Federal agencies" (USOMB 2003, p. 22). EPA's own peer-reviewed *Guidelines for Preparing Economic Analysis* (USEPA 2010a) indicate that the use of SP study data, when the study is conducted properly in accord with best current practices, is the only potential method for monetizing non-use values. However, EPA recognizes that controversy remains over the use of stated preference results in benefit-cost analysis for rulemaking, at least in this particular instance. Consistent with established best practices for SP surveys, EPA has sought to minimize possible biases by careful and thorough construction and testing of the survey instrument.

While in EPA's view, the study incorporates current best professional practice in the conduct of SP studies, EPA acknowledges that the results of any empirical study depend on the methodology applied. The Agency recognizes that potential biases may still remain and may influence the results of the study. The magnitude and direction of any effects on benefits estimates is unknown. Refer to the "Peer Review Report – 316(b) Stated Preference Survey Report Document (Final Submission)" (Applied Planning Corporation 2012) in the 316(b) rulemaking docket for additional detail on the external peer review process and peer reviewer comments. EPA notes that its analysis of the survey data and models is ongoing. EPA plans to obtain SAB review of the SP survey EPA conducted. SAB review will provide additional high caliber, independent professional judgment concerning the quality of the survey done to date, including possible improvements EPA could make. EPA is also seeking SAB input on whether, how, and in what circumstances this or similar surveys could be used, as support for national rulemakings or 316(b) NPDES.

12 Analysis of New Units at Existing Facilities

12.1 Introduction

In addition to the analysis presented in the preceding chapters for existing units at regulated facilities, EPA analyzed benefits for new units at existing facilities. The new unit provision of the final rule applies to newly constructed electric power generating units at existing facilities and repowering of existing generating units where the turbine and condenser are replaced. Unlike the case for the existing unit provision, EPA cannot predict the facilities at which such new or repowered units will be constructed, or the number and size of new or repowered units that will be constructed. Instead, EPA estimated the potential coverage of the new unit provision of the final rule based on the quantity of electric power generating capacity that will be installed and subject to the new unit provision in future years. In addition, EPA considered a range of options for the final rule's new unit provision, each of which would cover a different quantity of new units capacity.

- **Option A:** Entrainment performance requirements for all stand-alone new units and all types of repowered units.
- **Option B:** Entrainment performance requirements for all stand-alone new units, and replaced or repowered units in which turbine or condenser are newly built or replaced.
- **Option C:** Entrainment performance requirements for all stand-alone new units, and repowered new units where the turbine and condenser are newly built or replaced, but excluding high efficiency systems.
- **Final Rule – New Units (Option D):** Entrainment performance requirements for all stand-alone new units only.

This chapter presents EPA's benefits analysis under the final rule and options considered for new units. Section 12.2 presents EPA's analysis of IM&E reductions and associated benefits. Section 12.3 presents EPA's analysis of GHG emissions reductions and associated benefits. Section 12.3 summarizes monetized benefits for new units including benefits associated with IM&E reductions and GHG emissions reductions. Refer to Chapter 8 of the Technical Development Document (TDD) for additional information on the engineering analysis for new units.

12.2 Analysis Approach and Benefits for IM&E Reductions at New Units

EPA's methodology for estimating IM&E reductions at existing units involves extrapolating facility-specific data to other existing facilities within the same region. EPA could not apply the existing units methodology directly to new units because facility-specific information is unavailable for new units. Instead, EPA estimated per mgd IM&E reductions and the monetary value of benefits for new units based on the analysis of existing units.

12.2.1 Flow Reductions at New Units

The engineering analysis provided the annual reduction in intake flow at CWIS nationally under the final rule and options considered for new units. The annual flow reductions are cumulative over the analysis period. For example, an annual flow reduction of 10 mgd would mean a reduction of 10 mgd in year 1, 20 mgd (10 mgd × 2) by year 2, 30 mgd (10 mgd × 3) by year 3, and so on. The flow reductions are projected to begin in 2014 and end in 2059, the final year of the compliance period. The peak, or maximum, flow reduction is the flow reduction achieved in 2059. EPA included a declining profile at the end of the compliance period for recreational and commercial fishing, nonuse, and T&E species benefits consistent with the analyses for existing units.

Table 12-1 presents the estimated annual and peak flow reductions at new units under the final rule and options considered for new units. The final rule will result in an annual flow reduction of 68 mgd, with a total peak flow reduction of 3,128 mgd nationally in 2059. Refer to Appendix D for additional discussion of the compliance schedule.

Table 12-1: Flow Reductions for New Units Under the Final Rule for New Units and Options Considered (mgd)

Option	Annual Flow Reduction	Peak Flow Reduction
Option A	1,282	58,972
Option B	462	21,252
Option C	68	3,128
Final Rule – New Units	7	322

Source: U.S. EPA analysis for this report

12.2.2 IM&E Reductions and Associated Benefits per MGD

EPA calculated the reduction in IM&E per mgd of flow reduction nationally by dividing estimated baseline IM&E losses at existing facilities by baseline weighted AIF (in mgd). EPA also calculated *benefits* per mgd by dividing the monetized value of baseline IM&E losses by baseline weighted AIF (in mgd). EPA calculated separate per mgd values by loss mode (impingement mortality versus entrainment) in order to account for differences in baseline IM technology across new and existing units. EPA assumed that, in the absence of the rule for new units, baseline best professional judgment requirements imposed by permitting authorities for once-through cooling would be equivalent to modified Ristroph screens or intake velocity of 0.5 feet per second.

Table 12-2 presents the annual IM&E reductions per mgd and Table 12-3 presents annual benefits per mgd, both by loss mode. The benefits values underlying Table 11-3 are based on benefits estimation methods described in the Chapter 5 through 8. EPA notes that these are partial benefits estimates for the final rule and options considered because EPA was unable to estimate nonuse benefits for five of seven regions using the benefits transfer approach described in Chapter 8.

Table 12-4 presents annual benefits per mgd by loss mode based on EPA's SP survey.[75] As discussed in Chapter 11, EPA does not include benefits estimates based on the SP survey in its quantitative comparison of benefits and costs for the final rule. The survey values are presented here for illustrative purposes. EPA also notes the SP survey was designed to assess existing, rather than new units. All values and maps presented in the survey reflected only existing units.

[75] Per mgd values for the SP survey were calculated using the sum of regional survey versions.

EPA calculated IM&E reductions and benefits for each year of the analysis period by multiplying the IM flow reduction and E flow reduction in that year by the respective "per mgd" values. EPA summed across loss modes to generate total IM&E reductions and benefits for each year. EPA discounted and annualized benefits using 3 percent and 7 percent discount rates.

Table 12-2: Annual IM&E Reductions per MGD of Flow Reduction for New Units by Loss Mode[a]

IM&E Loss Mode	A1E per mgd			Commercial and Recreational Harvest (fish per mgd)
	Forage Species	Commercial and Recreational Species	All Species	
IM	4,340	712	5,052	133
E	4,069	1,922	5,991	175

Notes:
IM = impingement mortality; E = entrainment; A1E = age-one equivalent; mgd = millions of gallons per day
[a]EPA calculated the reduction in IM&E per mgd of flow reduction nationally by dividing estimated baseline IM&E losses at existing facilities by baseline weighted AIF (in mgd).
Source: U.S. EPA analysis for this report

Table 12-3: Annual Benefits per MGD of Flow Reduction for New Units by Loss Mode (2011$)[a]

IM&E Loss Mode	Recreational			Commercial	T&E	Nonuse
	Low	Mean	High			
IM	$112	$216	$426	$11	$5	$4
E	$173	$304	$551	$41	$3	$562

Notes:
IM = impingement mortality; E = entrainment
[a] EPA calculated benefits per mgd by dividing the monetized value of baseline IM&E losses at existing facilities by baseline weighted AIF (in mgd).
[b] Benefits presented in this table do not include benefits associated with changes in greenhouse gas emissions.
Source: U.S. EPA analysis for this report

Table 12-4: Annual Benefits per MGD of Flow Reduction for New Units by Loss Mode based on the SP Survey (2011$)[a]

IM&E Loss Mode	5th Percentile	Mean	95th Percentile
IM	$9,117	$15,042	$20,950
E	$15,142	$23,464	$33,214

Notes:
IM = impingement mortality; E = entrainment
[a] EPA calculated benefits per mgd based on the SP survey by dividing the estimated value of baseline IM&E losses at existing facilities by baseline weighted AIF (in mgd).
Source: U.S. EPA analysis for this report

12.2.3 IM&E Reductions and Associated Benefits under the final Rule and Options Considered for New Units

Table 12-5 summarizes national IM&E reductions under the final rule for new units and options considered. IM&E reductions will increase throughout the compliance period. The values presented in Table 12-5 reflect the peak reduction achieved in 2059, the final year of the compliance period. The final rule for new units will result in a peak reduction of about 2.3 million A1E.

Table 12-5: National IM&E Reductions under the Final Rule and Options Considered for New Units[a]

Regulatory Option	A1E (in millions)			Commercial and Recreational Harvest (millions of fish)
	Forage Species	Commercial and Recreational Species	All Species	
Option A	303.94	123.86	427.81	12.28
Option B	109.53	44.64	154.17	4.43
Option C	16.12	6.57	22.69	0.65
Final Rule - New Units	1.66	0.68	2.34	0.07

Notes:
A1E = age-one equivalent
[a] The IM&E reductions presented in this table reflect the peak reduction achieved in 2059, the final year of the compliance period.
Source: U.S. EPA analysis for this report

Table 12-6 presents national annualized benefits under the final rule and options considered for new units based on the benefits estimation methods described in Chapters 5 through 8. Mean annualized benefits under the final rule for new units will be $0.1 million using a 3 percent discount rate and less than $0.1 million using a 7 percent discount rate. Annualized benefits under other options considered for new units range from $1.1 to $21.4 million using a 3 percent discount rate and $0.8 to $14.5 million using a 7 percent discount rate.

Table 12-7 presents national benefits for new units based on the results of the SP survey. Using the SP survey, mean annualized benefits under the final rule for new units would be$3.3 million using a 3 percent discount rate and $2.3 million using a 7 percent discount rate. Mean annualized benefits under other options considered for new units range from $31.6 to $596.7 million using a 3 percent discount rate and from $22.4 to $423.1 million using a 7 percent discount rate. As noted above, EPA has presented benefits estimates based the SP survey for illustrative purposes and does not include values based on the SP survey in its quantitative comparison of costs and benefits for the rule.

Table 12-6: National Annualized Benefits for IM&E Reductions under the Final Rule and Options Considered for New Units (2011$, 1,000s)

Regulatory Option	Recreational			Commercial	T&E	Nonuse	Total Benefits		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
Option A	$4,138.2	$7,370.2	$13,553.0	$893.6	$90.7	$13,077.4	$18,199.9	$21,431.9	$27,614.7
Option B	$1,491.3	$2,656.0	$4,884.1	$322.0	$32.7	$4,712.8	$6,558.8	$7,723.5	$9,951.6
Option C	$219.5	$390.9	$718.9	$47.4	$4.8	$693.7	$965.4	$1,136.8	$1,464.7
Final Rule-New Units	$22.6	$40.2	$74.0	$4.9	$0.5	$71.4	$99.4	$117.0	$150.8
7% Discount Rate									
Option A	$2,722.0	$4,848.0	$8,914.9	$587.8	$59.7	$8,958.6	$12,328.0	$14,454.0	$18,520.9
Option B	$980.9	$1,747.1	$3,212.7	$211.8	$21.5	$3,228.4	$4,442.7	$5,208.9	$6,674.5
Option C	$144.4	$257.1	$472.9	$31.2	$3.2	$475.2	$653.9	$766.7	$982.4
Final Rule-New Units	$14.9	$26.5	$48.7	$3.2	$0.3	$48.9	$67.3	$78.9	$101.1

Source: U.S. EPA analysis for this report

Table 12-7: National Annualized Benefits for IM&E Reductions under the Final Rule and Options Considered for New Units based on the SP Survey (2011$, millions)

Regulatory Option	5th Percentile	Mean	95th Percentile
3 % Discount Rate			
Option A	$381.8	$596.7	$842.7
Option B	$137.6	$215.0	$303.7
Option C	$20.3	$31.6	$44.7
Final Rule-New Units	$2.1	$3.3	$4.6
7 % Discount Rate			
Option A	$270.7	$423.1	$597.5
Option B	$97.6	$152.5	$215.3
Option C	$14.4	$22.4	$31.7
Final Rule-New Units	$1.5	$2.3	$3.3

Source: U.S. EPA analysis for this report

12.2.4 Limitations and Uncertainties for the Analysis of IM&E Reductions and Associated Benefits for New Units

EPA's methodology for analyzing benefits from reducing IM&E at new units relies on the estimated IM&E reductions and monetary benefits from the analysis of existing units. Thus, it is subject to limitations and uncertainties inherent in the EPA's methodology for existing units. Refer to Section 3.4 for a discussion of limitations and uncertainties in EPA's analysis of IM&E for existing units and Chapters 5 through 8 for monetary benefits, and Chapter 11 for the SP survey. Additional limitations and uncertainties specific to EPA's analysis of new units also apply. These are addressed below in Table 12-8.

Table 12-8: Limitations and Uncertainties in EPA's Analysis of IM&E Reductions and Associated Benefits at New Units

Issue	Impact on Benefits Estimate	Comments
National rather than regional flow reductions	Uncertain	EPA's analysis for existing units examined IM&E and the economic benefits of reducing these losses at a regional scale. To obtain regional IM&E estimates, EPA extrapolated losses observed at model facilities to existing units at regulated facilities within the same region. Regional flow reductions were unavailable for new units; therefore, EPA extrapolated per mgd benefits to new units based on national benefits and national weighted flow from the analysis for existing units. This assumption could lead to the over- or under-estimation of benefits for new units depending on their ultimate regional distribution.
Timing of flow reductions	Uncertain	The annual flow reduction for new units is constant with the total flow reduction increasing linearly over the compliance period. As a result, peak IM&E is not achieved until the 2059, the final year of the compliance period. This assumption would tend to under-estimate annualized benefits if the new units come into operation sooner than projected and over-estimate benefits if they come into operation later than projected.
Engineering uncertainty	Uncertain	EPA's evaluation of IM&E was also affected by uncertainty about the engineering and operating characteristics of the new units. Units defined as "new" under the rule would be required to meet equivalent performance to closed-cycle recirculating systems. EPA expects that most new units will install wet cooling towers. EPA may over- or under-estimate benefits for new units if the flow at new units and percentage flow reduction due to the rule deviate from EPA's assumptions. Refer to Chapter 8 of the TDD for additional information on the engineering analysis for new units and potential uncertainties.

12.3 Analysis of Social Cost of Carbon for New Units

Because EPA does not expect Electric Generators to shut down to install cooling towers at new units, for new units, EPA estimated the change in CO_2 resulting from the energy penalty only. Energy penalty effects result from reduced energy conversion efficiency of the power generating system. Refer to Appendix I of the economic analysis for the final rule (USEPA 2014) for additional detail on compliance technology effects that impose costs via impact on revenue or energy requirements.

12.3.1 Analysis Approach and Data Inputs

EPA estimated the monetary value of higher CO_2 emissions resulting from auxiliary energy requirements associated with operating cooling towers as follows:

- EPA first calculated the amount of additional electricity (in MWh) required to operate cooling towers at new units, assuming Electric Generators would incur this additional energy requirement beginning in the first year any new generating unit would begin to operate a cooling tower, i.e., 2017, through 2059.[76]

[76] As discussed in *Chapter 3* of the Economic Analysis, EPA estimates that facilities will require four years to install cooling towers. EPA assumed that 2014 will be the first year when any Electric Generator will begin installation of its cooling tower according to the new unit provision of the final rule.

- EPA next estimated the amount of fuel required to generate this additional electricity (in BTUs). The Agency assumed that existing facilities will be able to generate additional electricity onsite, i.e., at new units at those facilities. EPA estimated additional fuel requirement for coal and combined cycle natural gas units by multiplying the additional energy requirement by heat rates for coal and combined cycle natural gas electric generating units, respectively.[77]
- The Agency then multiplied the resulting fuel usage values by coal or natural gas carbon dioxide emissions coefficients published by EIA (USDOE 2013c), depending on the new unit type, to estimate an increase in CO_2 emissions due to the energy penalty.[78]
- Finally, EPA multiplied the estimated CO_2 emission values, by year, by the same unit SCC values as those used for Electric Generators (Table 9-3).

12.3.2 Key Findings for Regulatory Options

Table 12-9 presents the total reduction in CO_2 emissions and associated SCC values in 2013 for new units at Electric Generators, by option and discount rate. EPA estimates that the new unit provision of the final rule will result in a *total* increase of 0.3 million of tCO2eq. Using the 3 percent average SCC values, EPA estimates the *average annual* benefit associated with this increase in carbon emissions to be -\$0.3 million at the 3 percent discount rate and -\$0.2 million at the 7 percent discount rate. EPA estimates that under the other new units options considered – Options A, B, and C –*total* carbon emissions would increase by 22.0, 8.9, and 2.0 million of tCO2eq, respectively. Using the 3 percent average SCC values, EPA estimates the *average annual* benefit associated with these increases in carbon emissions to be -\$22.5 million, -\$9.1 million, and -\$2.1 million at the 3 percent discount rate and -\$13.8 million, -\$5.6 million, and -\$1.3 million at the 7 percent discount rate, respectively.

Table 12-9: Reduction in Carbon Emissions and Associated Average Annual Benefits - New Units (SCC Values in 2013; \$2011, millions)

Option	Total Emissions (Millions; tCO2eq)	Discount Rate for Calculating SCC Unit Values			
		2.5%	3%		5%
		Average SCC Value	Average SCC Value	High SCC Value	Average SCC Value
3% Discount Rate for Annualizing Benefits					
Option A	-22.0	-\$31.3	-\$22.5	-\$69.7	-\$7.7
Option B	-8.9	-\$12.6	-\$9.1	-\$28.1	-\$3.1
Option C	-2.0	-\$2.9	-\$2.1	-\$6.4	-\$0.7
Final Rule – New Units	-0.3	-\$0.4	-\$0.3	-\$0.9	-\$0.1
7% Discount Rate for Annualizing Benefits					
Option A	-22.0	-\$19.5	-\$13.8	-\$42.8	-\$4.6
Option B	-8.9	-\$7.9	-\$5.6	-\$17.2	-\$1.9
Option C	-2.0	-\$1.8	-\$1.3	-\$3.9	-\$0.4
Final Rule – New Units	-0.3	-\$0.3	-\$0.2	-\$0.6	-\$0.1
Source: U.S. EPA analysis for this report					

77 EPA used heat rates based on higher heating values (HHV) of fuel.

78 For details see Carbon Dioxide Emissions Coefficients by Fuel published on February 14, 2013 available online at http://www.eia.gov/environment/emissions/co2_vol_mass.cfm.

12.4 Monetized Benefits for New Units

Table 12-10 summarizes the annual monetized benefits associated with IM&E reductions and changes in GHG emissions for new units. Using 3 percent average SCC values, mean annualized benefits for the final rule for new units are -$0.2 million using a 3 percent discount rate and -$0.1 million using a 7 percent discount rate. Benefits for other options considered for new units range from -$0.9 to -$1.1 million using a 3 percent discount rate and -$0.5 to $0.6 million using a 7 percent discount rate.

Table 12-10: National Annualized Benefits under the Final Rule and Options Considered for New Units (2011$, millions)

Regulatory Option	Recreational			Commercial	T&E	Nonuse	Total Benefits		
	Low	Mean	High				Low	Mean	High
3% Discount Rate									
Option A	$4,138.2	$7,370.2	$13,553.0	$893.6	$90.7	$13,077.4	$18,199.9	$21,431.9	$27,614.7
Option B	$1,491.3	$2,656.0	$4,884.1	$322.0	$32.7	$4,712.8	$6,558.8	$7,723.5	$9,951.6
Option C	$219.5	$390.9	$718.9	$47.4	$4.8	$693.7	$965.4	$1,136.8	$1,464.7
Final Rule-New Units	$22.6	$40.2	$74.0	$4.9	$0.5	$71.4	$99.4	$117.0	$150.8
7% Discount Rate									
Option A	$2,722.0	$4,848.0	$8,914.9	$587.8	$59.7	$8,958.6	$12,328.0	$14,454.0	$18,520.9
Option B	$980.9	$1,747.1	$3,212.7	$211.8	$21.5	$3,228.4	$4,442.7	$5,208.9	$6,674.5
Option C	$144.4	$257.1	$472.9	$31.2	$3.2	$475.2	$653.9	$766.7	$982.4
Final Rule-New Units	$14.9	$26.5	$48.7	$3.2	$0.3	$48.9	$67.3	$78.9	$101.1

Source: U.S. EPA analysis for this report

13 Summary of National IM&E Reductions and Benefits for Existing and New Units

13.1 Introduction

This chapter summarizes the results of the seven regional analyses, and presents EPA's estimates of the national benefits of the final rule and options considered for new and existing units at regulated facilities. As described in Chapter 1, EPA considered three options for the existing units based on two technologies:

- **Proposal Option 4: IM for Facilities > 50 mgd.** Establish impingement mortality controls at all existing facilities that withdraw over 50 mgd; determine entrainment controls for facilities greater than 2 mgd DIF on a site-specific basis.
- **Final Rule – Existing Units: IM Everywhere.** Establish impingement mortality controls at all existing facilities that withdraw over 2 mgd; determine entrainment controls for facilities greater than 2 mgd DIF on a site-specific basis.
- **Proposal Option 2: IM Everywhere and E for Facilities > 125 mgd.** Establish impingement mortality controls at all existing facilities that withdraw over 2 mgd DIF; require flow reduction commensurate with closed-cycle recirculating system for entrainment control by facilities greater than 125 mgd DIF.

The final rule will establish entrainment controls for facility greater than 2 mgd DIF on a site-specific basis, as would Proposal Option 4. EPA did not analyze entrainment benefits under the final rule or Proposal Option 4 because entrainment requirements are site specific.

EPA considered four regulatory options for new units at existing facilities:

- **Option A:** Entrainment performance requirements for all stand-alone new units and all types of repowered units.
- **Option B:** Entrainment performance requirements for all stand-alone new units, and replaced or repowered units in which the turbine or condenser are newly built or replaced.
- **Option C:** Entrainment performance requirements for all stand-alone new units, and repowered new units where the turbine and condenser are newly built or replaced, but excluding high efficiency systems.
- **Final Rule – New Units (Option D):** Entrainment performance requirements for all stand-alone new units only.

Refer to Section VI of the preamble for additional description of the final rule and other options considered for existing and new units.

Section 13.2 describes EPA's methodology for aggregating benefits at the national level; Section 13.3 summarizes baseline IM&E and estimated reductions in IM&E under the final rule and options considered; Section 13.4 presents national benefits; and Section 13.5 summarizes results of the SP survey, and Section 13.6 discusses nonuse benefits and presents a break-even analysis.

13.2 Summary of Limitations and Uncertainties

EPA notes that quantifying and monetizing the benefits that result from reductions in IM&E and GHG emissions under the final rule and options considered for the existing facilities rule is challenging. The preceding sections discuss specific limitations and uncertainties associated with estimating reductions in IM&E and monetized benefits. EPA estimated national-level benefits associated with IM&E reductions by summing benefit estimates over the seven study regions. Thus, national benefit estimates are subject to the same uncertainties inherent in the valuation approaches EPA used for assessing each of the four benefit categories associated with IM&E reductions (threatened and endangered species, commercial fishing, recreational fishing, and nonuse values). The combined effect of these uncertainties is of unknown magnitude and direction (i.e., the estimates may over- or understate the anticipated national level of use benefits). Nevertheless, EPA has no data to indicate that the results for any of the benefit categories are atypical or unreasonable. EPA's analysis of changes in GHG emissions and associated benefits was conducted at the national level, regional benefits were not estimated. EPA calculated national benefits based on the SP survey estimates by summing results for the four SP survey regions. As noted above, estimates based on EPA's SP survey are included to illustrate the potential magnitude of total values of ecological improvements resulting from the final rule.

13.3 Summary of Baseline IM&E Losses and IM&E Reductions

Based on the results of the regional analyses, EPA calculated total IM&E under baseline (i.e., pre-regulatory) conditions and the total amount by which losses would be reduced under the final rule and options considered. The number of fish lost at regulated facilities is presented in terms of A1E losses (i.e., the number of individual fish of different ages impinged and entrained by facility intakes, expressed as A1E).

Table 13-1 presents baseline impingement, entrainment, and total IM&E for existing units. The table shows that total national annual losses for all regulated facilities are 1.9 billion fish in terms of A1E. EPA notes that the count of total lost organisms is larger than values expressed in A1E. This table shows that about 39 percent, or 0.8 billion fish of all A1E losses, occur in the Inland region, followed by the Mid-Atlantic region with 0.6 billion fish lost. Chapter 3 provides a more detailed discussion of IM&E in each region.

Table 13-1: Baseline National A1E Losses at All Regulated Facilities (millions of A1E)

Region	IM	E	IM&E
California	1.1	50.4	51.5
North Atlantic	0.6	57.2	57.9
Mid-Atlantic	39.1	591.9	631.0
South Atlantic	17.1	9.2	26.4
Gulf of Mexico	53.5	93.5	147.0
Great Lakes	236.7	24.6	261.3
Inland	476.0	279.9	756.0
Total	**824.2**	**1,106.7**	**1,931.0**

Notes:
A1E = age-one equivalent; IM = impingement mortality; E = entrainment; IM&E = impingement mortality and entrainment
Source: U.S. EPA analysis for this report

EPA also calculated the total national IM&E avoided based on the expected reductions in IM&E at each facility due to technology installation required by the final rule and under each option considered. Table 13-2 through Table 13-4 present expected annual reductions at existing units, expressed as A1E, by region. The final rule will reduce annual A1E losses by 0.7 billion fish existing units. In comparison, Proposal Option 4 would reduce A1E losses by 0.6 billion fish and Proposal Option 2 would reduce annual A1E losses by 1.6 billion fish. Table 13-5 presents reductions in A1E losses for the final rule and options considered for new units. The final rule, including both new and existing units, will reduce A1E losses by 0.7 billion fish (Table 13-6).

Table 13-2: Reductions in National A1E Losses for All Regulated Facilities (millions of A1E) under Proposal Option 4

Region	IM	E	IM&E
California	0.7	<0.01	0.7
North Atlantic	0.4	<0.01	0.4
Mid-Atlantic	29.6	0.93	30.5
South Atlantic	11.6	<0.01	11.6
Gulf of Mexico	38.7	0.08	38.8
Great Lakes	184.0	0.02	184.0
Inland	347.7	0.39	348.1
Total	**612.8**	**1.41**	**614.2**

Notes:
A1E = age-one equivalent; IM = impingement mortality; E = entrainment; IM&E = impingement mortality and entrainment
Source: U.S. EPA analysis for this report

Table 13-3: Reductions in National A1E Losses for All Regulated Facilities (millions of A1E) under the Final Rule

Region	IM	E	IM&E
California	0.7	<0.01	0.7
North Atlantic	0.4	0.51	0.9
Mid-Atlantic	31.6	1.40	33.0
South Atlantic	12.4	0.48	12.9
Gulf of Mexico	40.2	0.08	40.3
Great Lakes	202.5	0.06	202.6
Inland	359.6	2.00	361.6
Total	**647.5**	**4.53**	**652.0**

Notes:
A1E = age-one equivalent; IM = impingement mortality; E = entrainment; IM&E = impingement mortality and entrainment
Source: U.S. EPA analysis for this report

Table 13-4: Reductions in National A1E Losses for All Regulated Facilities (millions of A1E) under Proposal Option 2

Region	IM	E	IM&E
California	0.8	30.8	31.5
North Atlantic	0.6	43.8	44.4
Mid-Atlantic	36.1	515.8	551.9
South Atlantic	17.0	8.6	25.6
Gulf of Mexico	48.2	55.2	103.4
Great Lakes	230.8	17.7	248.5
Inland	414.7	217.4	632.2
Total	**748.2**	**889.3**	**1,637.5**

Notes:
A1E = age-one equivalent; IM = impingement mortality; E = entrainment; IM&E = impingement mortality and entrainment
Source: U.S. EPA analysis for this report

Table 13-5: Reductions in National A1E Reductions under the Final Rule and Options Considered for New Units (millions of A1E)			
Regulatory Option	**IM**	**E**	**IM&E**
Option A	74.5	353.3	427.8
Option B	26.8	127.3	154.2
Option C	4.0	18.7	22.7
Final Rule - New Units	0.4	1.9	2.3

Notes:
A1E = age-one equivalent; IM = impingement mortality; E = entrainment; IM&E = impingement mortality and entrainment
Source: U.S. EPA analysis for this report

Table 13-6: Reductions in National A1E Reductions under the Final Rule – Existing and New Units (millions of A1E)			
Regulatory Option	**IM**	**E**	**IM&E**
Final Rule-Existing Units	647.5	4.5	652.0
Final Rule-New Units	0.4	1.9	2.3
Final Rule-Existing and New Untis	647.9	6.5	654.3

Notes:
A1E = age-one equivalent; IM = impingement mortality; E = entrainment; IM&E = impingement mortality and entrainment
Source: U.S. EPA analysis for this report

Table 13-7 presents EPA's estimates of the current level of total annual IM&E and the reduction in total annual IM&E for the baseline, final rule and other options considered for existing units using the three metrics presented in Section 3.2.2. The final rule will provide greater IM&E reductions at existing units than Proposal Option 4, but lesser IM&E reductions than Proposal Option 2. Table 13-8 presents IM&E reductions under the final rule and other options considered for new units according to the same metrics as Table 13-7. The final rule, including both new and existing units, will reduce annual foregone fishery yield by 13.5 million pounds and annual biomass prodution foregone by 139.8 million pounds (Table 13-9).

Table 13-7: Baseline National IM&E and IM&E Reductions for Regulated Facilities for the Final Rule and Options Considered			
Regulatory Option	**Millions of A1E**	**Foregone Fishery Yield (million lbs)[a]**	**Biomass Production Forgone (million lbs)**
Proposal Option 4	614.2	12.6	130.3
Final Rule-Existing Units	652.0	13.4	138.9
Proposal Option 2	1,637.5	51.1	494.2
Baseline	1,931.0	69.8	626.6

Notes:
A1E = age-one equivalents
[a] The reductions in foregone fishery yield presented here are equal to increases in commercial and recreational harvest. Refer to Chapter 3 for additional detail regarding the calculation of foregone fishery yield and biomass production forgone.
Source: U.S. EPA analysis for this report

Table 13-8: Reductions in IM&E under the Final Rule and Options Considered for New Units

Regulatory Option	Millions of A1E	Foregone Fishery Yield (million lbs)[a]	Biomass Production Forgone (million lbs)
Option A	427.8	18.4	160.0
Option B	154.2	6.6	57.7
Option C	22.7	1.0	8.5
Final Rule-New Units	2.3	0.1	0.9

Notes:
A1E = age-one equivalents
[a] The reductions in foregone fishery yield presented here are equal to increases in commercial and recreational harvest. Refer to Chapter 3 for additional detail regarding the calculation of foregone fishery yield and biomass production forgone.
Source: U.S. EPA analysis for this report

Table 13-9: Reductions in IM&E under the Final Rule – Existing and New Units

Regulatory Option	Millions of A1E	Foregone Fishery Yield (million lbs)[a]	Biomass Production Forgone (million lbs)
Final Rule-Existing Units	652.0	13.4	138.9
Final Rule-New Units	2.3	0.1	0.9
Final Rule-Existing and New Units	654.3	13.5	139.8

Notes:
A1E = age-one equivalents
[a] The reductions in foregone fishery yield presented here are equal to increases in commercial and recreational harvest. Refer to Chapter 3 for additional detail regarding the calculation of foregone fishery yield and biomass production forgone.
Source: U.S. EPA analysis for this report

As shown for all regions in Table 13-10, Table 13-11, Table 13-12, and by region in Chapter 3, the harvested commercial and recreational fish species that have direct use values comprise between 1 and 9 percent of baseline IM&E in each region, resulting in a national average of only 3 percent of IM&E for which EPA monetized value based on direct use. The remaining 97 percent of IM&E includes unharvested recreational and commercial fish and forage fish which are not associated with direct use. EPA's nonuse benefit transfer was limited to two of the seven benefits regions, and EPA did not include nonuse values for unharvested fish in its primary benefits analysis for the remaining five regions. Thus, EPA has likely understated the total benefits significantly due to the regional limitations of its nonuse analysis and the relatively large fraction of IM&E reductions which are not commercially or recreationally harvested.

Table 13-10: Distribution of National IM&E Reduction for Existing Units for All Regulated Facilities for the Final Rule and Other Regulatory Options Considered

Regulatory Option	All Species (millions of A1E)	Forage Species (millions of A1E)	Commercial and Recreational Species (millions of A1E)	Commercial and Recreational Harvest (millions of fish harvested)	Percent of Fish with Monetized Use Value[a]
Proposal Option 4	614.2	528.2	85.9	16.1	2.6%
Final Rule - Existing Units	652.0	560.8	91.2	17.1	2.6%
Proposal Option 2	1,637.5	1,258.7	378.8	44.7	2.7%
Baseline	1,931.0	1,459.7	471.3	54.0	2.8%

Notes:
A1E = age-one equivalent
[a] "Percent of fish with monetized use value" is equal to "commercial and recreational harvest (millions of fish harvested)" divided by "all species (millions of A1E)."
Source: U.S. EPA Analysis for this report

Table 13-11: Distribution of National IM&E Reductions under the Final Rule and Options Considered for New Units

Regulatory Option	All Species (millions of A1E)	Forage Species (millions of A1E)	Commercial and Recreational Species (millions of A1E)	Commercial and Recreational Harvest (millions of fish harvested)	Percent of Fish with Monetized Use Value[a]
Option A	427.8	303.9	123.9	12.3	2.9%
Option B	154.2	109.5	44.6	4.4	2.9%
Option C	22.7	16.1	6.6	0.7	2.9%
Final Rule - New Units	2.3	1.7	0.7	0.1	2.9%

Notes:
A1E = age-one equivalent
[a] "Percent of fish with monetized use value" is equal to "commercial and recreational harvest (millions of fish harvested)" divided by "all species (millions of A1E)."
Source: U.S. EPA Analysis for this report

Table 13-12: Distribution of National IM&E Reductions under the Final Rule – Existing and New Units

Regulatory Option	All Species (millions of A1E)	Forage Species (millions of A1E)	Commercial and Recreational Species (millions of A1E)	Commercial and Recreational Harvest (millions of fish harvested)	Percent of Fish with Monetized Use Value[a]
Final Rule-Existing Units	652.0	560.8	91.2	17.1	2.6%
Final Rule-New Units	2.3	1.7	0.7	0.1	2.9%
Final Rule-Existing and New Units	654.3	562.5	91.9	17.2	2.9%

Notes:
A1E = age-one equivalent
[a] "Percent of fish with monetized use value" is equal to "commercial and recreational harvest (millions of fish harvested)" divided by "all species (millions of A1E)."
Source: U.S. EPA Analysis for this report

13.4 Summary of National Monetized Benefits

EPA based its estimates of total national baseline losses and total national benefits associated with IM&E reductions under the final rule and options considered on its estimates of regional monetized baseline losses and final rule and regulatory option benefits. To address the differences in the timing of benefits and costs, EPA developed a time profile of total benefits from all regulated facilities that reflects when benefits from compliance-related changes at each facility will be realized. EPA then discounted and annualized benefits using 3 percent and 7 percent discount rates.[79] Appendix D of this report provides detail on EPA's development of the timeline of benefits.

EPA estimated mean national use values, as well as values that include the 5th percentile lower bound and 95th percentile upper bound of the recreational benefit estimates.[80] Table 13-13 and Table 13-14 present these results for each region and for the nation as a whole. The national benefit estimates do not include benefits based on EPA's SP survey presented in Chapter 11.

Table 13-13 summarizes EPA's estimates of the regional and national annualized benefits of reducing IM&E and GHG emissions under the final rule and each of the regulatory options EPA considered for existing units (discounted at 3 percent and 7 percent). Table 13-14 presents the sum of benefits for the final rule for existing units and new units. Refer to Chapter 10 for additional detail regarding benefits for existing units and Chapter 12 for additional detail regarding benefits for new units. The national value of these reductions in IM&E and GHG emissions, evaluated at a 3 percent discount rate, is as follows:

- Proposal Option 4 results in national benefits of $31.0 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $22.8 million and $47.6 million (Table 13-13).
- The final rule for existing units results in national benefits of $33.0 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $24.1 million and $50.6 million (Table 13-13). Including requirements for new units, the final rule results in national benefits of $32.8 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $23.9 million and $50.5 million (Table 13-14).
- Proposal Option 2 results in national benefits of -$1,542.6 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling -$1,562.2million and -$1,504.5 million (Table 13-13).

Evaluated at a 7 percent discount rate, the national use benefits of the regulatory analysis options are somewhat smaller for the final rule and Proposal Option 4, and greater for Proposal Option 2:

- Proposal Option 4 results in national benefits of $27.2 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $21.1 million and $39.5 million (Table 13-13).

79 The 3 percent rate represents a reasonable estimate of the social rate of time preference. The 7 percent rate represents an alternative discount rate, recommended by the Office of Management and Budget (OMB) that reflects an estimated opportunity cost of capital.

80 The lower estimates of value presented in this chapter are measured by the sum of the 5th percentile lower bound estimates of recreational values plus the mean value estimates for all other categories of value. The higher estimates of value presented in this chapter are measured by the sum of the 95th percentile upper bound estimates of recreational values plus the mean value estimates for all other categories of value.

- The final rule for existing units results in national benefits of $28.7 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $22.2 million and $41.8 million (Table 13-13). Including requirements for new units, the final rule results in national benefits of $28.6 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling $22.1 million and $41.7 million (Table 13-14).
- Proposal Option 2 results in national use benefits of -$1,148.2 million per year, with estimates based on the 5th percentile lower bound and 95th percentile upper bound for recreational values, totaling -$1,161.7 million and -$1,122.0 million (Table 13-13).

More detailed discussions of benefits under each option are provided in Chapters 5 through 9. National benefits for new units are discussed in Chapter 12.

Table 13-13: Summary of National Annualized Benefits for Existing Units for All Regulated Facilities ((2011$, millions)[a]

Regulatory Option	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	SCC[e]	Total Benefits		
	Low	Mean	High					Low	Mean	High
3% Discount Rate										
Proposal Option 4	$8.8	$17.1	$33.6	$0.9	$0.4	$0.3	$12.4	$22.8	$31.0	$47.6
Final Rule	$9.4	$18.2	$35.9	$0.9	$0.4	$1.0	$12.4	$24.1	$33.0	$50.6
Proposal Option 2	$23.4	$43.0	$81.1	$3.9	$0.7	$51.1	-$1,641.3	-$1,562.2	-$1,542.6	-$1,504.5
7% Discount Rate										
Proposal Option 4	$6.5	$12.6	$24.9	$0.7	$0.3	$0.3	$13.4	$21.1	$27.2	$39.5
Final Rule	$7.0	$13.5	$26.6	$0.7	$0.3	$0.8	$13.4	$22.2	$28.7	$41.8
Proposal Option 2	$16.1	$29.5	$55.8	$2.7	$0.5	$37.3	-$1,218.2	-$1,161.7	-$1,148.2	-$1,122.0

[a] All benefits presented in this table are annualized, i.e., represent the sum of the discounted stream of benefits annualized over 51 years (2014 to 2064). See Appendix D for detail.

[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region- and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.

[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon). See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.

[e] SCC results presented here are based on 3 percent average SCC values.

Source: U.S. EPA analysis for this report

Table 13-14: Summary of National Annualized Benefits for the Final Rule for Existing Units and New Units (2011$, millions)[a]

Regulatory Option	Recreational Fishing Benefits			Commercial Fishing Benefits[c]	T&E Species Benefits[d,e]	Nonuse Benefits	SCC	Total Benefits		
	Low	Mean	High					Low	Mean	High
3% Discount Rate										
Final Rule - Existing Units	$9.4	$18.2	$35.9	$0.9	$0.4	$1.0	$12.4	$24.1	$33.0	$50.6
Final Rule - New Units	$0.0	$0.0	$0.1	$0.0	$0.0	$0.1	-$0.3	-$0.2	-$0.2	-$0.1
Final Rule - Existing Units + New Units	$9.4	$18.3	$36.0	$0.9	$0.4	$1.1	$12.1	$23.9	$32.8	$50.5
7% Discount Rate										
Final Rule - Existing Units	$7.0	$13.5	$26.6	$0.7	$0.3	$0.8	$13.4	$22.2	$28.7	$41.8
Final Rule - New Units	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	-$0.2	-$0.1	-$0.1	-$0.1
Final Rule - Existing Units + New Units	$7.0	$13.5	$26.7	$0.7	$0.3	$0.9	$13.2	$22.1	$28.6	$41.7

[a] All benefits presented in this table are annualized, i.e., represent the sum of the discounted stream of benefits annualized over 51 years (2014 to 2064). See Appendix D for detail.
[b] A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique, to estimate the 5th and 95th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a region- and species-specific range of gross revenue, as explained in Chapter 6 of this report. EPA estimated recreational use benefits for some T&E species, as explained in Chapter 5. To calculate the total monetizable value columns (low, mean, high), the values for commercial fishing benefits and T&E species benefits are added to the respective low, mean, and high values for recreational fishing benefits.
[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.
[d] Recreational use benefits from increased abundance of T&E species with potentially high recreational use values (e.g., paddlefish and sturgeon).
See Chapter 5 of this report for more detail on EPA's analysis of T&E benefits.
[e] SCC results presented here are based on 3 percent average SCC values.
Source: U.S. EPA analysis for this report.

13.5 Results based on the SP Survey

Table 13-15 and Table 13-16 summarize national benefit estimates for the final rule and options considered for existing and new units based on EPA's SP survey. The national totals are based on the sum of estimates for each survey region. As described in Chapter 12, EPA does not include benefit estimates based on the survey in its comparison of benefits and costs for the final rule and options considered. However, the magnitude of benefits estimated based on the survey results illustrate that total values of ecological improvements may be substantially greater than the partial monetized benefits used for the benefit cost comparison (Table 13-13 and Table 13-14).

Table 13-15: Summary of National Benefits for the Final Rule and Options Considered for Existing Units based on the SP Survey (2011$, millions)

Regulatory Option	3 % Discount Rate			7 % Discount Rate		
	5th	Mean	95th	5th	Mean	95th
Proposal Option 4	$829.1	$1,363.1	$1,898.8	$642.6	$1,056.8	$1,472.2
Final Rule - Existing Units	$880.5	$1,448.8	$2,019.0	$682.5	$1,123.2	$1,565.3
Proposal Option 2	$2,159.9	$3,430.7	$4,823.7	$1,442.4	$2,294.5	$3,226.1
Source: U.S. EPA analysis for this report						

Table 13-16: Summary of National Benefits for the Final Rule for Existing and New Units based on the SP Survey (2011$, millions)

Regulatory Option	3 % Discount Rate			7 % Discount Rate		
	5th	Mean	95th	5th	Mean	95th
Final Rule - Existing Units	$880.5	$1,448.8	$2,019.0	$682.5	$1,123.2	$1,565.3
Final Rule - New Units	$2.1	$3.3	$4.6	$1.5	$2.3	$3.3
Final Rule - Existing and New Units	$882.6	$1,452.1	$2,023.6	$683.9	$1,125.5	$1,568.6
Source: U.S. EPA analysis for this report						

13.6 Break-Even Analysis

Comprehensive estimates of total resource value include both use and nonuse values and may be compared to total social cost. Recent economic literature provides strong support for the hypothesis that mean nonuse values are greater than zero. This is supported by the results of EPA's stated preference survey as described in Section 13.5. The per-capita nonuse values need not be large to result in substantial benefits for the final rule. When small per-capita nonuse values are held by a substantial fraction of the population, the aggregate value can be very large. However, in this specific context, EPA included nonuse values for only two of the seven benefits regions within its primary estimates of national benefits for the final rule and other options considered. EPA did include benefit estimates based on the SP survey in its comparison of benefits and costs for the final rule and options considered.

As shown in Table 13-12 above, nearly all—97 percent—IM&E at cooling water intake structures under current conditions (the baseline scenario) consist of either forage species or unlanded recreational and commercial species that are not harvested and thus not reflected in EPA's estimated direct use values. Although individuals do not use these resources directly, they may value changes in the status or quality of these resources. EPA did not include nonuse values for forage and unlanded species occurring in five of the seven benefits regions. Due to the uncertainties of providing estimates of the magnitude of nonuse values associated with the regulatory options for all regions, this section provides an alternative approach. EPA used an alternative "break-even" analysis approach for evaluating the potential relationship between costs and benefits associated with IM&E reductions. This approach identifies what the unmonetized nonuse values would have to be in order for the benefits of the proposed options to equal costs.

To calculate a break-even value, EPA subtracted its estimates of monetized commercial and recreational use benefits for the final rule and regulatory options considered from the estimated annual compliance costs incurred by facilities subject to the final rule. The resulting "net cost" enabled EPA to work backwards to estimate what the nonuse values would need to be (in terms of WTP per household per year) in order for total annualized benefits to equal annualized costs. Table 13-17 provides this assessment for the final rule and options considered. The table shows benefit values using a 3 percent or 7 percent discount rate, respectively.

As shown in Table 13-17, for total annualized benefits to equal total annualized costs, nonuse values per household would have to be at least $2.27 for the final rule using a 3 percent discount rate and $2.59 using a 7 percent discount rate.

Table 13-17: Implicit Nonuse Value—Break-Even Analysis (2011$)

Regulatory Option[a]	Use Benefits of IM&E Reductions (2011$, millions)[a]	Annual Social Cost (2011$, millions)[b]	Annual Nonuse Benefits Necessary to Break Even (2011$)[c]	Number of Households in States with Regulated Facilities (millions)[d]	Annual Break-Even Nonuse WTP per Household (2011$)[e]
3% Discount Rate					
Proposal Option 4	$19.6	$251.8	$232.2	114.9	$2.02
Final Rule - Existing and New Units	$14.5	$274.9	$260.4	114.9	$2.27
Proposal Option 2	$0.0	$3,643.2	$3,643.2	114.9	$31.72
7% Discount Rate					
Proposal Option 4	$14.5	$272.1	$257.6	114.9	$2.24
Final Rule - Existing and New Units	$0.0	$297.3	$297.3	114.9	$2.59
Proposal Option 2	$0.0	$3,583.0	$3,583.0	114.9	$31.19

[a] Benefits are discounted using a 3% or 7% discount rate, respectively. Use benefits include estimated commercial fishing benefits, recreational fishing benefits, and use benefits for T&E species.
[b] The total social cost of the final rule includes facility compliance costs and administrative costs.
[c] Annualized compliance costs minus annualized use benefits.
[d] Includes households in states with at least one surveyed facility. Household counts are based on Census 2010 (U.S. Census Bureau 2010).
[e] Dollars per household per year that, when added to use benefits, would yield a total annualized benefit (use plus nonuse) equal to the annualized costs.
Source: U.S. EPA analysis for this report; U.S. Census Bureau, 2010

While this approach of backing out the "break-even" nonuse value per household does not answer the question of what nonuse values might actually be for the final rule and regulatory options considered, these results do frame what the unknown values would have to be in order for benefits to equal or exceed costs. The break-even approach poses the question: "Is the true per-household WTP for the nonuse amenities (existence and bequest) associated with an option likely to be greater or less than the ‘break-even’ benefit levels displayed in Table 13-17?” The results of EPA’s SP survey (Chapter 11) illustrate the potential magnitude of nonuse and total values for 316(b) regulatory options and suggest that household values may exceed the break-even point for the final rule. Mean household WTP for the final rule based on the survey ranges from $0.69 in the Pacific region to $27.57 in the Inland region.

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Appendix A: Extrapolation Methods

A.1 Introduction

This appendix provides detail on estimating facility-level weights used in estimating benefits at a regional level. EPA built its weighting approach on the sample weights developed for manufacturing facilities and electric power generating facilities in the analysis of 316(b) Phase II and Phase III regulations (USEPA 2004a; USEPA 2006b). EPA expanded on the existing approach by developing new facility-level weights that account for differences between electric power facilities that received the Detailed Questionnaire (DQ) and those that received the Short Technical Questionnaire (STQ), and to account for facility location, a key parameter in the benefits analysis. EPA used this new set of "benefits weights" to estimate baseline IM&E losses and reductions in IM&E losses under the final rule and other options considered and to adjust for the timing of these reductions and associated benefits.

A.2 Manufacturing Facilities

The current analysis of manufacturing facilities incorporates a set of weights that EPA developed for the 2006 Final Phase III Rule, which EPA refers to as technical weights. The technical weights are based on engineering information obtained from the 316(b) Manufacturers Questionnaire. The technical weights account for the number of affected facilities and the cost of installing new technology, but do not account for facility location or intake flow at a regional level. EPA developed additional adjustments to the technical weights because IM&E losses are a function of facility location and intake flow. The purpose of the additional adjustments is to ensure thatweighted regional mean operational, or actual, intake flow (AIF)for survey facilities is consistent with EPA's best estimates for all regulated manufacturing facilities in each of eight regions: North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, California, Pacific Northwest,[81] Great Lakes, and Inland regions.[82]

EPA developed the weight adjustments separately for traditional manufacturers (MN facilities) and non-utility manufacturers (MU facilities).[83] Data was not available for total regional intake flow for MN and MU facilities. Thus, rather than calibrating the weights based on flow, EPA calibrated them based on facility counts such that the weighted number of surveyed facilities in each region equals the total number of facilities in that region. This approach assumes that the flow characteristics of the non-surveyed facilities, which are represented by weights, are the same as surveyed facilities (DQ facilities).

81 The Pacific Northwest region ultimately is excluded from the benefits analysis because it includes a single DQ facility which is projected to close as baseline.

82 See Chapter 1 for additional information regarding regional definitions.

83 MN facilities include aluminum, steel, chemical, pulp and paper, and petroleum refining manufacturing industries. Note that Food and Kindred Products is not included in this list of industries for two reasons: a) this industry was not included in the original stratification of manufacturers, and b) all facilities later identified to be in the Food and Kindred Product industries were part of the MU universe.

The following two sections describe development of weight adjustment factors for MN and MU facilities, respectively.

A.2.1 Traditional Manufacturers (MN Facilities)

EPA stratified the universe of MN facilities by region and industry category.[84] EPA first determined the distribution of regulated facilities by study region, and then calculated adjusted benefits weights based on this distribution.

A.2.1.1 Determining the Distribution of Regulated Facilities by Study Region

The industry survey requested that responding facilities provide Standard Industrial Classification (SIC) codes. [85] EPA used PCS (Permit Compliance System) and ICIS-NPDES (Integrated Compliance Information System- NPDES) to obtain latitude-longitude coordinates (lat-long) for all facilities in relevant SIC codes. Facilities within relevant SIC codes were assigned to a study region using lat-long. A map of RF1 reacheswas also used to indicate whether the facility location is coastal/estuarine or inland.[86] Table A-1 presents the distribution of the facility universe according to region and industry based on the PCS/ICIS data.

The sample frame for the survey screener of manufacturing facilities did not include all facilities in the relevant SIC codes. Information on which facilities were included is not available. Therefore, EPA used two simplifying assumptions to develop weight adjustment factors: (1) the total number regulated facilities in any single industry equals the sum of technical weights,[87] and (2) the geographic distribution of NPDES permitted facilities in the relevant SIC codes is representative of the geographic distribution of regulated facilities.

For each industry, EPA assumed that the geographic distribution of facilities included in the EPA PCS/ICIS database is equivalent to the geographic distribution of the DQ sample frame. To implement this assumption, EPA redistributed the weights of DQ facilities in each study region to match the geographic distribution of facilities in the PCS/ICIS database. The second and third columns in Table A-1 present the estimated distribution of regulated MN facilities based on PCS/ICIS data.[88]

A.2.1.2 Calculating Adjusted Weights for the Benefits Analysis

EPA first compared the regional distribution of DQ facilities to the distribution of facilities present in the PCS/ICIS universe. Table A-1 presents the distribution of DQ facilities based on technical weights, the weight adjustment factors for MN facilities, and the expected number of

84 EPA did not adjust weights for petroleum refineries because survey screeners were sent to the entire universe and DQs were sent to all regulated facilities. EPA assigned a weight of 1 to facilities determined to be in other industries after receipt of the DQ. No adjustment was made to these weights.

85 The SIC code describes the primary activity of the facility. EPA did not convert SIC codes to North American Industry Classification codes (NAICS) when developing benefits weights because the industry survey used SIC codes and relevant databases were searchable by SIC code.

86 EPA's reach file (RF1) is a database of interconnected steam segments of "reaches" that comprise the surface water drainage system for the United States.

87 As noted in Section A.2, the technical weights account for the number of affected facilities.

88 EPA used the following databases to obtain information on the number of facilities in each SIC code: FRS (Federal Registry System), PCS (Permit Compliance System), ICIS-NPDES (Integrated Compliance Information System- NPDES) and TRI (Toxics Release Inventory). None of these databases contains intake flow.

DQ facilities for all regions. EPA re-estimated the number of DQ facilities in each region using the PCS/ICIS distribution of facilities in that region. This adjustment factor was defined as the quotient of the number of DQ facilities within a region and industry divided by the original number of weighted DQ facilities assigned to the same stratum. If the PCS/ICIS facilities universe indicated that a region had a small number of facilities within a single industry and did not have DQ facilities (e.g., the North Atlantic region for the Aluminum sector), EPA assumed that no regulated facilities exist within the stratum.

Because regions without DQ facilities comprised a small fraction of the PCS/ICIS facility universe, this assumption is likely to introduce negligible error. If the adjusted weight for a sample DQ facility was less than one, EPA used a weight of one to fully count the flow. In the economic analysis, EPA estimated that 20 MN facilities will close under baseline conditions. Accordingly, EPA excluded these facilities from the weights readjustment and benefits analysis. The final two columns of Table A-1 present estimated total flow for each sector and region when both original DQ and adjusted weights have been applied. In the paper and steel sectors, adjusted-weighted AIF is slightly smaller due to the lack of DQ facilities for those combinations of sector and region. Conversely, adjusted-weighted AIF in the chemical sector increases slightly due to good coverage of DQ facilities, which shifted weights to facilities with above-average flow.

Table A-1: MN DQ Distribution and Calculation of Weight Adjustment Factors							
Benefits Region	Distribution of Facilities in PCS/ISIS		DQ-weighted Facility Count[a]	Adjustment Factor[b]	Adjusted Weight Facility Count	DQ-weighted AIF	Adjusted-Weighted AIF
	Number	%					
Aluminum							
North Atlantic	7	6%	0[c]		0	0	0
Mid-Atlantic	11	9%	0		0	0	0
South Atlantic	1	1%	0		0	0	0
Great Lakes	2	2%	3	0.09	0	0	0
Gulf of Mexico	1	1%	0		0	0	0
Pacific Northwest	0	0%	0		0	0	0
California	0	0%	0		0	0	0
Inland	95	81%	13	1.01	13	87	88.3
Total	**117**	**100%**	**16**		**13**	**87**	**88.3**
Chemical							
North Atlantic	16	1%	0		0	0	0
Mid-Atlantic	75	6%	4	2.14	9	28.7	61.3
South Atlantic	9	1%	4	0.26	1	56.4	14.5
Great Lakes	32	3%	17	0.23	2	80.5	18.7
Gulf of Mexico	100	8%	4	2.85	12	283.9	809.8
Pacific Northwest	4	0%	0		0	0	0
California	5	0%	4	0.14	1	1.5	0.4
Inland	951	80%	112	1.04	117	1,782.8	1,860.0
Total	**1,192**	**100%**	**146**		**142**	**2,233.8**	**2,764.8**
Paper							
North Atlantic	2	1%	0		0	0	0
Mid-Atlantic	7	2%	0		0	0	0
South Atlantic	8	2%	0		0	0	0
Great Lakes	19	5%	3	1.68	5	6.7	11.2
Gulf of Mexico	2	1%	0		0	0	0
Pacific Northwest	3	1%	0		0	0	0
California[d]	0	0%	3	1	3	32.2	32.2
Inland	354	90%	91	0.95	84	1,193.3	1,134.30
Total	**395**	**100%**	**96**		**91**	**1,232.2**	**1,177.7**
Steel							
North Atlantic	3	1%	0		0	0	0
Mid-Atlantic	5	2%	0		0	0	0
South Atlantic	1	0%	0		0	0	0
Great Lakes	25	10%	6	0.54	3	2,054.3	1,112.1
Gulf of Mexico	3	1%	0		0	0	0
Pacific Northwest	1	0%	0		0	0	0
California	2	1%	0		0	0	0
Inland	214	84%	28	1.03	29	519.6	535
Total	**254**	**100%**	**34**		**32**	**2,573.9**	**1,647.1**
Petroleum							
North Atlantic	0	0%	0		0	0	0
Mid-Atlantic	2	11%	2	1	2	203.4	203.4
South Atlantic	0	0%	0		0	0	0
Great Lakes	0	0%	0[e]		0	0	0
Gulf of Mexico	1	5%	1	1	1	42.6	42.6

Table A-1: MN DQ Distribution and Calculation of Weight Adjustment Factors							
Benefits Region	Distribution of Facilities in PCS/ISIS		DQ-weighted Facility Count[a]	Adjustment Factor[b]	Adjusted Weight Facility Count	DQ-weighted AIF	Adjusted-Weighted AIF
	Number	%					
Pacific Northwest	0	0%	0		0	0	0
California	1	5%	1	1	1	31.8	31.8
Inland	16	79%	16	1	16	391.2	391.2
Total	**20**	**100%**	**20**		**20**	**668.9**	**668.9**
Other							
Inland	2	100%	2	1	2	4.6	4.6
Total	**2**	**100%**	**2**		**2**	**4.6**	**4.6**
Total for All Industries							
North Atlantic	28	1%	0		0	0	0
Mid-Atlantic	100	5%	6		11	232	264.7
South Atlantic	19	1%	4		1	56.4	14.5
Great Lakes	78	4%	29		10	2,141.4	1,142.0
Gulf of Mexico	107	5%	5		13	326.5	852.4
Pacific Northwest	8	0%	0		0	0	0
California	8	0%	8		5	65.5	64.4
Inland	1,632	82%	261		260	3,978.5	4,013.4
Total	**1,980**	**100%**	**314**		**300**	**6,800.4**	**6,351.4**

[a] EPA did not adjust weights for petroleum refineries or facilities in "other industries" because they are not in the five SIC codes for which EPA developed weights. EPA assumed that these facilities do not represent any other facilities.

[b] Blank cells indicate that an adjustment factor was not estimated.

[c] Though these regions account for more than 5 percent of aluminum manufacturers, the average flow for aluminum manufacturers is less than 10 mgd. Potential benefits associated with these facilities would be relatively minor.

[d] Although the PCS/ICIS data did not identify any paper facilities in the California region, there is 1 facility in this region that received a DQ with a weight of 3. This weight was not adjusted.

[e] There was 1 refinery in the Great Lakes region that received a DQ. However, this facility was assessed as a baseline closure in the economic analysis, and thus receives an adjustment factor of 0, and excluded from the benefits analysis.

Sources: U.S. EPA PCS and ICIS-NPDES databases, U.S. EPA analysis for this report

A.2.2 Non-Utility Manufacturers (MU Facilities)

EPA accounted for the geographic distribution of MU facilities using a methodology similar to that used for MN facilities. EPA adjusted the weights so that the distribution of the weighted number of DQ facilities matched the actual geographic distribution of the facility universe. Under this approach, EPA first determined the distribution of regulated facility by study region, and then calculated adjusted weights for use in the benefits analysis.

A.2.2.1 Determining the Distribution of Regulated Facilities by Study Region

The entire universe of MU facilities was known based on the survey screener, and the EPA used the Online Tracking Information System (OTIS) facility-finder tool was used to obtain facility location data.[89] EPA distributed the universe of facilities among study regions based on the regional distribution of MU facilities with location data from OTIS Facility-finder.

89 While the survey screener asked for facilities' flow, EPA was unable to develop adjustment factors using total flow as a control variable.

A.2.2.2 Calculating Adjusted Weights for the Benefits Analysis

For each study region, EPA compared the estimated number of MU facilities with the DQ-weighted number of facilities in the region. An adjustment factor was calculated as the quotient of the estimated number of facilities in each region divided by the DQ-weighted number of facilities in each region. If the adjusted weight for a facility was less than one, EPA assigned a weight of one to account fully for the flow of the sampled facility. Accordingly, EPA excluded 9 baseline closures from the benefits analysis and weights readjustment.[90] Adjustment factors and adjusted flow by benefits region are presented in Table A-2.

Table A-2: MU Adjustment Factors and Adjusted Flow by Benefits Region

Benefits Region	Facility Distribution from OTIS	DQ-weighted Facilities	Adjustment Factor[a]	Total Original Weighted Flow (mgd)	Total Adjusted Weighted Flow (mgd)
MU Facilities					
North Atlantic	6	5	1.2	220.9	275.3
Mid-Atlantic	4	7	0.5	474.5	384.9
South Atlantic	2	0		No DQs	0.0
Great Lakes	14	12	1.2	1,186.4	1,500.0
Gulf of Mexico	8	6	1.3	577.0	744.0
Pacific Northwest	0	1	0.0	0	0.0
California	2	1	2.0	3.6	7.3
Inland	164	175	0.9	6,841.7	6,615.2
Total	**200**	**207**		**9,303.7**	**9,526.7**
Non-Utility (NU) Facilities Determined to be Manufacturers[b]					
Inland	N/A	12	1.0	386.7	386.7
Total					
Grand Total	**N/A**	**219**	**-**	**9,690.4**	**9,913.3**

Notes:
DQ = detailed questionnaire; mgd = millions of gallons per day; MU = Non-utility manufacturers
[a] Blank cells indicate that an adjustment factor was not estimated.
[b] Two facilities that were surveyed as non-utilities were later determined to be non-utility manufacturers, and are analyzed as such in the economic and benefits analyses. Their weights were not adjusted because they were not part of the original MU facility universe and are both in the inland region. Given that the majority of MU facilities are located in the Inland region, the use of original weights is unlikely to bias regional benefit results.
Source: U.S. EPA analysis for this report

A.3 Electric Power Generating Facilities

The benefits analysis for electric power generating facilities uses a combination of weights from the 316(b) Phase II and Phase III analyses and new sample weights. Weights from Phase II and Phase III accounted for non-sampled facilities and non-respondents to industry surveys and are referred to as the original survey weights.[91]

When estimating national-level benefits, use of only survey weights based on facility-specific (e.g., size and engineering) characteristics can lead to conditional bias. In particular, the original survey weights do not not consider factors influencing the occurrence and size of benefits, such as

[90] This total includes one facility that would be subject to the New York state regulation of CWIS.

[91] In general, the original survey weights are numerically very low, as EPA had either DQ or STQ information for 621 of the 634 regulated electric generating facilities. For more information on EPA's Section 316(b) Industry Surveys, refer to the Information Collection Request (USEPA 2000).

the location of facilities subject to the final rule and regulatory options, AIF, similarities among aquatic species affected by these facilities, and characteristics of commercial and recreational fishing activities in the area. EPA used a post-stratification weight adjustment to calculate benefits weights that account for data dimensions not included in the original sample design. These benefits weights re-scale DQ-based weights using additional information from the STQ so that total regional flows represented by both weighting systems are equivalent.

The remainder of this appendix describes the post-stratification weight adjustment for electric power generating facilities. Section A.3.1 describes how the strata were defined. Section A.3.2 presents and discusses the estimates resulting from the post-stratified weighting schemes and compares these to the original DQ weights.

A.3.1 Defining the Strata and Control Variables

EPA included six study regions when developing benefits weights for electric power generating facilities: North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, Great Lakes, Inland, and California regions. Strata characteristics used to adjust weights are presented in Table A-3.

IM&E is largely a function of mean AIF and characteristics of local fishery resources. Therefore, regional, non-recirculated AIF is the most important factor in defining strata for the benefits estimation. It is more important to group estimated total benefits by non-recirculated intake flow in a study region than by number of facilities. When calculating weights, EPA included a strata based on a 125 mgd DIF so that benefit estimates accurately reflect changes in technology under the final rule and other options considered under the regulation.

Table A-3: Matrix of Strata and Control Variables for Adjusting DQ Weights for Electric Generating Facilities

Strata	AIF (mgd)			
	Recirculating Facilities[a]		Non-Recirculating Facilities[b]	
	DIF < 125 mgd	DIF > 125 mgd	DIF < 125 mgd	DIF > 125 mgd
North Atlantic	0	0	238	6,259
Mid-Atlantic	68	0	257	24,203
South Atlantic	46	0	0	5,943
Gulf of Mexico	0	46	0	9,347
Great Lakes	57	181	255	14,774
Inland	1,397	16,060	1,753	98.653
California[c]	0	0	62	11,249
Total	**1,569**	**16,286**	**2,564**	**170,428**

Notes:
DQ = detailed questionnaire; AIF = actual intake flow; DIF = design intake flow; mgd = millions of gallons per day
[a] Recirculating facilities are facilities with closed-cycle recirculating systems or impoundments that qualify as closed-cycle recirculating systems.
[b] Non-recirculating facilities includes facilities with CWIS classified as once-through.
[c] The California region includes three facilities in Hawaii.
Source: U.S. EPA analysis for this report

A.3.2 Comparison of Results of the Detailed Questionnaire and Post-Stratified Weighting Schemes

EPA assigned post-stratification weights so that tabulations of total mean AIF for each region and DIF threshold correspond to the best estimates of AIF. The best estimates, or control totals, for each region are calculated using AIF data from the DQ and STQ, and facility-level sample weights that account for non-sampled facilities and non-respondents. The DQ total is the total AIF of facilities to which weights adjustments are applied. Table A-4 summarizes DQ and control totals by region, DIF threshold, and baseline recirculating technology. By design, the post-stratification estimate of mean AIF equals the control total estimate (i.e., benefits weights are the quotient of the control total divided by the DQ total).

AIF is the most important factor in determining benefits. Therefore,, accounting for flow while minimizing the variance of the weights is the best approach. This is accomplished by assigning an equal weight to all facilities within a given stratum. One alternative would be to adjust the original DQ weight, but that would increase the variance of new weights. The additional variance is not likely to reflect the characteristics on which the estimates depend, and therefore these weights would be inferior.

Table A-4: Comparison of Results of the DQ and Post-Stratified Weighting Schemes[a]

Region	AIF for Recirculating Facilities[b]				AIF for Non-Recirculating Facilities[c]			
	DIF < 125 mgd		DIF > 125 mgd		DIF < 125 mgd		DIF > 125 mgd	
	DQ Total (mgd)	Control Total (mgd)[d]	DQ Total (mgd)	Control Total (mgd)[d]	DQ Total (mgd)	Control Total (mgd)[d]	DQ Total (mgd)	Control Total (mgd)[d]
North Atlantic	0	0	0	0	209	238	3,163	6,259
Mid-Atlantic	58	68	0	0	231	257	7,649	24,203
South Atlantic	0	46	0	0	0	0	2,391	5,943
Gulf of Mexico	0	0	46	46	0	0	5,963	9,347
Great Lakes	0	57	0	181	66	255	4,002	14,774
Inland	615	1,397	3,223	16,060	1,036	1,753	46,235	98.653
California[e]	0	0	0	0	62	62	1,205	11,249
Total	**673**	**1,569**	**3,269**	**16,286**	**1,604**	**2,564**	**70,609**	**170,428**

Notes:
DQ = detailed questionnaire; AIF= actual intake flow; DIF = design intake flow; mgd = millions of gallons per day
[a] A limited number of total STQ facilities did not have a DQ facility to represent them within the technology class (recirculating versus non-recirculating), region, and DIF strata. Their flow was added to the respective totals for the other technology class when calculating benefits weights, and is assigned the same benefits weights as the other technology class within the same region and DIF stata.
[b] Recirculating facilities are facilities with closed-cycle recirculating systems or impoundments that qualify as closed-cycle recirculating systems.
[c] Non-recirculating facilities include facilities with CWIS classified as once-through.
[d] The control totals are the best estimates for each region are calculated using operational flow data from DQ and STQ, and facility-level sample weights that account for non-sampled facilities and non-respondents.
[e] The California region includes three facilities in Hawaii.
Source: U.S. EPA analysis for this report

A.4 Adjustment for State Regulations of CWIS

EPA also included an adjustment to account for the California and New York state regulations of CWIS. The California state regulation requires closed-cycle recirculating systems for coastal electric generating facilities and the New York state regulation requires closed-cycle recirculating systems for all in-state facilities with DIF greater than or equal to 20 mgd. Fourteen surveyed facilities fall within the scope of the California state regulation and 32 surveyed facilities fall within the scope of the New York state regulation. EPA's benefits analysis assigns these facilities baseline IM&E commensurate with compliance with the state regulations.

EPA included a weight adjustment to account for the state regulations because the assumed technology (i.e., closed-cycle recirculating system) at facilities which are within the scope of the state regulations does not accurately represent technology at facilities which are not within the scope of the state regulations. Failing to account for state regulations would result in the underestimation of baseline IM&E losses and IM&E reductions under the final rule and options considered.

EPA calculated the best estimate of flow for facilities subject to state regulations (i.e., control flow) based on the difference between total DQ-weighted flow in each region with these facilities included and excluded from the weighting analysis. Table A-5 presents the regional DQ-weighted AIF and control AIF totals for facilities subject to state regulations. EPA adjusted the DQ-weighted total for each region upward to match the respective control total. In the California region, EPA only adjusted weights for coastal generators within the state of California; it did not adjust weights for California manufacturing facilities and Hawaii facilities which are not subject to the state regulation. The Mid-Atlantic, Great Lakes, and Inland regions all include facilities which are subject to the New York state regulation. For these regions, EPA grouped generators and manufacturers when estimating adjustment factors to ensure that each region had at least one DQ facility to represent facilities within the region subject to the New York state regulation.

Table A-5: Matrix of Strata and Control Variables for Facilities Subject to State Regulations for CWIS

Region	Weighted AIF Including Facilities Subject to State Regulations (mgd) (a)	Weighted AIF Excluding Facilities Subject to State Regulations (mgd) (b)	DQ Total (mgd)	Control Total (mgd) (a-b)
North Atlantic	6,772	6,772	0	0
Mid-Atlantic	25,199	16,862	1,043	8,337
South Atlantic[a]	5,943	5,943	0	0
Gulf of Mexico	10,989	10,989	0	0
Great Lakes	17,639	13,840	281	3,799
Inland	131,291	127,730	3,351	3,561
California – Coastal Generators	10,175	0	895	10,175
California – Manufacturers and Hawaii Facilities	1,221	1,221	0	0
Total	**209,230**	**183,357**	**5,569**	**25,872**

Notes:
AIF = actual intake flow; DQ = detailed questionnaire; mgd = millions of gallons per day
Source: U.S. EPA analysis for this report

Appendix B: Consideration of Potential Effects due to Thermal Discharges

B.1 Introduction

Impacts of thermal discharges, along with other stressors, are a relevant consideration when assessing the potential impacts of electric power facility cooling water intakes and associated discharges. Several studies have demonstrated the adverse effects that increased temperatures or altered seasonal thermal regimes have on local biota and fauna. In some cases, studies have indicated little or no apparent harm is caused by the thermal discharges. This emphasizes the need for NPDES permit writers to consider site-specific factors when assessing the potential ecological effects due to thermal discharges.

This appendix provides information on the general effects of thermal discharges on aquatic biota and ecosystems, considers the influence of site-specific factors and environmental settings on determining the level (if any) of ecological impacts, and discusses limitation and uncertainty associated with thermal studies. This appendix also presents three case studies from power facilities in different environmental settings (Brayton Point Station, Quad Cities Nuclear Station, and Point Beach Nuclear Plant) which underwent detailed thermal studies under CWA section 316(a) provisions, and which show the importance of site-specific factors in determining the potential for appreciable harm. The section 316(a) demonstrations described in the three case studies represent unusually complete and thorough investigations of thermal impacts to receiving aquatic ecosystems. Thermal investigations at other power facilities are highly site specific, but typically have a much reduced scope and effort compared to those portrayed by the case studies.

It should be noted that even at power facilities where demonstrations of no appreciable harm have been made to regulatory authorities under section 316(a), supporting thermal studies nonetheless often show periods during which thermal limits are exceeded. Impacts of thermal discharges should therefore be revisited on a case-by-case basis as conditions change, for example (i) if facilities increase their power capacity (i.e., “uprate”) and increase thermal loads to the receiving waterbody; (ii) if the thermal assimilative capacity of the receiving waterbody is otherwise compromised; or (iii) in the face of new evidence that cooling water discharges are causing appreciable harm to the balanced, indigenous population/community of shellfish, fish, and wildlife or fail to ensure the protection or propagation of the population. Such assessments need to consider the extent, duration, timing, and frequency of adverse thermal impacts, the target threshold temperature for each species, the potential for adverse temperature effects on larger ecological processes, and other relevant site-specific factors.

B.2 General Effects of Thermal Discharges on Aquatic Biota and Ecosystems

Thermal discharges affect aquatic organisms by elevating water temperatures or altering seasonal patterns of temperature change. Temperature is a vitally important variable for aquatic ecosystems, affecting virtually all biota and biologically mediated processes, chemical reactions, as well as structuring the physical environment of the water column. There is a well-established scientific literature cataloguing the impacts of elevated or variable temperature on a wide spectrum of aquatic life, including numerous species-specific determinations of thermal tolerance limits for growth, survival, reproduction, and behavior (e.g., Beitinger et al. 2000; Leffler 1972; McMahon 1975).

Much of the relevant primary research on power plant thermal discharges dates from the 1970's-1980's; typically based on laboratory studies, field investigations, or environmental impact assessments associated with the siting, permitting, and/or operation of power facilities with significant thermal plumes (e.g., Barnett 1972; Coles 1984; Hillman et al. 1977; Langford 1990 (for review); Squires et al. 1979). These studies found that the thermal discharges may affect aquatic species growth, survival, and reproduction, alter community diversity and density, and may have led to shifts in ecological habitat. The character and magnitude of the observed impacts varies among the studies, however.

Interest in this topic and relevant studies have also re-emerged in the last decade as part of a greater effort associated with the assessment and characterization of potential effects of global climate change (e.g., Schiel et al. 2004). The material below provides a representative, exemplary mix of studies on thermal effects for organisms and communities in a range of trophic levels or ecosystems with some emphasis on more recent research. The majority of the cited studies were identified from internet searches and cross-referencing appropriate permitting databases.[92]

B.2.1 Primary Producers

Thermal discharges affect aquatic primary production through direct effects on photosynthetic activity and selection of temperature-tolerant species in phytoplankton, periphyton, macroalgae and submerged aquatic vegetation (SAV), and indirectly through temperature-related changes in nutrient availability and grazer activities. Several studies reported that thermal discharges substantially altered the local abundance and structure of the aquatic community, particularly benthos and periphyton (e.g., Chuang et al. 2009; Martinez-Arroyo et al. 2000; Schiel et al. 2004; Squires et al. 1979). Studies by Mallin et al. (1994) suggest that indirect effects of discharge altered the phytoplankton community taxonomic structure near the outfall and in general, support different communities of algae than those present in the background waters. Several authors suggest that residual chlorine (anti-fouling agent) may also influence these patterns (Choi et al. 2002; Moss Landing Marine Laboratories 2006; Poornima et al. 2005).

B.2.2 Primary Heterotrophs

The bacterial and microbial components of aquatic ecosystems generally have a positive response to increasing water temperature – growth rates and bacterially mediated processes are enhanced until temperature tolerance limits are approached. Most studies found that the growth rates of bacteria and water temperatures are positively correlated. In contrast, Choi et al. (2002) found lower rates of bacteria production near outfalls but attributes this effect to residual chlorine in the discharge water rather than temperature alone.

[92] Abt Associates used several general search engines for preliminary searches for scientific and grey literature including Scirus: http://www.scirus.com/; Google Scholar: http://scholar.google.com/; and Dogpile: http://www.dogpile.com/, as well as publicly available information from NPDES permits and related section 316a/316b studies.

B.2.3 Zooplankton

Zooplankton and other pelagic macroinvertebrates typically increase their grazing activities and growth rate in response to increased temperature. Marasse et al. (1992) observed a higher rate of bacteria consumption (i.e., bacterivory) by samples of plankton that were incubated at higher temperatures. Jiang et al. (2009) suggests that copepod species with larger body sizes are more sensitive to thermal increases, and that this water temperature increase induces mortalities of copepods. As noted for other organisms, estuarine copepods have more tolerance to thermal stress than those from more stenothermal, deepwater environments.

B.2.4 Benthic Community

Benthic species and communities are often particularly vulnerable to thermal discharge due to association with the substrate and limited ability to migrate from impacted areas. Growth rates and spawning times are usually accelerated by increased temperature (Barnett 1972). McMahon (1975) and Leffler (1972) found that snails and blue crabs, respectively, exhibit more rapid growth at higher temperatures, but both studies also observe greater species mortality. The study by Coles (1984) found a positive effect with the thermal effluent as both the number of organisms and the colonization by coral reef propagules near the outfall were significantly greater than background areas. A recent study of benthic communities and associated biota near a nuclear power plant discharge show that the thermal pollution alters composition and decreases richness in benthic cover (Teixeira et al. 2009).

B.2.5 Fish

Fish are extremely well-studied with regard to temperature tolerance and thermal limits in both the laboratory and field. The thermal habitat requirements of coldwater, coolwater, and warmwater fish species are well-characterized (e.g., Beitinger et al. 2000; Sullivan et al. 2000), and these may be the basis for regulatory sub-classification of water bodies. Thermal discharges can influence the spatial distribution of fish due to direct responses to altered temperature (i.e., attraction, avoidance), effect on dissolved oxygen concentrations, and impacts to prey and habitat availability (Cooke et al. 2004; Sullivan et al. 2000). Rapid fluctuations and decreases in water temperature, usually associated with steep thermal gradients in temperate winter waters, can lead to “cold shock” with reduced survival (Ash et al. 1974; Deacutis 1978).

Smythe and Sawyko (2000) evaluated the effect of “cold shock” on fish and found no effect on larger predator species, though a forage species (gizzard shad) had lower survival rates. Some studies of thermal discharges have not observed significant effects in local fish communities. Hillman et al. (1977) and Krishnamoorthy et al. (2008) found that impacts on shore-zone fish and fingerlings from power station discharges were minimal. A study of salmonids by Sullivan et al. (2000) maintains that direct mortality from temperature is unlikely since acute lethal temperatures are rarely, if ever, observed in the field. Specifically, this study suggests that there is little or no risk of mortality if the annual maximum temperature is less than 26°C, but suggests a site-specific analysis when annual maximum temperatures exceed 24°C.

B.2.6 Ecosystem Functions and Services

In addition to the species-specific impacts, investigators have looked at the effects of thermal discharges on the structuring of species assemblages and communities, as well as secondary ecosystem function and services. Thermal discharges may have both detrimental and beneficial effects. For example, the bleaching and destruction of coral reefs by elevated thermal discharges is well documented, but Coles (1984) in the Moss Landing study found that the thermal effluent may have some beneficial effects, such as enhancing new coral regrowth or providing preferred water temperatures for avian birds and mammals.

Work in seven Southeastern U.S. cooling reservoirs indicated that direct thermal effects on phytoplankton communities were generally minimal, but that the smaller reservoirs were more prone to algal blooms due to nutrient trapping and elevated temperatures (Mallin et al. 1994). Indirect effects of excessive thermal loads in these reservoirs caused ecosystem-wide alterations arising from both top-down (higher trophic consumers) and bottom-up (primary producers) effects. Martinez-Arroyo et al. (2000) found that phytoplankton subjected to elevated water temperature exhibited lowered photosynthetic capacity and light harvesting efficiency, and required more light to reach a net oxygen production. Thus, primary production and oxygen levels, both critical ecosystem functions, may be decreased as a result of elevated temperatures.

Teixeira et al. (2009) evaluated the effect of thermal discharge on fish communities and habitat structure in rocky substrates near a nuclear power plant in southeastern Brazil. Their studies indicate the heated effluents affected habitat structure as well as fish community structure and its eco-spatial distribution. Lowered fish species richness was observed in the impacted area, attributed to a reduction in benthic cover of a habitat-forming species (*Sargassum* sp.).

B.3 Influence of Site-Specific Factors and Environmental Setting on Thermal Effects

As noted above, the environmental setting (i.e., the nature of the receiving waters) can have a pronounced influence on the potential for and the magnitude of adverse thermal impacts on biota. While physical features near the discharge and temporal climatic patterns usually dictate the observed level of thermal deviations for any given discharge, several environmental factors may be important in determining the magnitude of potential impacts, including: geographic location, marine vs. freshwater environments, volume of receiving water, rate of water exchange, other heat loads, and local habitats.

B.3.1 Geographic Location

Geographic location determines the duration and intensity of annual solar heating and usually dictates the resulting maximum ambient temperatures for the receiving waters. The more southerly the facility, the higher the seasonal temperature maxima is likely to be, increasing the possibility of reaching upper thermal temperature limits for sensitive organisms. Despite acclimation, relatively few North American aquatic organisms will tolerate chronic water temperatures in excess of 35-40^{o}C (Brock 1985).

Northerly receiving waters will have lower maximum ambient temperatures in summer, but will also exhibit greater seasonal variation; with a more extreme temperature gradient between discharge and surface water during winter. Conversely, sub-tropical water temperatures have less seasonal variation, and a more consistent thermal gradient is maintained between discharge and ambient conditions. Adverse effects to aquatic organisms are generally most pronounced at the acute and chronic high lethal temperatures and/or due to rapid fluctuations (e.g., "cold shock").

B.3.2 Marine vs. Freshwater Receiving Waters

Adverse thermal impacts have been documented in both freshwater and marine ecosystems, but the likelihood of impacts may be considered slightly greater in freshwaters simply due to the presumption that marine waters constitute a greater thermal reservoir due to larger volume and tidal flushing. However, as noted above, site-specific features will dictate the effective volume and the flushing rate, which are likely to be the key to vulnerability of receiving water ecosystem to thermal impacts. Clearly, the magnitude of thermal impacts also depends on the composition of the local biota and whether such organisms are temperature-sensitive. The sensitivity of coldwater freshwater fish (e.g., trout, salmonids, darters) to increased water temperature and associated lowering of available dissolved oxygen has been well characterized (Beitinger et al. 2000; Sullivan et al. 2000). There is less temperature-sensitivity in marine estuarine fish, which are often more tolerant than offshore fish, since estuarine fish are subject to regular environmental fluctuations.

B.3.3 Receiving Water Volume

The volume of the receiving water is a critical factor since it determines the total amount of heat that can be absorbed by a water body while still remaining at an acceptable temperature. The effective volume subject to the thermal discharge may be significantly less than that of the entire water body if it is constrained physically (e.g., narrow discharge channel, small coastal embayment) or can vary in the short term (e.g., low tide, hydropower releases), seasonally (e.g., thermally stratified lakes, salinity stratified estuary), or longer (e.g., multi-year droughts). Due to the buoyant properties of warm water, the effective mixed volume can be reduced even further if the thermal plume is not effectively or rapidly mixed into the receiving waters.

B.3.4 Rate of Water Exchange

The rate of water exchange is another factor which can compensate for a small effective volume. A short hydraulic residence time (HRT) (i.e., rapid flushing) of the receiving water at the point of the thermal discharge can rapidly dissipate a high heat load. Large fast rivers, open ocean outfalls, and coastal embayments with sweeping longshore currents, etc. can generally better tolerate thermal discharges and have limited or highly localized impacts to biota. Poorly flushed systems, those with seasonal flow minima, or episodic hydrologic inputs, are more likely to experience widespread or persistent thermal impacts. In some cases, the flow or volume of the thermal discharge may be very much greater than the receiving water.

B.3.5 Local Land Use

Local land uses may also be influential in that they can provide additional thermal loads to the water body independent of the thermal discharge. Developed urban watersheds with large percentages of impervious cover may produce large storm water flows with temperatures that are well above ambient temperatures in the receiving waters. Agricultural lands and irrigation return water may also increase local thermal loading. Channelization and removal of riparian buffer vegetation can increase water temperature through lack of shading, reflective artificial substrates, and removal of deep pool habitats.

B.3.6 Local Habitats

Benthic biota and/or habitats (e.g., oyster reefs, eelgrass, and mussel beds) found in nearshore environments are often subject to greater impact since these largely sessile communities are affixed to the substrate. On the other hand, mobile aquatic organisms can track temperature change and fine-tune their temporal and spatial distribution (Cooke et al. 2004). Biota can sometimes avoid adverse thermal impacts by seeking out localized areas of cooler or better aerated waters (e.g., deep pool, tributary stream, bottom waters) for short-term or seasonal residence. These areas provide habitat that may allow the temperature-sensitive organisms to persist and emigrate back into the affected water body once the thermal stress is reduced. Thermal effects could be more severe in homogenous environments (e.g., open water column, unstratified reservoir) where the biota does not have access to these refugia. Thermal displacements from spawning habitat due to dam construction and operation (e.g., bottom water releases) has also been a concern in western rivers and elsewhere (Bartholow et al. 2004; Hayes et al. 2006).

B.4 Uncertainties and Limitations of Assessing Thermal Impacts

One of the major difficulties in accurately characterizing the influence of thermal discharges on aquatic communities is the uncertainty due to the potential influence of other abiotic water quality factors. Thermal discharges from power plant cooling systems often contain elevated levels of additional constituents including, but not restricted to: residual chlorine, total suspended solids, total dissolved solids, cleaning agents and surfactants, metals, and nutrients. The presence of these constituents may complicate the interpretation of the environmental factor(s) that are responsible for observed changes in biotic communities.

For example, several of our studies on thermal effects on primary producers noted that residual chlorine in the discharge may be responsible for some of the observed effects (Chuang et al. 2009; Poornima et al. 2005). Interaction of thermal effects and heavy metals was responsible for some phytoplankton taxonomic changes in one reservoir investigated by Mallin et al. (1994). Looking at the behavior of smallmouth bass, Cooke et al (2004) found that a majority of a local radio-tagged population overwintered in the warmest portions of a thermal discharge to Lake Erie. However, this area also was high in habitat complexity, had adequate flow velocity refuges, and abundant forage, so selection for this habitat may not be a simple thermal preference.

Adverse temperature effects may also be more pronounced in aquatic ecosystems which are already subject to other environmental stressors such as high biochemical oxygen demand (BOD) levels, sediment contamination, or pathogens. Thermal discharges may have indirect effects on fish and other vertebrate populations through increasing pathogen growth and infection rates. Langford (1990) reviewed several studies on disease incidence and temperature, and while he found no simple, causal relationship between the two, he did note that it was clear that warmer water enhances the growth rates and survival of pathogens, and that infection rates tended to be lower in cooler waters.

B.5 Case Studies

Three case studies were selected for large power generating stations from which thermal discharges may have a potential impact to the local aquatic community/ecosystem. These three case studies provide examples of investigations of thermal impacts in different environmental settings (marine coastal embayment, coastal Great Lake, and freshwater river), and at differing spatial scales (community, habitat, ecosystem).

B.5.1 Brayton Point Station

Brayton Point Station (BPS) is a 1538 megawatt (MW) coal and oil-fired electrical generating station located in Somerset, MA. This facility takes cooling water from and discharges heated effluent to Mount Hope Bay (MHB), a large coastal embayment within Massachusetts and Rhode Island. Generation Unit 1 began operating in 1963, Unit 2 in 1964, Unit 3 in 1969, and Unit 4 in 1974 (Dominion 2011).

One of the most thorough examinations of the individual and cumulative effects of a power plant thermal discharge was conducted as part of the regulatory review of the CWA section 316(a) variance request application submitted in May 2001 as part of the NPDES discharge permit (Permit No. MA 003654) renewal for BPS. The permitee's 316(a) variance request application sought to keep the existing permit temperature criteria (maximum temperature of 95°F; delta (departure from ambient) temperature of 22° F), and to reduce the total heat load from the existing permit limits. However, these thermal criteria were still less stringent than what would be required by either technology-based or water quality-based discharge limits.

CWA 316(a) authorizes alternative thermal discharge limits when it is demonstrable that the proposed thermal limits "will assure the protection and propagation of a balanced indigenous population (BIP) of shellfish, fish, and wildlife in and on that body of water." To evaluate whether the thermal limits proposed in the May 2001 316(a) variance request application would meet this protective criterion, EPA, in accordance with the 316(a) Technical Guidance Manual (USEPA 1977), conducted a review of the historical and current conditions of MHB biota on a community-by-community evaluation, and considered potential thermal impacts to phytoplankton, zooplankton, habitat formers, shellfish, finfish, and other vertebrate (i.e., sea turtles and mammalian) wildlife. The findings of the community impact analyses are contained in the "*Clean Water Act NPDES Permitting Determinations for Thermal Discharge and Cooling Water Intake from Brayton Point Station in Somerset, MA*" (USEPA 2002a) dated July 22, 2002 (hereafter "*Determinations*") and summarized below.

For each of the community types, the *Determinations* provides a preliminary consideration of whether the community's nature, estuarine setting, and water column distribution within MHB relative to the location and magnitude of the BPS thermal discharge would result in a finding of "low potential impact areas" and lessened environmental concerns for the granting of the 316(a) variance. For those communities in MHB for which a "low potential impact" conclusion was not possible, the severity of the thermal effect was gauged by comparison to a list of *a priori* decision criteria for each community.

EPA judged that MBH was not a low potential impact area for phytoplankton. As seagrasses and salt marshes have historically declined in importance in MHB, the phytoplankton community is the dominant primary producer (USEPA 2002a). The recent (2001) occurrence of a nuisance blue-green algal bloom (dominated by the cyanophyte *Anacystis aeruginosa*) in MHB near BPS may be due to the high nutrients and warm water temperatures which favor formation of such bloom. It was considered likely that thermal plume from BPS was a contributing factor.

Perhaps of greater importance is the finding that the MHB phytoplankton community does not undergo the typical winter-spring phytoplankton bloom cycle (Keller et al. 1999). Extensive work was conducted on plankton communities in experimental mesocosms where temperature was shifted to mimic the expected thermal conditions in MHB surface waters. Extrapolating these changes seen in the mesocosms, such changes in phytoplankton population dynamics could very likely lead to significant impacts within the trophic dynamics of the MHB food web. Redirecting carbon away from benthic consumers and into pelagic food webs could represent a reduction in prey species for benthic-feeding finfish such as winter flounder, windowpane flounder, hogchoker, and tautog.

EPA judged that MHB was not a low potential impact area for zooplankton since it is an estuary that serves as a spawning site for numerous fish and invertebrate species (USEPA 2002a). The most noticeable thermal effect in this community is the recent increase in abundance of the ctenophore *Mneimiopsis leidyi*, and increased overwintering in MHB for this formerly seasonal resident. Dramatic increases in comb jellies (i.e., ctenophores) are usually indicative of stressed ecosystems with symptoms of increased water temperatures, increased nutrient levels, and depleted fish stocks (Pohl 2002). Since *M. leidyi* is a voracious consumer of pelagic fish eggs as well as zooplankton by which it competes with young-of-year winter flounder, it was concluded that BPS was significantly contributing to thermal increases in MHB, and facilitating expansion of the range and time of year distribution of the comb jellies.

Eelgrass is a coldwater plant that ranges from North Carolina to Canada and grows well in soft-bottom, low energy environments. Despite the current lack of eelgrass, the EPA judged that MBH was not a low potential impact area for habitat formers since the historic presence of extensive eelgrass meadows shows that it is capable of supporting this habitat type (USEPA 2002a). Experimental work has shown that optimal temperature ranges for photosynthesis decrease with increasing turbidity (Bulthuis 1987) so that in turbid waters, eelgrass growth decreases with increased temperature, because photosynthetic rates decrease and respiration rates increase. Based on the current lack of eelgrass, it was concluded that the combination of poor water quality and increased water temperature result in an “exclusion zone” for eelgrass growth in MHB (USEPA 2002a). Since BPS helps to elevate the water temperature over significant portions of the bay, it is considered a contributory cause to this exclusion.

EPA judged that MBH was not a low potential impact area for shellfish and macroinvertebrates due to the presence of commercially important species, the “substantial” densities of these species, the spawning and nursery areas in MHB, and the important role in ecosystem function that this community provides (USEPA 2002a). Benthic sampling indicated that there have been no significant changes in the benthic community between the 1970’s and mid-1990’s or over the span of time when BPS has been active and the annual heat flux was increased. The sampling also indicates a strong representation in the benthic community of the amphipod *Ampelisca* which is a preferred prey item for juvenile winter flounder. Overall, EPA found no substantial evidence of harm to shellfish and macroinvertebrates from the current thermal discharge, and any alternative which reduces the thermal discharge would be acceptable.

EPA judged that MHB was not a low potential impact area for finfish due to the presence of numerous recreational and commercially important species, the important spawning and nursery areas, and the potential for blockage of fish migration (USEPA 2002a). The analysis for finfish was specifically targeted at determining the appropriate thermal discharge limits for BPS in order to protect finfish populations, and included a retrospective examination of total finfish abundance trends in relation to plant operations. The analysis determined an acceptable annual flux of heat into MHB that is protective of finfish populations, based on the temperature thresholds for acute and chronic mortality as well as for several sub-lethal effects for some representative important species (RIS).

The finfish stocks in MHB have declined precipitously since 1984-1985, a period which marked the shift of Unit 4 at BPS from closed-cycle recirculating to once-through cooling operations. Further, work by Gibson (2002) suggests that winter flounder have been declining since at least the initiation of sampling in 1972. Although BPS had been operational for 9 years at that point, no fishery data are available to estimate what the finfish community was like prior to 1972. Comparison of the record of annual heat flux to MHB over that last 28 year period to records of finfish abundance led EPA to conclude that an annual heat flux of 28 trillion British thermal units (tBTU) to MHB, as proposed in the 316(a) variance request application, would be unable to stop or reverse a decline in fish populations, and thus would not be protective of the finfish community.

The temperature tolerance limits of 16 RIS were reviewed to establish temperature thresholds for the more sensitive of these species (winter flounder, striped bass). These thresholds were used to establish critical temperatures for three target depth strata (surface, middle, and bottom waters) at two key seasonal periods (winter, summer). Winter corresponds to the period (March 1 -31) of active winter flounder spawning, and when large numbers of larval planktonic winter flounder are present in MHB. The summer index period (July 15 – August 15) corresponds to the warmest time of the year.

Predictive hydrothermal models (CORMIX for near-field effects; WQMAP for far-field effects) of MHB provided a means of evaluating the potential thermal impacts caused by the current (i.e., existing permit), the proposed (i.e., the requested 316(a) variance), and two alternative reduced heat flux options for BPS operations, as well as a “no-plant” condition. During warm summer conditions, the proposed operational heat flux would impact 62 percent of the bottom water strata as compared to 4 percent under a no-plant scenario, while other alternative operating options would have reduced impact proportional to their proposed total heat fluxes. Using this method, it is possible to show impacts to all target depth strata during summer conditions and impacts to the bottom strata during winter.

The study also considered other heat effects on finfish caused by the thermal discharge. The first involved the attractive nuisance nature of the thermal plume (USEPA 2002a). The plume acts as an attractant for large numbers of striped bass and bluefish in the fall and winter, and disrupts the seasonal migration of these species. The crowding of large numbers of these species into a restricted area increases the potential for weakening or disease since the warm temperatures increase the metabolism of these fish at the same time there is reduced feeding due to a lack of prey.

Similarly, the trapping of Atlantic menhaden in the thermal plume affects the migration of this species, and likely increases impingement mortality and entrainment (IM&E) due to longer periods spent in proximity to intake structures, which has been evidenced by several recent large winter impingement loss events. Another effect noted was the establishment in MHB of smallmouth flounder (*Etropus microstomus*) which is at the northern limit of its geographic distribution range. It is important to note that an increased abundance or distribution shift to a warm water species is not indicative of protection of a BIP.

EPA judged that MBH is a low potential impact area for other vertebrate life since it is not a significant habitat for marine mammals or sea turtles (USEPA 2002a). Overall, there is no potential for harm from the current thermal discharge, and any alternative which reduces the thermal discharge would be acceptable.

A summary of current ecosystem thermal effects and predicted impacts associated with the proposed thermal flux was prepared (USEPA 2002a). The current thermal effects for which there appears to be no disagreement include:

- Appearance of nuisance algal blooms;
- Absence of normal winter-spring phytoplankton bloom;
- Overwintering of the ctenophore Mneimiopsis leidyi;
- Overwintering of striped bass and bluefish in discharge canal;
- Increased abundance of smallmouth flounder in MHB;
- Thermal avoidance of most of MHB by adult winter flounder; and
- Multiple fish kills as a result of large impingement events in the winter.

Evaluating the proposed 316(a) variance request, EPA predicted that, under the proposed thermal discharge under the 316(a) variance request, the following would occur:

- Large areas of MHB would be avoided by juvenile winter flounder and striped bass during warm summer months;
- Extensive areas of MHB would experience water temperatures resulting in chronic toxicity to juvenile winter flounder;
- Reduced winter flounder egg hatching success for the entire MHB for the warmest winter months;
- Increased predation on winter flounder eggs and larvae by sand shrimp; and
- Potential exclusion of eelgrass.

EPA also considered potential impacts from other stressors that could be responsible for mortality of finfish in MHB; including overfishing, predators, water quality, brown tides, and IM&E (USEPA 2002a). Each of these stressors was examined for its potential role in causing or contributing to the finfish collapse. Analyses of these other potential stressors indicated that while possibly contributory, the adverse effects of each were generally exacerbated by the thermal conditions caused by the BPS plume.

Based on the hydrothermal and ecological analyses conducted and documented in the *Determinations* document, EPA concluded that a BIP has not been maintained in MHB, and that the current BPS thermal discharge is a significant contributor to this problem (USEPA 2002a). Further, the proposed thermal reductions in annual heat flux contained in the 316(a) variance request application would not allow for the recovery of the winter flounder or the wider balanced indigenous ecosystem. Accordingly, EPA denied the permitee’s variance request, and reissued the NPDES permit in 2003 with the provision for installing closed-cycle recirculating systems in all four of the power units.

B.5.2 Quad Cities Nuclear Station

Quad Cities Nuclear Station (QCNS) is a dual-unit nuclear fueled steam electric generating facility (SIC 4911) located on a 765-acre site along the Mississippi River in Cordova, Illinois. QCNS Units I (866 net megawatts (MW)) and 2 (871 net MW) began commercial production of electricity in 1973. QCNS withdraws water from the Mississippi River for non-contact condenser cooling and various service water uses. After passing through the condensers, the cooling water from Units 1 and 2 mixes and then exits to the River via a discharge canal. QCNS is located on

Pool 14 of the Mississippi River, at approximate River Mile 506.5 above the confluence of the Ohio River.

The thermal discharge is authorized under the Station's NPDES Permit, issued by the Illinois EPA (ILEPA). Thermal limits in the NPDES Permit are based on Illinois environmental regulations, and studies and Demonstrations related to the thermal plume are performed under CWA section 316(a). During the latest NDPES permit renewal cycle, QCNS requested issuance of a 316(a) variance for a proposed alternative thermal standard, specifically relaxation of a maximum thermal excursion temperature limits by 2^{o}F during late summer months (July-September), which would increase the predicted frequency of expected thermal excursions from 1 percent to 3 percent. This variance request was based on a demonstration that future operations of QCNS would assure the protection and propagation of a balanced indigenous community (BIC) of fish, wildlife, and shellfish, particularly within Pool 14.

To evaluate the potential thermal impacts of QCNS' discharge on Pool 14, a number of comprehensive studies were conducted (including thermal plume modeling and field surveys, review of current ("prospective analysis") and historic ("retrospective demonstration") biota monitoring, and water quality assessment. The thermal plume modeling is contained in "*River temperature predictions downstream of Quad Cities Nuclear Generating Station*" (Holly Jr. et al. 2004). The elements and findings of the biological and water quality assessments are contained in the "*Quad Cities Nuclear Station Adjusted Thermal Standard CWA 316(a) Demonstration, Final Draft*" (HDR 2009) dated November 2009 (hereafter "*Demonstration*") and summarized below.

The thermal plume model study was able to successfully reproduce temperature field data (collected September 2003) without any adjustment of non-physical parameters (Holly Jr. et al. 2004). The model was used to show compliance of the thermal plume with the proposed alternative standard. The model validation revealed the importance of including site-specific river-entraining structures such as wing dams and chute closure dams in the model, as these have an important influence on the thermal flow patterns in the vicinity of the QCNS and local Steamboat Island (Holly Jr. et al. 2004).

Current and past monitoring efforts have collected data on a variety of aquatic communities, including phytoplankton, zooplankton, benthic macroinvertebrates (including freshwater mussels), ichthyoplankton, and finfish, which are summarized in the *Demonstration* (HDR 2009). For the prospective assessment, QCNS conducted comprehensive literature surveys, analyzed field data, and followed EPA approved protocols for assessing potential thermal impacts on RIS of fish. RIS species selected for the QCNS *Demonstration* included largemouth bass, channel catfish, spotfin shiner, and walleye. River and plant operating conditions were selected to provide a conservative assessment of potential power plant-related biological effects (i.e., the biothermal assessment focused on the months of June, July, August, and September). The results indicate that the proposed alternative thermal standard would have a negligible impact on largemouth bass, channel catfish, and a slightly positive one for spotfin shiner (i.e., increased growth) (HDR 2009). Walleye chronic mortality could be increased by 8.5 percent immediately downstream of the mixing zone, but placed in the areal relationship of the discharge to Pool 14, this would translate to a <1 percent effect on the walleye population in the pool (HDR 2009).

The retrospective assessment indicated some changes in the upper trophic levels (i.e., finfish) in Pool 14 since the Station began operating, but concluded that those changes are not attributable to the thermal input from QCNS (HDR 2009). In addition, the overall stability and health of upper trophic levels over the length of the monitoring period suggests that lower trophic levels (i.e., zooplankton, phytoplankton) have remained stable and abundant, providing an adequate food supply to allow and sustain growth of the finfish and mussel populations. The retrospective assessment also found that neither nuisance species (e.g., zebra mussel) nor heat tolerant species of fish have come to predominate in Pool 14 due to QCNS operations (HDR 2009).

In addition, the *Demonstration* examined the potential for harmful interactions between the QCNS thermal discharge and other pollutants, including dissolved organic carbon, total phosphorus, total nitrogen, biocides (i.e., anti-fouling chemicals), heavy metals, and other thermal discharges located upstream. This analysis indicated that there was no evidence to suggest that the small amount of additional heat that would be permitted to be discharged to Pool 14 under the proposed alternative standard would have an adverse synergistic effect with other pollutants (HDR 2009).

QCNS, based on their interpretation of EPA guidance documents and 316(a) Demonstrations for other facilities, maintained that the overall standard of compliance (i.e., protection of the BIC) would be demonstrated by meeting a series of functional criteria. Because this is a request for a change in the thermal standard, the *Demonstration* needed to show that these conditions will be satisfied in the future if the proposed standard was adopted:

- No substantial increase in abundance or distribution of any nuisance species or heat tolerant community;
- No substantial decreases in formerly abundant indigenous species or community structure to resemble a simpler successional stage than is natural for the locality and season, other than nuisance species;
- No unaesthetic appearance, odor, or taste of the water;
- No elimination of an established or potential economic or recreational use of the waters;
- No reduction in the successful completion of life cycles of indigenous species, including those of migratory species;
- No substantial reduction of community heterogeneity or trophic structure;
- No adverse impact on threatened or endangered species;
- No destruction of unique or rare habitat, without a detailed and convincing justification of why the destruction should not constitute a basis of denial; and
- No detrimental interaction with other pollutants, discharges, or water-use activities.

Based on the results of the thermal plume modeling study, the prospective analysis, the retrospective assessment, and the successful meeting of the criteria listed above, QCNS concluded that past or future operations have not caused appreciable harm to the BIC.

B.5.3 Point Beach Nuclear Station

Point Beach Nuclear Plant (PBNP) is located on the western shore of Lake Michigan in Two Rivers, Manitowoc County, WI. The facility consists of two nuclear powered steam electric generating units with a total net capacity of 1,540 megawatts thermal (MWt) each. Generation Unit 1 began commercial operation in December 1970 and Unit 2 in October 1972 (EA 2008). The units operate with a once-through cooling water system (EA 2008). Cooling water is withdrawn from a deep intake (22 ft. contour) in Lake Michigan, and current pumping capacity is estimated to be 680,000 gallons per minute. Each unit discharges the non-contact cooling water to Lake Michigan via its own outfall located at a mean temperature increase of 11.5°C (20.7°F) above the intake water temperature at the maximum flow rate (EA 2008).

PBNP planned to implement an extended power uprate (EPU) at both units in the 2010/2011 time frame that was expected to increase the existing plant output by approximately 17 percent. The proposed EPU does not result in an increase in water being withdrawn from Lake Michigan, nor will it result in an increase in the amount of water discharged to Lake Michigan (NRC 2010). However, EPU did require modification of the facility's Wisconsin Discharge Elimination System (WPDES) permit for the discharge of a pollutant from a point source into waters of the state (which includes the addition of heat from a point source). According to a modeling study performed by PBNP in 2008, the temperature of the discharge water was expected to increase by a maximum of 3.6 °F (2.0 °C), and the thermal plume expand as a result of the proposed EPU (NRC 2010).

In support of the permit modification request, PBNP prepared an assessment of the potential impacts of the thermal discharge from the planned EPU (i.e., the "Planned Change"). This assessment is summarized in "*Point Beach Nuclear Plant Evaluation of the Thermal Effects Due to a Planned Extended Power Uprate*" (EA 2008). Since there currently are no temperature limits in the PBNP WPDES permit or thermal water quality standards for Lake Michigan, this assessment represented a "good faith effort" by PBNP to demonstrate that the impacts of the EPU would not have a significant effect on the fish or shellfish communities in Lake Michigan (EA 2008).

Evaluation of the potential effects on the Lake Michigan aquatic community in the vicinity of the PBNP post-EPU discharge was based on a review of historical and current monitoring data collected in the vicinity of the facility and other power facilities that utilize Lake Michigan water for once-through cooling (EA 2008). Those study results were compared to expected responses of 16 Wisconsin Department of Natural Resource (WDNR) selected Representative Important Species (RIS) to the projected higher discharge temperatures and larger thermal plume that will result from the planned EPU. The evaluation placed emphasis on the RIS, and whether or not the BIC in the vicinity of the PBNP discharge would continue to be protected.

The assessment relied heavily on the findings of the Type I CWA section 316(a) Demonstration conducted by the facility in the 1970s as well as the 1976 finding by WDNR that no appreciable harm had occurred to the local BIC due to facility operations (EA 2008). The studies involved investigations of primary and secondary trophic levels from phytoplankton through fish in both reference and thermally affected areas (EA Engineering 2008; Limnetics 1974, as cited in EA 2008).

Recent entrainment and impingement monitoring studies at PBNP indicate that the same species that were common in the vicinity of the facility during the Type I Demonstration remain common near the facility despite lake-wide changes in the Lake Michigan fish community (Kitchell 2007, as cited in EA 2008). Recent fisheries data collected from both PBNP and the Kewaunee Nuclear Power Plant (KNPP), which is located only five miles north of PBNP, show that the same species seasonally occur in nearshore areas in the vicinity of the shoreline discharge structures. These findings indicate that the BIC is protected under similar operating conditions as have occurred historically at PBNP.

Evaluation of the modeled discharge temperatures and plume configurations under the planned EPU indicates that the predicted area, volume, and behavior of the plume will not be substantially different than under current PBNP operating conditions and similar to those evaluated during the Type 1 Demonstration (EA 2008). Based on the thermal model results using a 0.2 ft./sec along-shore current, the planned EPU would expand the surface area of the 6.0ºC contour from 27 to 39 acres; the 4.0ºC contour would increase from 79 to 105 acres; and the 2.0ºC contour would increase from 315 to 390 acres (EA 2008). These projected increases in plume size are relatively small compared to the surface area available for mixing. Under critical summer conditions the buoyant plume provides an area of safety as well as a zone of passage when discharge temperatures approach or exceed upper avoidance temperatures of the RIS fish.

The RIS evaluation showed that the predicted impact of the warmer and larger thermal plume as a result of the EPU at PBNP will be negligible (EA 2008). Thermal criteria for some of the 12 RIS fish species would be exceeded in the plume, but mainly at the point of discharge or in small areas for relatively brief periods of time. Fish readily move into and out of thermal discharge plumes, depending on their thermal requirements and the thermal regime of the plume at any given time. Cool and coldwater fish species would be somewhat restricted with regard to use of the plume area, especially during summer, but these species generally spend the summer well offshore. In addition, the warmwater RIS could slightly benefit from the warmer temperatures. Combining these observations with the size of the PBNP plume relative to available lake habitat, it was concluded that the larger and warmer thermal plume resulting from the planned EPU would have a minimal and insignificant impact on the fish community in Lake Michigan (EA 2008). Similar conclusions were reached for the four invertebrate RIS (shellfish and opossum shrimp).

Overall, the assessment concluded that the increased heat load to the discharge would not endanger the protection and propagation of a BIC of shellfish, fish, and wildlife in and on Lake Michigan. This conclusion was based on several lines of evidence including:

- The PBNP Type I Demonstration established that the original thermal plume did not cause “prior appreciable harm;”
- The PBNP thermal plumes resulting from the planned EPU will not be substantially larger than the original/existing plumes;
- There have been no changes in the aquatic community attributable to operation of the facility that would preclude reliance on the results of the Type I Demonstration for PBNP;
- The changes to the Lake Michigan fish community that have occurred during the past 50 years have occurred on a lake-wide basis;
- The impacts on RIS will be negligible; and
- The conclusion with respect to the effect of the planned EPU is consistent with assessments undertaken at other power facilities on Lake Michigan.

While the cooling water thermal plume of PBNP was expected to be larger as a result of the proposed EPU, it was not expected to disrupt the local BIC or have a significant impact on RIS of Lake Michigan (EA 2008). Recently, as part of the facilities’ operating license renewal, the Nuclear Regulatory Commission developed a draft Environmental Assessment (EA) for the power uprate. The draft EA was issued in December 2010 with a finding of no significant impact (NRC 2010).

Appendix C: Details of Regional IM&E

C.1 California Region

Table C-1: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the California Region (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
All forage species	0.17	0.18	0.20	0.29	<0.01	<0.01	14.81	24.28	0.17	0.18	15.00	24.56
All harvested species	0.50	0.54	0.58	0.85	<0.01	<0.01	15.94	26.14	0.50	0.54	16.52	26.98
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cabezon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.08	<0.01	<0.01	0.05	0.08
California halibut	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.20	0.33	<0.01	<0.01	0.20	0.33
California scorpionfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crabs (other)	0.02	0.02	0.02	0.03	<0.01	<0.01	6.65	10.91	0.02	0.02	6.68	10.94
Sea Basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.42	3.96	<0.01	<0.01	<0.01	3.96
Shrimp (other)	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.53	0.88	<0.01	<0.01	0.54	0.89
Drums and croakers	0.04	0.04	0.04	0.07	<0.01	<0.01	0.19	0.32	0.04	0.04	0.24	0.38
Dungeness crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Flounders	<0.01	<0.01	0.01	0.02	<0.01	<0.01	0.08	0.13	<0.01	<0.01	0.09	0.15
Fish (other)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02
Northern anchovy	0.29	0.32	0.33	0.49	<0.01	<0.01	0.03	0.04	0.29	0.32	0.36	0.54
Rockfishes	0.01	0.01	0.02	0.02	<0.01	<0.01	5.40	8.85	0.01	0.01	5.42	8.88
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sculpins	0.01	0.01	0.01	0.02	<0.01	<0.01	0.36	0.60	0.01	0.01	0.38	0.62
Smelts	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01	<0.01	0.01	0.02
Sunfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Surfperches	0.10	0.11	0.11	0.16	<0.01	<0.01	<0.01	<0.01	0.10	0.11	0.11	0.16
Total (all species)	**0.68**	**0.73**	**0.77**	**1.13**	**<0.01**	**<0.01**	**30.75**	**50.42**	**0.68**	**0.73**	**31.52**	**51.55**

Notes:
P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline
Source: U.S. EPA analysis for this report

Table C-2: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the California Region (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blennies	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	390.33	639.92	<0.01	<0.01	390.33	639.92
Bluegill	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Brown bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cabezon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.84	4.65	<0.01	<0.01	2.84	4.65
California halibut	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	3.29	5.40	<0.01	<0.01	3.29	5.40
California scorpionfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chinook salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crabs (other)	0.02	0.02	0.03	0.04	<0.01	<0.01	3,088.48	5,063.36	0.02	0.02	3,088.51	5,063.39
Delta smelt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Drums and croakers	0.18	0.19	0.20	0.30	<0.01	<0.01	390.48	640.16	0.18	0.19	390.68	640.46
Dungeness crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.06	<0.01	<0.01	0.04	0.06
Fish (other)	0.04	0.04	0.04	0.06	<0.01	<0.01	554.48	909.03	0.04	0.04	554.52	909.10
Flounders	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	136.20	223.29	<0.01	<0.01	136.20	223.30
Gobies	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	673.78	1,104.62	<0.01	<0.01	673.78	1,104.62
Herrings	0.02	0.03	0.03	0.04	<0.01	<0.01	11.19	18.35	0.02	0.03	11.22	18.39
Longfin smelt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Northern anchovy	0.37	0.39	0.42	0.61	<0.01	<0.01	352.68	578.20	0.37	0.39	353.10	578.81
Pacific herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	15.43	25.30	<0.01	<0.01	15.43	25.30
Rockfishes	0.01	0.01	0.01	0.02	<0.01	<0.01	27.29	44.74	0.01	0.01	27.30	44.76
Sacramento splittail	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sculpins	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	20.45	33.53	<0.01	<0.01	20.46	33.54
Sea Basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	5.65	9.26	<0.01	<0.01	5.65	9.26
Shrimp (other)	0.01	0.02	0.02	0.02	<0.01	<0.01	183.13	300.24	0.01	0.02	183.15	300.26
Silversides	0.05	0.05	0.05	0.08	<0.01	<0.01	51.98	85.22	0.05	0.05	52.04	85.30
Smallmouth bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Smelts	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.55	2.54	<0.01	<0.01	1.55	2.54
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	4.82	7.91	<0.01	<0.01	4.82	7.91
Sunfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Surfperches	0.06	0.06	0.06	0.09	<0.01	<0.01	<0.01	<0.01	0.06	0.06	0.06	0.09
Total (all species)	**0.77**	**0.83**	**0.88**	**1.30**	**<0.01**	**<0.01**	**5,914.12**	**9,695.80**	**0.77**	**0.83**	**5,915.00**	**9,697.09**

Notes:
P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline
Source: U.S. EPA analysis for this report

C.2 North Atlantic Region

Table C-3: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the North Atlantic (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
All forage species	0.35	0.37	0.50	0.53	<0.01	0.40	34.30	44.80	0.35	0.77	34.80	45.34
All harvested species	0.05	0.05	0.07	0.08	<0.01	0.11	9.52	12.44	0.05	0.16	9.60	12.52
American plaice	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic cod	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01
Atlantic herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.09	0.12	<0.01	<0.01	0.09	0.12
Atlantic mackerel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.02	0.02
Atlantic menhaden	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.04	<0.01	<0.01	0.03	0.04
Bluefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crabs (other)	0.02	0.02	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.03
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	3.14	4.10	<0.01	0.04	3.14	4.11
Fish (other)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pollock	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Red hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sculpins	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	1.43	1.87	<0.01	0.02	1.44	1.87
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Silver hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Skates	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.11	<0.01	<0.01	0.08	0.11
Weakfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
White perch	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Windowpane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.02	0.02
Winter flounder	0.02	0.02	0.02	0.02	<0.01	0.05	4.69	6.13	0.02	0.07	4.71	6.15
Total (all species)	**0.40**	**0.42**	**0.57**	**0.61**	**<0.01**	**0.51**	**43.83**	**57.24**	**0.40**	**0.93**	**44.40**	**57.86**

Notes:
P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline
Source: U.S. EPA analysis for this report

Table C-4: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the North Atlantic (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Alewife	0.02	0.02	0.02	0.03	<0.01	0.02	2.13	2.78	0.02	0.04	2.15	2.80
American plaice	<0.01	<0.01	<0.01	<0.01	<0.01	0.86	73.53	96.04	<0.01	0.86	73.53	96.04
American sand lance	0.05	0.05	0.07	0.08	<0.01	6.31	542.26	708.25	0.05	6.36	542.33	708.33
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic cod	<0.01	<0.01	<0.01	<0.01	<0.01	0.50	43.33	56.59	<0.01	0.50	43.33	56.59
Atlantic herring	<0.01	<0.01	0.01	0.01	<0.01	0.37	32.23	42.09	<0.01	0.38	32.24	42.11
Atlantic mackerel	<0.01	<0.01	<0.01	<0.01	<0.01	30.35	2,608.87	3,407.48	<0.01	30.35	2,608.87	3,407.48
Atlantic menhaden	<0.01	<0.01	<0.01	<0.01	<0.01	18.06	1,552.60	2,027.86	<0.01	18.07	1,552.60	2,027.87
Atlantic silverside	0.04	0.05	0.06	0.07	<0.01	0.41	35.65	4.56	0.04	0.46	35.71	46.63
Atlantic tomcod	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	2.32	3.03	<0.01	0.03	2.32	3.03
Bay anchovy	<0.01	0.01	0.01	0.01	<0.01	239.73	20,604.68	26,912.03	<0.01	239.74	20,604.69	26,912.04
Blueback herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.03	<0.01	<0.01	0.02	0.03
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	4.48	5.86	<0.01	0.05	4.49	5.86
Crabs (other)	0.01	0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.02
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	125.28	10,767.77	14,063.92	<0.01	125.28	10,767.78	14,063.92
Fish (other)	0.02	0.02	0.03	0.03	<0.01	2.24	192.48	251.40	0.02	2.26	192.51	251.43
Fourbeard rockling	<0.01	<0.01	<0.01	<0.01	<0.01	1.99	171.36	223.81	<0.01	1.99	171.36	223.81
Grubby	<0.01	<0.01	0.01	0.01	<0.01	1.85	159.12	207.83	<0.01	1.86	159.13	207.84
Hogchoker	0.01	0.01	0.02	0.02	<0.01	2.36	202.71	264.77	0.01	2.37	202.73	264.79
Lumpfish	<0.01	<0.01	<0.01	<0.01	<0.01	0.19	16.57	21.64	<0.01	0.19	16.57	21.64
Northern pipefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.42	0.55	<0.01	<0.01	0.43	0.56
Pollock	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	1.28	1.67	<0.01	0.02	1.28	1.67
Radiated shanny	<0.01	<0.01	<0.01	<0.01	<0.01	0.47	40.74	53.21	<0.01	0.47	40.74	53.21
Rainbow smelt	0.02	0.02	0.02	0.02	<0.01	0.08	6.51	8.51	0.02	0.09	6.54	8.53
Red hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rock gunnel	<0.01	<0.01	<0.01	<0.01	<0.01	1.70	146.13	190.86	<0.01	1.70	146.13	190.86
Sculpins	<0.01	<0.01	<0.01	<0.01	<0.01	0.94	80.72	105.42	<0.01	0.94	80.72	105.43
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	6.14	8.02	<0.01	0.07	6.14	8.03
Seaboard goby	<0.01	<0.01	<0.01	<0.01	<0.01	10.22	878.37	1,147.25	<0.01	10.22	878.37	1,147.25
Searobin	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	4.24	5.53	<0.01	0.05	4.24	5.53
Silver hake	0.01	0.01	0.02	0.02	<0.01	2.44	209.93	274.19	0.01	2.45	209.94	274.20
Skates	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped killifish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.03	<0.01	<0.01	0.02	0.03
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	125.83	10,815.39	14,126.11	<0.01	125.84	10,815.39	14,126.11
Threespine stickleback	<0.01	<0.01	0.01	0.01	<0.01	<0.01	0.03	0.04	<0.01	<0.01	0.04	0.06
Weakfish	<0.01	<0.01	<0.01	<0.01	<0.01	1.47	126.32	164.99	<0.01	1.47	126.32	164.99

Table C-4: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the North Atlantic (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
White perch	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	0.14	<0.01	<0.01	0.11	0.14
Windowpane	<0.01	<0.01	<0.01	<0.01	<0.01	8.88	762.82	996.32	<0.01	8.88	762.82	996.33
Winter flounder	0.03	0.03	0.04	0.04	<0.01	28.72	2,468.75	3,224.46	0.03	28.75	2,468.79	3,224.51
Total (all species)	**0.28**	**0.30**	**0.40**	**0.44**	**<0.01**	**611.52**	**52,560.02**	**68,649.28**	**0.28**	**611.82**	**52,560.42**	**68,649.72**

Notes:
P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline
Source: U.S. EPA analysis for this report

C.3 Mid-Atlantic Region

Table C-5: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Mid-Atlantic (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
All forage species	10.91	11.65	13.32	14.42	0.72	1.09	402.14	461.47	11.63	12.75	415.46	475.89
All harvested species	18.66	19.94	22.79	24.67	0.20	0.31	113.65	130.42	18.87	20.25	136.44	155.08
Alewife	0.02	0.03	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.02	0.03	0.03	0.04
American shad	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic croaker	0.18	0.19	0.22	0.24	0.02	0.03	11.85	13.60	0.20	0.23	12.08	13.84
Atlantic herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic menhaden	12.67	13.53	15.47	16.74	<0.01	<0.01	1.73	1.99	12.67	13.54	17.20	18.73
Black crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Black drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blue crab	0.84	0.90	1.03	1.11	0.11	0.16	59.39	68.16	0.95	1.06	60.42	69.27
Bluefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluegill	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Brown bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Bullheads	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel catfish	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01
Crabs (other)	0.02	0.02	0.02	0.03	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.03
Crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Freshwater drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	0.76	0.81	0.92	1.00	0.01	0.02	5.93	6.81	0.77	0.24	0.34	7.81
Red drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Red hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver perch	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Smallmouth bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Spot	1.72	1.84	2.10	2.27	0.03	0.05	19.30	22.15	1.75	1.89	21.40	24.42

Table C-5: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Mid-Atlantic (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Spotted seatrout	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.76	0.88	<0.01	<0.01	0.77	0.88
Striped mullet	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Summer flounder	0.01	0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.02
Sunfish	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Weakfish	0.84	0.89	1.02	1.11	<0.01	<0.01	1.49	1.70	0.84	0.90	2.51	2.81
White perch	1.55	1.66	1.89	2.05	0.02	0.04	13.11	15.04	1.57	1.69	15.00	17.09
Whitefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Windowpane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Winter flounder	<0.01	0.01	0.01	0.01	<0.01	<0.01	0.06	0.07	<0.01	0.01	0.07	0.08
Total (all species)	**29.57**	**31.60**	**36.11**	**39.08**	**0.93**	**1.40**	**515.78**	**591.89**	**30.50**	**32.99**	**551.90**	**630.97**

Notes:

P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline

Source: U.S. EPA analysis for this report

Table C-6: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Mid-Atlantic (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Alewife	0.10	0.10	0.12	0.13	<0.01	<0.01	1.68	1.92	0.10	0.11	1.80	2.05
American shad	0.02	0.02	0.02	0.02	0.03	0.05	18.41	21.13	0.05	0.07	18.43	21.15
Atlantic croaker	0.66	0.71	0.81	0.88	0.34	0.51	189.17	217.08	1.01	1.22	189.98	217.96
Atlantic herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atlantic menhaden	20.54	21.95	25.08	27.15	0.06	0.09	33.65	38.62	20.60	22.04	58.74	65.77
Atlantic silverside	0.41	0.44	0.50	0.54	0.05	0.08	30.24	34.70	0.46	0.52	30.74	35.24
Atlantic tomcod	0.04	0.04	0.05	0.05	<0.01	<0.01	<0.01	<0.01	0.04	0.04	0.05	0.05
Bay anchovy	4.02	4.29	4.91	5.31	48.59	73.22	26,996.15	30,979.52	52.60	77.51	27,001.05	30,984.82
Black crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Black drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blue crab	0.84	0.89	1.02	1.10	1.68	2.53	932.50	1,070.10	2.51	3.42	933.53	1,071.20
Blueback herring	0.37	0.39	0.45	0.49	0.01	0.02	6.66	7.65	0.38	0.41	7.11	8.13
Bluefish	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Bluegill	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluntnose minnow	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Brown bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.03	<0.01	<0.01	0.03	0.04
Bullheads	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Carp	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chain pipefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel catfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crabs (other)	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01
Crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Darters	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	1.56	1.66	1.90	2.06	1.88	2.83	1,044.61	1,198.74	3.44	4.50	1,046.51	1,200.80
Freshwater drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Gizzard shad	0.10	0.11	0.12	0.13	<0.01	<0.01	<0.01	<0.01	0.10	0.11	0.12	0.13
Gobies	<0.01	<0.01	<0.01	<0.01	0.07	0.11	39.50	45.33	0.07	0.11	39.50	45.33
Grubby	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Herrings	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hogchoker	0.15	0.16	0.19	0.20	12.83	19.34	7,129.97	8,182.02	12.99	19.50	7,130.16	8,182.22
Menhadens	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.03	<0.01	<0.01	0.03	0.03
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Northern pipefish	<0.01	0.01	0.01	0.01	<0.01	<0.01	2.92	3.35	0.01	0.02	2.93	3.37
Rainbow smelt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Red drum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Red hake	0.02	0.02	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.03

Table C-6: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Mid-Atlantic (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Seaboard goby	<0.01	<0.01	<0.01	<0.01	6.76	10.20	3,758.88	4,313.52	6.77	10.20	3,758.89	4,313.52
Searobin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Shiners	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.27	0.31	<0.01	<0.01	0.27	0.31
Silver hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver perch	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silversides	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.78	0.90	<0.01	<0.01	0.78	0.90
Smallmouth bass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Spot	2.67	2.86	3.26	3.53	0.11	0.17	63.87	73.29	2.79	3.03	67.13	76.82
Spotted seatrout	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	0.01	0.01	0.01	0.01	0.52	0.79	291.01	333.95	0.53	0.80	291.03	333.97
Striped killifish	0.09	0.10	0.11	0.12	<0.01	<0.01	<0.01	<0.01	0.09	0.10	0.11	0.12
Striped mullet	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Suckers	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Summer flounder	0.02	0.02	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.03
Sunfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Threespine stickleback	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Weakfish	0.96	1.03	1.18	1.27	0.24	0.36	133.56	153.27	1.20	1.39	134.74	154.55
White perch	0.82	0.87	1.00	1.08	1.15	1.74	641.08	735.68	1.97	2.61	642.08	736.76
Whitefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Windowpane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Winter flounder	0.02	0.02	0.02	0.02	0.05	0.07	25.26	28.99	0.06	0.09	25.28	29.01
Total (all species)	**33.49**	**35.78**	**40.90**	**44.26**	**74.40**	**112.13**	**41,340.26**	**47,440.14**	**107.89**	**147.91**	**41,381.16**	**47,484.40**

Notes:

P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline

Source: U.S. EPA analysis for this report

C.4 South Atlantic Region

Table C-7: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the South Atlantic (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
All forage species	10.98	11.77	16.05	16.21	<0.01	0.44	7.86	8.41	10.98	12.21	23.91	24.61
All harvested species	0.63	0.68	0.92	0.93	<0.01	0.04	0.76	0.82	0.63	0.72	1.69	1.75
Atlantic menhaden	0.13	0.14	0.19	0.19	<0.01	<0.01	0.02	0.03	0.13	0.14	0.21	0.22
Blue crab	0.23	0.25	0.34	0.34	<0.01	<0.01	<0.01	<0.01	0.23	0.25	0.34	0.34
Crabs (other)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.02	0.02
Drums and croakers	0.01	0.01	0.02	0.02	<0.01	0.04	0.63	0.68	0.01	0.05	0.65	0.70
Flounders	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Pinfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver perch	0.14	0.15	0.21	0.21	<0.01	<0.01	<0.01	<0.01	0.14	0.15	0.21	0.21
Spot	0.10	0.11	0.15	0.15	<0.01	<0.01	0.08	0.08	0.10	0.11	0.23	0.23
Spotted seatrout	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Stone crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Weakfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total (all species)	**11.61**	**12.44**	**16.97**	**17.14**	**<0.01**	**0.48**	**8.62**	**9.22**	**11.61**	**12.93**	**25.60**	**26.36**

Notes:
P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline
Source: U.S. EPA analysis for this report

Table C-8: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the South Atlantic (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	**F**	**P2**	**B**	**P4**	**F**	**P2**	**B**	**P4**	**F**	**P2**	**B**
Atlantic menhaden	0.21	0.23	0.31	0.31	<0.01	3.48	62.28	66.59	0.21	3.71	62.59	66.90
Atlantic silverside	0.03	0.03	0.05	0.05	<0.01	<0.01	<0.01	<0.01	0.03	0.03	0.05	0.05
Bay anchovy	6.59	7.06	9.63	9.73	<0.01	53.13	949.88	1,015.58	6.59	60.19	959.52	1,025.31
Blue crab	0.23	0.25	0.34	0.34	<0.01	<0.01	<0.01	<0.01	0.23	0.25	0.34	0.34
Crabs (other)	<0.01	<0.01	<0.01	<0.01	<0.01	14.77	264.07	282.33	<0.01	14.77	264.07	282.33
Drums and croakers	0.06	0.06	0.08	0.08	<0.01	52.55	939.64	1,004.62	0.06	52.61	939.72	1,004.70
Fish (other)	0.43	0.46	0.63	0.64	<0.01	6.04	107.92	115.39	0.43	6.50	108.55	116.02
Flounders	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Gobies	<0.01	<0.01	<0.01	<0.01	<0.01	79.08	1,413.86	1,511.63	<0.01	79.08	1,413.86	1,511.63
Herrings	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pinfish	<0.01	<0.01	<0.01	<0.01	<0.01	1.58	28.20	30.15	<0.01	1.58	28.20	30.15
Scaled sardine	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Shrimp (other)	2.30	2.46	3.36	3.39	<0.01	23.01	411.34	439.78	2.30	25.47	414.69	443.17
Silver perch	0.12	0.12	0.17	0.17	<0.01	<0.01	<0.01	<0.01	0.12	0.12	0.17	0.17
Spot	0.18	0.20	0.27	0.27	<0.01	47.60	851.08	909.94	0.18	47.80	851.35	910.21
Spotted seatrout	<0.01	<0.01	<0.01	<0.01	<0.01	0.78	13.96	14.92	<0.01	0.78	13.96	14.92
Stone crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Weakfish	0.01	0.01	0.02	0.02	<0.01	2.23	39.93	42.69	0.01	2.25	39.94	42.70
Total (all species)	**10.17**	**10.90**	**14.87**	**15.02**	**<0.01**	**284.24**	**5,082.16**	**5,433.62**	**10.17**	**295.15**	**5,097.03**	**5,448.64**

Notes:

P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline

Source: U.S. EPA analysis for this report

C.5 Gulf of Mexico Region

Table C-9: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Gulf of Mexico (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
All forage species	4.84	5.03	6.03	6.70	0.04	0.04	25.66	43.45	4.88	5.06	31.69	50.15
All harvested species	33.90	35.18	42.20	46.85	0.04	0.04	29.53	50.01	33.94	35.22	71.73	96.86
Atlantic croaker	1.42	1.48	1.77	1.96	<0.01	<0.01	<0.01	<0.01	1.42	1.48	1.77	1.97
Black drum	0.01	0.01	0.01	0.02	<0.01	<0.01	3.61	6.12	0.02	0.02	3.62	6.13
Blue crab	4.86	5.05	6.06	6.72	0.02	0.02	11.59	19.63	4.88	5.06	17.65	26.35
Leatherjacket	0.59	0.62	0.74	0.82	<0.01	<0.01	0.02	0.03	0.59	0.62	0.76	0.85
Mackerels	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	4.26	4.42	5.30	5.89	<0.01	<0.01	0.03	0.05	4.26	4.42	5.33	5.94
Fish (other)	1.28	1.32	1.59	1.76	<0.01	<0.01	0.10	0.16	1.28	0.97	1.18	1.93
Pinfish	0.02	0.03	0.03	0.03	<0.01	<0.01	0.65	1.11	0.03	0.03	0.68	1.14
Pink shrimp	18.44	19.14	22.95	25.48	0.01	0.01	8.17	13.83	18.45	19.15	31.12	39.31
Red drum	0.07	0.07	0.09	0.10	<0.01	<0.01	<0.01	0.01	0.07	0.07	0.10	0.11
Sea basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	0.80	0.83	1.00	1.11	<0.01	<0.01	0.22	0.38	0.80	0.84	1.22	1.49
Sheepshead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.04	<0.01	<0.01	0.02	0.04
Silver perch	0.24	0.25	0.30	0.33	<0.01	<0.01	3.12	5.28	0.25	0.26	3.42	5.61
Spot	0.33	0.34	0.41	0.45	<0.01	<0.01	0.05	0.09	0.33	0.34	0.46	0.54
Spotted seatrout	1.08	1.12	1.35	1.50	<0.01	<0.01	0.09	0.15	1.08	1.12	1.44	1.65
Stone crab	0.16	0.17	0.20	0.22	<0.01	<0.01	0.25	0.43	0.16	0.17	0.45	0.65
Striped mullet	0.32	0.33	0.40	0.44	<0.01	<0.01	1.59	2.70	0.32	0.33	1.99	3.14
Total (all species)	**38.74**	**40.21**	**48.23**	**53.55**	**0.08**	**0.08**	**55.19**	**93.46**	**38.82**	**40.29**	**103.42**	**147.01**

Notes:
P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline
Source: U.S. EPA analysis for this report

Table C-10: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Gulf of Mexico (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Atlantic croaker	6.64	6.90	8.27	9.18	0.07	0.07	49.45	83.75	6.71	6.96	57.73	92.93
Bay anchovy	1.86	1.93	2.32	2.57	126.59	126.59	91,714.39	155,318.87	128.45	128.52	91,716.71	155,321.44
Black drum	0.01	0.01	0.01	0.01	40.50	40.50	29,342.08	49,690.98	40.51	40.51	29,342.09	49,691.00
Blue crab	4.84	5.03	6.03	6.69	0.12	0.12	85.58	144.93	4.96	5.14	91.61	151.63
Chain pipefish	0.03	0.03	0.04	0.04	<0.01	<0.01	0.65	1.10	0.03	0.03	0.68	1.14
Fish (other)	3.19	3.32	3.98	4.42	4.11	4.11	2,980.35	5,047.23	7.31	7.43	2,984.32	5,051.65
Gobies	0.06	0.06	0.07	0.08	1.43	1.43	1,038.00	1,757.86	1.49	1.49	1,038.07	1,757.94
Gulf killifish	0.02	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.02
Hogchoker	0.06	0.06	0.08	0.09	0.08	0.08	60.53	102.51	0.15	0.15	60.61	102.60
Leatherjacket	0.41	0.42	0.51	0.56	0.33	0.33	241.86	409.59	0.74	0.76	242.37	410.16
Mackerels	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	6.91	7.17	8.60	9.54	0.11	0.11	81.98	138.83	7.02	7.28	90.58	148.37
Pinfish	0.05	0.05	0.06	0.07	0.05	0.05	32.83	55.60	0.10	0.10	32.90	55.68
Pink shrimp	18.80	19.51	23.41	25.98	0.05	0.05	38.48	65.16	18.85	19.57	61.88	91.15
Red drum	0.07	0.07	0.08	0.09	<0.01	<0.01	0.33	0.57	0.07	0.07	0.42	0.66
Scaled sardine	0.14	0.14	0.17	0.19	1.25	1.25	902.35	1,528.14	1.38	1.39	902.52	1,528.33
Sea basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	0.51	0.52	0.63	0.70	0.03	0.03	20.96	35.50	0.53	0.55	21.59	36.20
Sheepshead	<0.01	<0.01	<0.01	<0.01	0.16	0.16	116.63	197.51	0.16	0.16	116.63	197.51
Silver perch	0.20	0.20	0.24	0.27	37.41	37.41	27,105.51	45,903.34	37.61	37.62	27,105.75	45,903.61
Spot	0.60	0.62	0.74	0.82	0.01	0.01	10.59	17.93	0.61	0.63	11.33	18.75
Spotted seatrout	0.52	0.54	0.64	0.71	2.24	2.24	1,625.98	2,753.61	2.76	2.78	1,626.63	2,754.33
Stone crab	0.12	0.12	0.15	0.16	12.07	12.07	8,745.52	14,810.59	12.19	12.19	8,745.67	14,810.76
Striped mullet	0.19	0.20	0.24	0.27	<0.01	<0.01	4.62	7.82	0.20	0.21	4.86	8.09
Tidewater silverside	0.13	0.13	0.16	0.18	0.01	0.01	10.47	17.73	0.14	0.15	10.63	17.90
Total (all species)	**45.35**	**47.07**	**56.46**	**62.68**	**226.65**	**226.65**	**164,209.14**	**278,089.16**	**272.00**	**273.72**	**164,265.60**	**278,151.84**

Notes:

P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline

Source: U.S. EPA analysis for this report

C.6 Great Lakes Region

Table C-11: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Great Lakes (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
All forage species	175.87	193.55	220.56	226.20	0.01	0.03	9.94	13.81	175.88	193.58	230.50	240.01
All harvested species	8.15	8.97	10.22	10.49	<0.01	0.03	7.75	10.76	8.16	9.00	17.97	21.25
Black bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Black crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluegill	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Brown bullhead	0.02	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.02
Bullheads	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel catfish	0.16	0.17	0.19	0.20	<0.01	<0.01	<0.01	<0.01	0.16	0.17	0.20	0.20
Crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.02	0.02
Freshwater drum	0.31	0.34	0.38	0.39	<0.01	<0.01	0.46	0.64	0.31	0.34	0.84	1.03
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	0.03	0.04	0.04	0.04	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	0.04
Rainbow smelt	0.35	0.38	0.44	0.45	<0.01	0.02	5.33	7.40	0.35	0.40	5.76	7.85
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sauger	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sculpins	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01	<0.01	0.01	0.02
Smallmouth bass	0.05	0.05	0.06	0.06	<0.01	<0.01	<0.01	<0.01	0.05	0.05	0.06	0.06
Smelts	2.60	2.87	3.27	3.35	<0.01	<0.01	0.01	0.01	2.60	2.87	3.28	3.36
Sunfish	0.06	0.06	0.07	0.07	<0.01	<0.01	0.86	1.19	0.06	0.07	0.93	1.26
Walleye	0.06	0.07	0.08	0.08	<0.01	<0.01	0.24	0.33	0.06	0.07	0.31	0.41
White bass	3.83	4.21	4.80	4.92	<0.01	<0.01	0.76	1.06	3.83	4.21	5.56	5.98
Whitefish	0.13	0.15	0.17	0.17	<0.01	<0.01	<0.01	<0.01	0.13	0.15	0.17	0.17
Yellow perch	0.54	0.60	0.68	0.70	<0.01	<0.01	0.07	0.09	0.54	0.60	0.75	0.79
Total (all species)	**184.02**	**202.52**	**230.78**	**236.69**	**0.02**	**0.06**	**17.68**	**24.57**	**184.04**	**202.58**	**248.47**	**261.26**

Notes:

P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline

Source: U.S. EPA analysis for this report

Table C-12: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Great Lakes (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Alewife	9.70	10.68	12.17	12.48	10.31	32.56	10,003.26	3,898.65	20.02	43.24	10,015.44	13,911.13
Black bullhead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Black crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blueback herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluegill	0.04	0.05	0.06	0.06	<0.01	<0.01	0.05	0.07	0.05	0.05	0.11	0.13
Bluntnose minnow	0.03	0.03	0.04	0.04	<0.01	0.01	3.42	4.75	0.03	0.04	3.45	4.79
Brown bullhead	0.01	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.02	0.02	0.02
Bullheads	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Burbot	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.29	0.40	<0.01	<0.01	0.29	0.40
Carp	0.03	0.03	0.04	0.04	0.89	2.82	866.66	1,204.14	0.92	2.85	866.69	1,204.18
Channel catfish	0.10	0.11	0.12	0.12	<0.01	<0.01	0.61	0.85	0.10	0.11	0.74	0.98
Chinook salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crappie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.38	0.53	<0.01	<0.01	0.39	0.54
Darters	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.75	1.05	<0.01	<0.01	0.76	1.05
Emerald shiner	26.33	28.98	33.02	33.87	0.04	0.12	36.38	50.55	26.37	29.10	69.40	84.41
Fish (other)	0.18	0.19	0.22	0.23	11.23	35.46	10,895.22	15,137.95	11.41	35.65	10,895.44	15,138.17
Freshwater drum	0.59	0.65	0.74	0.76	1.54	4.86	1,494.29	2,076.18	2.13	5.51	1,495.03	2,076.94
Gizzard shad	28.91	31.81	36.25	37.18	1.04	3.29	1,009.94	1,403.23	29.95	35.10	1,046.20	1,440.41
Golden redhorse	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Herrings	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.93	4.07	<0.01	<0.01	2.93	4.07
Logperch	0.27	0.30	0.34	0.35	0.03	0.10	31.55	43.83	0.30	0.40	31.88	44.18
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.32	0.44	<0.01	<0.01	0.32	0.44
Rainbow smelt	0.24	0.27	0.31	0.31	0.72	2.28	701.29	974.38	0.97	2.55	701.60	974.70
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.62	2.25	<0.01	<0.01	1.62	2.25
Sauger	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sculpins	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.92	1.28	<0.01	<0.01	0.92	1.28
Shiners	0.70	0.77	0.88	0.90	0.04	0.13	39.21	54.47	0.74	0.90	40.08	55.37
Silversides	0.04	0.04	0.05	0.05	<0.01	<0.01	<0.01	<0.01	0.04	0.04	0.05	0.05
Smallmouth bass	0.01	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.02	0.02	0.02
Smelts	1.18	1.30	1.48	1.52	0.04	0.13	39.56	54.97	1.22	1.43	41.04	56.49
Spotted sucker	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped killifish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Suckers	<0.01	<0.01	<0.01	<0.01	0.03	0.10	31.48	43.74	0.04	0.11	31.49	43.75
Sunfish	<0.01	0.01	0.01	0.01	<0.01	<0.01	2.54	3.53	0.01	.02	2.55	3.54
Threespine stickleback	0.02	0.02	0.03	0.03	<0.01	<0.01	0.18	0.25	0.02	0.02	0.21	0.28
Walleye	0.09	0.10	0.11	0.11	<0.01	0.03	9.25	12.86	0.10	0.13	9.36	12.97
White bass	2.14	2.35	2.68	2.75	0.06	0.19	57.17	79.44	2.20	2.54	59.86	82.19

Table C-12: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Great Lakes (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
White perch	9.14	10.06	11.46	11.76	0.25	0.80	245.11	340.56	9.39	10.86	256.57	352.31
Whitefish	0.03	0.03	0.04	0.04	<0.01	<0.01	0.08	0.11	0.03	0.03	0.12	0.15
Yellow perch	0.74	0.82	0.93	0.96	0.02	0.05	14.81	20.58	0.76	0.87	15.75	21.54
Total (all species)	**80.58**	**88.68**	**101.05**	**103.64**	**26.28**	**82.96**	**25,489.28**	**35,415.10**	**106.85**	**171.64**	**25,590.33**	**35,518.74**

Notes:

P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline

Source: U.S. EPA analysis for this report

C.7 Inland Region

Table C-13: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Inland Region (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
All forage species	324.12	335.14	386.58	443.70	0.21	1.11	120.73	155.43	324.34	336.25	507.31	599.13
All harvested species	23.61	24.42	28.16	32.33	0.17	0.89	96.71	124.51	23.79	25.31	124.88	156.84
American shad	0.04	0.04	0.04	0.05	<0.01	<0.01	<0.01	<0.01	0.04	0.04	0.04	0.05
Black bullhead	0.13	0.13	0.15	0.17	<0.01	<0.01	<0.01	<0.01	0.13	0.13	0.15	0.18
Black crappie	0.05	0.05	0.05	0.06	<0.01	<0.01	0.37	0.48	0.05	0.05	0.42	0.54
Bluegill	1.46	1.51	1.74	2.00	<0.01	<0.01	0.13	0.17	1.46	1.51	1.87	2.17
Brown bullhead	0.02	0.02	0.02	0.03	<0.01	<0.01	0.03	0.04	0.02	0.02	0.05	0.07
Bullheads	0.02	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.03
Channel catfish	1.13	1.16	1.34	1.54	<0.01	<0.01	0.74	0.95	1.13	1.17	2.08	2.50
Crappie	0.08	0.08	0.09	0.11	<0.01	<0.01	1.03	1.32	0.08	0.09	1.12	1.43
Freshwater drum	0.82	0.85	0.98	1.13	<0.01	0.04	4.64	5.97	0.83	0.89	5.62	7.10
Menhadens	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.06	<0.01	<0.01	0.05	0.07
Rainbow smelt	0.10	0.10	0.11	0.13	<0.01	<0.01	0.15	0.20	0.10	0.10	0.27	0.33
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sauger	0.07	0.07	0.08	0.09	<0.01	0.01	1.29	1.65	0.07	0.08	1.36	1.74
Smallmouth bass	0.16	0.17	0.19	0.22	<0.01	0.03	2.72	3.50	0.17	0.19	2.92	3.73
Smelts	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	0.11	0.11	0.13	0.15	<0.01	<0.01	<0.01	<0.01	0.11	0.11	0.13	0.15
Sturgeons	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.02	0.02
Sunfish	13.76	14.23	16.41	18.84	0.14	0.75	80.88	104.13	13.91	14.98	97.30	122.97
Walleye	0.04	0.04	0.05	0.05	<0.01	<0.01	0.50	0.65	0.04	0.04	0.55	0.70
White bass	1.62	1.68	1.94	2.22	<0.01	0.02	1.96	2.52	1.63	1.70	3.89	4.74
White perch	1.78	1.84	2.12	2.44	<0.01	<0.01	0.41	0.52	1.78	1.85	2.53	2.96
Whitefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Yellow perch	2.24	2.31	2.67	3.06	<0.01	0.02	1.79	2.31	2.24	2.33	4.46	5.37
Total (all species)	**347.74**	**359.55**	**414.75**	**476.03**	**0.39**	**2.00**	**217.45**	**279.94**	**348.12**	**361.55**	**632.19**	**755.97**

Notes:

P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline

Source: U.S. EPA analysis for this report

Table C-14: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Inland Region (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Alewife	14.78	15.29	17.63	20.24	<0.01	<0.01	0.47	0.61	14.78	15.29	18.10	20.85
American shad	6.58	6.80	7.84	9.00	<0.01	<0.01	<0.01	<0.01	6.58	6.80	7.84	9.00
Bay anchovy	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01
Bigmouth buffalo	0.01	0.01	0.02	0.02	<0.01	0.02	1.98	2.55	0.02	0.03	1.99	2.56
Black bullhead	0.12	0.12	0.14	0.16	<0.01	<0.01	0.02	0.02	0.12	0.12	0.16	0.18
Black crappie	0.12	0.12	0.14	0.16	0.02	0.08	9.12	11.74	0.14	0.21	9.26	11.90
Blue crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Blueback herring	64.16	66.34	76.52	87.83	1.14	5.92	643.06	827.87	65.30	72.26	719.58	915.70
Bluegill	12.29	12.71	14.66	16.82	0.03	0.16	17.65	22.72	12.32	12.87	32.31	39.55
Bluntnose minnow	0.05	0.05	0.06	0.07	3.21	16.65	1,807.24	2,326.63	3.26	16.70	1,807.31	2,326.70
Brown bullhead	0.02	0.02	0.02	0.02	<0.01	<0.01	0.13	0.17	0.02	0.02	0.15	0.19
Bullheads	0.02	0.02	0.02	0.02	<0.01	0.01	1.35	1.74	0.02	0.03	1.37	1.76
Burbot	<0.01	<0.01	<0.01	<0.01	0.01	0.05	5.89	7.59	0.01	0.06	5.90	7.59
Carp	0.13	0.13	0.15	0.18	2.74	14.25	1,546.60	1,991.08	2.87	14.38	1,546.75	1,991.25
Channel catfish	0.70	0.73	0.84	0.96	0.14	0.71	77.07	99.22	0.84	1.44	77.91	100.19
Crappie	0.21	0.21	0.24	0.28	0.04	0.23	24.87	32.02	0.25	0.44	25.12	32.30
Darters	0.34	0.36	0.41	0.47	0.11	0.55	59.43	76.51	0.45	0.90	59.84	76.98
Emerald shiner	1.38	1.42	1.64	1.89	0.47	2.45	266.39	342.94	1.85	3.88	268.03	344.83
Fish (other)	28.75	29.73	34.29	39.36	44.39	230.44	25,013.58	32,202.21	73.14	260.17	25,047.88	32,241.57
Freshwater drum	1.58	1.63	1.89	2.16	1.96	10.19	1,106.12	1,424.00	3.54	11.83	1,108.00	1,426.17
Gizzard shad	107.49	111.14	128.20	147.15	12.43	64.55	7,007.01	9,020.74	119.93	175.70	7,135.21	9,167.89
Gobies	<0.01	<0.01	<0.01	<0.01	0.05	0.27	29.82	38.39	0.05	0.27	29.82	38.39
Golden redhorse	0.02	0.02	0.03	0.03	<0.01	<0.01	1.05	1.35	0.02	0.03	1.08	1.38
Hogchoker	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Logperch	0.34	0.36	0.41	0.47	0.02	0.11	11.87	15.28	0.37	0.47	12.28	15.75
Menhadens	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Muskellunge	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Rainbow smelt	0.07	0.07	0.08	0.09	0.04	0.20	21.76	28.02	0.11	0.27	21.84	28.11
River carpsucker	0.01	0.01	0.01	0.02	<0.01	0.02	1.89	2.44	0.01	0.03	1.91	2.45
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sauger	0.08	0.08	0.09	0.11	0.20	1.06	115.46	148.65	0.28	1.14	115.56	148.75
Shiners	1.18	1.22	1.40	1.61	0.19	1.00	108.94	140.25	1.37	2.22	110.35	141.86
Silversides	0.01	0.01	0.02	0.02	0.03	0.16	17.09	22.00	0.04	0.17	17.11	22.02
Skipjack herring	0.53	0.54	0.63	0.72	<0.01	<0.01	0.20	0.25	0.53	0.55	0.83	0.97
Smallmouth bass	0.05	0.05	0.06	0.07	0.04	0.18	20.03	25.79	0.08	0.24	20.09	25.85
Smelts	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Spotted sucker	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Striped bass	0.57	0.59	0.68	0.78	<0.01	<0.01	<0.01	<0.01	0.57	0.59	0.68	0.78

Table C-14: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) in the Inland Region (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Striped killifish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sturgeons	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.54	0.69	<0.01	<0.01	0.54	0.69
Suckers	0.06	0.06	0.07	0.08	2.83	14.70	1,595.57	2,054.12	2.89	14.76	1,595.63	2,054.19
Sunfish	2.21	2.28	2.63	3.02	0.42	2.19	238.12	306.55	2.63	4.47	240.75	309.57
Threespine stickleback	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Walleye	0.05	0.05	0.06	0.07	0.11	0.57	62.39	80.32	0.16	0.63	62.45	80.39
White bass	0.91	0.94	1.08	1.24	0.70	3.61	392.34	505.10	1.60	4.55	393.42	506.34
White perch	1.34	1.38	1.60	1.83	0.43	2.24	242.75	312.51	1.77	3.62	244.34	314.34
Whitefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.28	0.36	<0.01	<0.01	0.28	0.36
Yellow perch	3.07	3.17	3.66	4.20	0.72	3.72	404.19	520.35	3.78	6.89	407.85	524.55
Total (all species)	**249.27**	**257.74**	**297.30**	**341.23**	**72.49**	**376.37**	**40,852.60**	**52,593.18**	**321.76**	**634.10**	**41,149.89**	**52,934.41**

Notes:

P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline

Source: U.S. EPA analysis for this report

C.8 National Estimates

Table C-15: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) Nationally (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
All forage species	527.24	557.69	643.23	708.05	0.98	3.11	615.44	751.65	528.22	560.80	1258.67	1459.70
All harvested species	85.51	89.79	104.95	116.18	0.42	1.42	273.87	355.09	85.94	91.20	378.82	471.28
Alewife	0.02	0.03	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.02	0.03	0.03	0.04
American plaice	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
American shad	0.04	0.04	0.04	0.05	<0.01	<0.01	<0.01	<0.01	0.04	0.04	0.05	0.05
Atlantic cod	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01
Atlantic croaker	1.60	1.67	1.99	2.21	0.02	0.03	11.86	13.61	1.63	1.70	13.85	15.81
Atlantic herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.09	0.12	<0.01	<0.01	0.10	0.12
Atlantic mackerel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.02	0.02
Atlantic menhaden	12.80	13.67	15.66	16.93	<0.01	<0.01	1.79	2.05	12.80	13.68	17.44	18.99
Black bullhead	0.13	0.13	0.15	0.17	<0.01	<0.01	<0.01	<0.01	0.13	0.13	0.16	0.18
Black crappie	0.05	0.05	0.05	0.06	<0.01	<0.01	0.37	0.48	0.05	0.05	0.42	0.54
Black drum	0.01	0.01	0.01	0.02	<0.01	<0.01	3.61	6.12	0.02	0.02	3.63	6.13
Blue crab	5.94	6.20	7.42	8.18	0.12	0.18	70.99	87.79	6.06	6.37	78.41	95.97
Bluefish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bluegill	1.46	1.51	1.75	2.00	<0.01	<0.01	0.13	0.17	1.46	1.51	1.88	2.17
Brown bullhead	0.04	0.04	0.04	0.05	<0.01	<0.01	0.04	0.05	0.04	0.04	0.08	0.10
Bullheads	0.02	0.02	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.04
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cabezon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.08	<0.01	<0.01	0.05	0.08
California halibut	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.20	0.33	<0.01	<0.01	0.20	0.33
California scorpionfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel catfish	1.29	1.35	1.55	1.75	<0.01	<0.01	0.74	0.96	1.29	1.35	2.29	2.71
Crabs (other)	0.06	0.06	0.08	0.09	<0.01	<0.01	6.67	10.93	0.06	0.07	6.75	11.02
Sea Basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.42	3.96	<0.01	<0.01	<0.01	3.96
Shrimp (other)	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.53	0.88	<0.01	<0.01	0.54	0.89
Crappie	0.08	0.08	0.09	0.11	<0.01	<0.01	1.04	1.35	0.08	0.09	1.14	1.45
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	3.14	4.10	<0.01	0.04	3.14	4.11
Drums and croakers	0.05	0.06	0.06	0.08	<0.01	0.04	0.83	1.00	0.05	0.09	0.89	1.08
Dungeness crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Flounders	0.01	0.01	0.01	0.02	<0.01	<0.01	0.08	0.13	0.01	0.01	0.09	0.15
Freshwater drum	1.13	1.19	1.37	1.52	<0.01	0.04	5.10	6.61	1.14	1.23	6.47	8.13

Table C-15: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) Nationally (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Leatherjacket	0.59	0.62	0.74	0.82	<0.01	<0.01	0.02	0.03	0.59	0.62	0.76	0.85
Mackerels	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	4.26	4.42	5.30	5.89	<0.01	<0.01	0.03	0.05	4.26	4.42	5.34	5.94
Muskellunge	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fish (other)	2.08	2.19	2.58	2.83	0.01	0.02	6.08	7.04	2.09	1.21	1.53	9.87
Northern anchovy	0.29	0.32	0.33	0.49	<0.01	<0.01	0.03	0.04	0.29	0.32	0.36	0.54
Pinfish	0.02	0.03	0.03	0.03	<0.01	<0.01	0.66	1.11	0.03	0.03	0.69	1.15
Pink shrimp	18.44	19.14	22.95	25.48	0.01	0.01	8.17	13.83	18.45	19.15	31.12	39.31
Pollock	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rainbow smelt	0.44	0.48	0.55	0.58	<0.01	0.02	5.48	7.60	0.45	0.50	6.03	8.18
Red drum	0.08	0.08	0.09	0.10	<0.01	<0.01	<0.01	0.01	0.08	0.08	0.10	0.12
Red hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rockfishes	0.01	0.01	0.02	0.02	<0.01	<0.01	5.40	8.85	0.01	0.01	5.42	8.88
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sauger	0.07	0.07	0.08	0.09	<0.01	0.01	1.29	1.65	0.07	0.08	1.36	1.75
Sculpins	0.02	0.02	0.02	0.03	<0.01	0.02	1.81	2.48	0.02	0.03	1.83	2.51
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sea basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Searobin	0.81	0.84	1.00	1.11	<0.01	<0.01	0.23	0.39	0.81	0.84	1.23	1.50
Sheepshead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.04	<0.01	<0.01	0.02	0.04
Silver hake	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver perch	0.39	0.41	0.51	0.55	<0.01	<0.01	3.12	5.28	0.39	0.41	3.63	5.83
Skates	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Smallmouth bass	0.21	0.22	0.26	0.29	<0.01	0.03	2.72	3.50	0.22	0.25	2.98	3.79
Smelts	2.61	2.87	3.27	3.36	<0.01	<0.01	0.01	0.02	2.61	2.87	3.28	3.37
Spot	2.15	2.28	2.65	2.87	0.03	0.06	19.43	22.32	2.18	2.34	22.09	25.20
Spotted seatrout	1.09	1.13	1.35	1.50	<0.01	<0.01	0.09	0.16	1.09	1.13	1.44	1.66
Stone crab	0.16	0.17	0.20	0.22	<0.01	<0.01	0.25	0.43	0.16	0.17	0.45	0.65
Striped bass	0.11	0.12	0.14	0.16	<0.01	<0.01	0.77	0.89	0.12	0.12	0.91	1.05
Striped mullet	0.32	0.33	0.40	0.44	<0.01	<0.01	1.59	2.70	0.32	0.33	1.99	3.14
Sturgeons	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.02	0.02
Summer flounder	0.01	0.01	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.02
Sunfish	13.83	14.31	16.50	18.93	0.14	0.75	81.74	105.32	13.98	15.05	98.24	124.24
Surfperches	0.10	0.11	0.11	0.16	<0.01	<0.01	<0.01	<0.01	0.10	0.11	0.11	0.16
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.08	0.11	<0.01	<0.01	0.08	0.11

Table C-15: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) Nationally (million A1Es per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Walleye	0.10	0.11	0.13	0.13	<0.01	<0.01	0.74	0.97	0.10	0.11	0.86	1.11
Weakfish	0.84	0.90	1.02	1.11	<0.01	<0.01	1.49	1.71	0.84	0.90	2.51	2.81
White bass	5.45	5.89	6.74	7.15	<0.01	0.02	2.72	3.58	5.46	5.91	9.46	10.72
White perch	3.33	3.50	4.02	4.49	0.02	0.04	13.52	15.57	3.36	3.54	17.53	20.06
Whitefish	0.14	0.15	0.17	0.17	<0.01	<0.01	<0.01	<0.01	0.14	0.15	0.17	0.17
Windowpane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.02	0.02
Winter flounder	0.03	0.03	0.03	0.04	<0.01	0.05	4.75	6.19	0.03	0.08	4.78	6.23
Yellow perch	2.78	2.91	3.35	3.76	<0.01	0.02	1.86	2.40	2.78	2.93	5.20	6.16
Total (all species)	**612.75**	**647.47**	**748.19**	**824.23**	**1.41**	**4.53**	**889.31**	**1106.74**	**614.16**	**652.00**	**1637.49**	**1930.97**

Notes:
P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline
Source: U.S. EPA analysis for this report

Table C-16: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) Nationally (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Alewife	24.60	26.09	29.95	32.87	10.32	32.59	10,007.54	13,903.96	34.92	58.68	10,037.49	13,936.83
American plaice	<0.01	<0.01	<0.01	<0.01	<0.01	0.86	73.53	96.04	<0.01	0.86	73.53	96.04
American sand lance	0.05	0.05	0.07	0.08	<0.01	6.31	542.26	708.25	0.05	6.36	542.33	708.33
American shad	6.59	6.82	7.86	9.03	0.03	0.05	18.42	21.14	6.63	6.87	26.28	30.16
Atlantic cod	<0.01	<0.01	<0.01	<0.01	<0.01	0.50	43.33	56.59	<0.01	0.50	43.33	56.59
Atlantic croaker	7.31	7.61	9.08	10.06	0.41	0.58	238.62	300.83	7.72	8.19	247.71	310.89
Atlantic herring	0.01	0.01	0.02	0.02	<0.01	0.37	32.23	42.09	0.01	0.39	32.24	42.11
Atlantic mackerel	<0.01	<0.01	<0.01	<0.01	<0.01	30.35	2,608.87	3,407.48	<0.01	30.35	2,608.87	3,407.48
Atlantic menhaden	20.76	22.18	25.40	27.47	0.06	21.64	1,648.53	2,133.07	20.82	43.82	1,673.93	2,160.54
Atlantic silverside	0.48	0.52	0.61	0.65	0.05	0.50	65.89	81.26	0.54	1.01	66.50	81.92
Atlantic tomcod	0.04	0.04	0.05	0.06	<0.01	0.03	2.32	3.03	0.04	0.07	2.37	3.08
Bay anchovy	12.49	13.31	16.89	17.64	175.17	492.67	140,265.10	214,225.98	187.66	505.98	140,281.99	214,243.63
Bigmouth buffalo	0.01	0.01	0.02	0.02	<0.01	0.02	1.98	2.55	0.02	0.03	1.99	2.56
Black bullhead	0.12	0.12	0.14	0.16	<0.01	<0.01	0.02	0.02	0.12	0.12	0.16	0.18
Black crappie	0.12	0.13	0.14	0.17	0.02	0.08	9.12	11.74	0.14	0.21	9.26	11.90
Black drum	0.01	0.01	0.01	0.02	40.50	40.50	29,342.08	49,690.98	40.51	40.51	29,342.09	49,691.00
Blennies	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	390.33	639.92	<0.01	<0.01	390.33	639.92
Blue crab	5.91	6.17	7.39	8.14	1.80	2.65	1,018.09	1,215.03	7.71	8.82	1,025.48	1,223.17
Blueback herring	64.53	66.74	76.98	88.32	1.15	5.94	649.73	835.52	65.68	72.68	726.70	923.84
Bluefish	<0.01	<0.01	0.01	0.01	<0.01	<0.01	0.02	0.03	<0.01	<0.01	0.03	0.04
Bluegill	12.33	12.76	14.71	16.88	0.03	0.16	17.70	22.79	12.37	12.92	32.41	39.67
Bluntnose minnow	0.08	0.09	0.10	0.11	3.21	16.66	1,810.66	2,331.37	3.29	16.75	1,810.76	2,331.48
Brown bullhead	0.03	0.04	0.04	0.05	<0.01	<0.01	0.16	0.20	0.03	0.04	0.20	0.25
Bullheads	0.02	0.02	0.02	0.03	<0.01	0.01	1.35	1.74	0.02	0.03	1.38	1.77
Burbot	<0.01	<0.01	<0.01	<0.01	0.01	0.06	6.18	7.99	0.01	0.06	6.19	7.99
Butterfish	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	4.48	5.86	<0.01	0.06	4.49	5.86
Cabezon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.84	4.65	<0.01	<0.01	2.84	4.65
California halibut	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	3.29	5.40	<0.01	<0.01	3.29	5.40
California scorpionfish	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Carp	0.16	0.17	0.19	0.21	3.64	17.07	2,413.26	3,195.22	3.80	17.24	2,413.45	3,195.43
Chain pipefish	0.03	0.03	0.04	0.04	<0.01	<0.01	0.65	1.10	0.03	0.03	0.68	1.14
Channel catfish	0.81	0.84	0.97	1.09	0.14	0.71	77.69	100.08	0.94	1.55	78.65	101.17
Chinook salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Crabs (other)	0.04	0.05	0.05	0.07	<0.01	14.77	3,352.55	5,345.69	0.04	14.82	3,352.61	5,345.76
Crappie	0.21	0.22	0.25	0.29	0.04	0.23	25.25	32.55	0.25	0.45	25.50	32.84
Cunner	<0.01	<0.01	<0.01	<0.01	<0.01	125.28	10,767.77	14,063.92	<0.01	125.28	10,767.78	14,063.92
Darters	0.35	0.36	0.42	0.48	0.11	0.55	60.18	77.56	0.45	0.91	60.60	78.03

Table C-16: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) Nationally (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Delta smelt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Drums and croakers	0.23	0.25	0.28	0.38	<0.01	52.55	1,330.12	1,644.78	0.23	52.80	1,330.40	1,645.16
Dungeness crab	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.06	<0.01	<0.01	0.04	0.06
Emerald shiner	27.71	30.40	34.66	35.75	0.51	2.57	302.77	393.49	28.22	32.97	337.43	429.24
Fish (other)	34.17	35.42	41.09	46.79	61.61	281.13	40,788.65	54,861.96	95.78	316.55	40,829.74	54,908.74
Flounders	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	136.20	223.29	<0.01	<0.01	136.20	223.30
Fourbeard rockling	<0.01	<0.01	<0.01	<0.01	<0.01	1.99	171.36	223.81	<0.01	1.99	171.36	223.81
Freshwater drum	2.17	2.28	2.62	2.92	3.50	15.05	2,600.41	3,500.19	5.67	17.33	2,603.03	3,503.11
Gizzard shad	136.50	143.06	164.58	184.46	13.48	67.84	8,016.95	10,423.97	149.97	210.90	8,181.53	10,608.43
Gobies	0.06	0.06	0.07	0.08	1.56	80.89	3,194.95	4,457.82	1.62	80.95	3,195.03	4,457.91
Golden redhorse	0.03	0.03	0.04	0.04	<0.01	<0.01	1.05	1.35	0.03	0.04	1.09	1.39
Grubby	<0.01	<0.01	0.01	0.01	<0.01	1.85	159.13	207.84	<0.01	1.86	159.14	207.85
Gulf killifish	0.02	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.02
Herrings	0.03	0.03	0.03	0.04	<0.01	<0.01	14.12	22.41	0.03	0.04	14.15	22.46
Hogchoker	0.24	0.25	0.30	0.32	12.92	21.78	7,393.21	8,549.29	13.15	22.03	7,393.51	8,549.62
Leatherjacket	0.41	0.42	0.51	0.56	0.33	0.33	241.86	409.59	0.74	0.76	242.37	410.16
Logperch	0.61	0.65	0.75	0.82	0.05	0.21	43.41	59.11	0.67	0.87	44.16	59.93
Longfin smelt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lumpfish	<0.01	<0.01	<0.01	<0.01	<0.01	0.19	16.57	21.64	<0.01	0.19	16.57	21.64
Mackerels	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Menhadens	6.91	7.17	8.60	9.55	0.11	0.11	82.01	138.87	7.02	7.28	90.61	148.41
Muskellunge	<0.01	<0.01	0.01	0.01	<0.01	<0.01	0.32	0.45	<0.01	<0.01	0.33	0.46
Northern anchovy	0.37	0.39	0.42	0.61	<0.01	<0.01	352.68	578.20	0.37	0.39	353.10	578.81
Northern pipefish	0.01	0.01	0.01	0.02	<0.01	0.01	3.35	3.91	0.02	0.03	3.36	3.92
Pacific herring	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	15.43	25.30	<0.01	<0.01	15.43	25.30
Pinfish	0.05	0.05	0.06	0.07	0.05	1.62	61.04	85.76	0.10	1.68	61.10	85.83
Pink shrimp	18.80	19.51	23.41	25.98	0.05	0.05	38.48	65.16	18.85	19.57	61.88	91.15
Pollock	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	1.28	1.67	<0.01	0.02	1.28	1.67
Radiated shanny	<0.01	<0.01	<0.01	<0.01	<0.01	0.47	40.74	53.21	<0.01	0.47	40.74	53.21
Rainbow smelt	0.33	0.35	0.41	0.43	0.76	2.56	729.57	1,010.91	1.09	2.91	729.98	1,011.34
Red drum	0.07	0.08	0.09	0.10	<0.01	<0.01	0.33	0.57	0.07	0.08	0.43	0.67
Red hake	0.02	0.02	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.03
River carpsucker	0.01	0.01	0.01	0.02	<0.01	0.02	1.89	2.44	0.01	0.03	1.91	2.45
Rock gunnel	<0.01	<0.01	<0.01	<0.01	<0.01	1.70	146.13	190.86	<0.01	1.70	146.13	190.86
Rockfishes	0.01	0.01	0.01	0.02	<0.01	<0.01	27.29	44.74	0.01	0.01	27.30	44.76
Sacramento splittail	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Salmon	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.62	2.25	<0.01	<0.01	1.62	2.25
Sauger	0.08	0.08	0.09	0.11	0.20	1.06	115.46	148.65	0.28	1.14	115.56	148.75

Table C-16: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) Nationally (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Scaled sardine	0.15	0.15	0.18	0.20	1.25	1.25	902.35	1,528.14	1.39	1.40	902.54	1,528.34
Sculpins	<0.01	0.01	0.01	0.02	<0.01	0.94	102.09	140.23	0.01	0.95	102.10	140.25
Scup	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	6.14	8.02	<0.01	0.07	6.14	8.03
Sea Basses	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	5.65	9.26	<0.01	<0.01	5.65	9.26
Seaboard goby	<0.01	<0.01	<0.01	<0.01	6.76	20.41	4,637.25	5,460.76	6.77	20.42	4,637.26	5,460.77
Searobin	0.51	0.53	0.63	0.70	0.03	0.08	25.20	41.04	0.54	0.60	25.83	41.74
Sheepshead	<0.01	<0.01	<0.01	<0.01	0.16	0.16	116.63	197.51	0.16	0.16	116.63	197.51
Shiners	1.88	1.99	2.28	2.51	0.23	1.13	148.42	195.04	2.11	3.12	150.70	197.55
Shrimp (other)	2.31	2.48	3.37	3.41	<0.01	23.01	594.47	740.02	2.31	25.48	597.84	743.43
Silver hake	0.02	0.02	0.02	0.02	<0.01	2.44	209.93	274.19	0.02	2.46	209.95	274.21
Silver perch	0.31	0.33	0.42	0.44	37.41	37.41	27,105.51	45,903.34	37.73	37.74	27,105.92	45,903.78
Silversides	0.10	0.11	0.12	0.15	0.03	0.16	69.85	108.12	0.13	0.27	69.97	108.27
Skates	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Skipjack herring	0.53	0.54	0.63	0.72	<0.01	<0.01	0.20	0.25	0.53	0.55	0.83	0.97
Smallmouth bass	0.06	0.07	0.08	0.09	0.04	0.18	20.03	25.79	0.10	0.25	20.11	25.87
Smelts	1.18	1.30	1.48	1.52	0.04	0.13	41.11	57.51	1.22	1.43	42.59	59.03
Spot	3.45	3.67	4.28	4.63	0.13	47.79	925.53	1,001.16	3.58	51.46	929.81	1,005.79
Spotted seatrout	0.52	0.54	0.64	0.72	2.24	3.02	1,639.94	2,768.53	2.76	3.56	1,640.58	2,769.25
Spotted sucker	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Stone crab	0.12	0.12	0.15	0.16	12.07	12.07	8,745.52	14,810.59	12.19	12.19	8,745.67	14,810.76
Striped bass	0.58	0.60	0.69	0.79	0.52	0.79	295.84	341.86	1.10	1.39	296.52	342.65
Striped killifish	0.09	0.10	0.12	0.13	<0.01	<0.01	0.02	0.03	0.09	0.10	0.14	0.16
Striped mullet	0.19	0.20	0.24	0.27	<0.01	<0.01	4.62	7.82	0.20	0.21	4.86	8.09
Sturgeons	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.54	0.69	<0.01	<0.01	0.54	0.69
Suckers	0.06	0.07	0.08	0.09	2.86	14.80	1,627.05	2,097.86	2.93	14.87	1,627.12	2,097.94
Summer flounder	0.02	0.02	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.03
Sunfish	2.22	2.29	2.64	3.03	0.43	2.20	240.66	310.09	2.64	4.49	243.31	313.12
Surfperches	0.06	0.06	0.06	0.09	<0.01	<0.01	<0.01	<0.01	0.06	0.06	0.06	0.09
Tautog	<0.01	<0.01	<0.01	<0.01	<0.01	125.83	10,815.39	14,126.11	<0.01	125.84	10,815.39	14,126.11
Threespine stickleback	0.03	0.04	0.04	0.05	<0.01	<0.01	0.21	0.29	0.03	0.04	0.26	0.34
Tidewater silverside	0.13	0.13	0.16	0.18	0.01	0.01	10.47	17.73	0.14	0.15	10.63	17.90
Walleye	0.14	0.15	0.17	0.18	0.12	0.60	71.64	93.18	0.26	0.75	71.81	93.36
Weakfish	0.98	1.04	1.20	1.29	0.24	4.06	299.81	360.95	1.22	5.11	301.01	362.24
White bass	3.05	3.29	3.77	4.00	0.76	3.80	449.52	584.53	3.80	7.09	453.28	588.53
White perch	11.30	12.32	14.06	14.67	1.84	4.77	1,129.04	1,388.88	13.14	17.09	1,143.10	1,403.55

Table C-16: Baseline IM&E at All Regulated Facilities (Manufacturing and Generating) Nationally (million individuals per year), and Reductions in IM&E for Option Scenarios Estimated for All Sources of Mortality

Species	Impingement				Entrainment				IM&E			
	P4	F	P2	B	P4	F	P2	B	P4	F	P2	B
Whitefish	0.03	0.03	0.04	0.04	<0.01	<0.01	0.36	0.47	0.03	0.04	0.39	0.51
Windowpane	<0.01	<0.01	<0.01	0.01	<0.01	8.88	762.82	996.32	<0.01	8.88	762.83	996.33
Winter flounder	0.05	0.05	0.06	0.07	0.05	28.79	2,494.01	3,253.45	0.09	28.84	2,494.07	3,253.52
Yellow perch	3.81	3.99	4.59	5.15	0.73	3.77	419.01	540.94	4.54	7.76	423.60	546.09
Total (all species)	**419.91**	**441.30**	**511.87**	**568.56**	**399.82**	**1,693.86**	**335,447.57**	**497,316.28**	**819.74**	**2,135.17**	**335,959.44**	**497,884.85**

Notes:
P4 = Proposal Option 4; F = Final Rule – Existing Units; P2 = Proposal Option 2; and B = Baseline
Source: U.S. EPA analysis for this report

Appendix D: Discounting Benefits

D.1 Introduction

Discounting refers to the economic conversion of future benefits and costs to present values, accounting for the fact that individuals tend to value future outcomes less than comparable near-term outcomes. Annualization refers to the conversion of a series of annual costs or benefits of differing amounts to an equivalent annual series of constant costs or benefits. Discounting and annualization are important techniques which allow the comparison of benefits and/or costs that occur in different time periods.

EPA's discounting and annualization methodology for the benefits analysis of the final rule and options considered, included three steps. First, EPA developed a time profile of benefits to show when benefits occur. Second, the Agency calculated the total discounted present value of the benefits as of the year 2013. Finally, EPA annualized the benefits of the final rule and other options considered, over a 51-year time span. The following sections explain these steps in detail.

D.2 Timing of Benefits

To calculate the annualized value of the potential welfare gains, EPA first calculated the undiscounted welfare gain from the expected annual regional reductions in IM&E under the final rule and other options considered assuming all facilities have installed required technology. Then, EPA created a time profile of benefits that takes into account the regulatory and biological time lags between the potential promulgation of the final rule and each regulatory option considered, and the realization of benefits.

EPA assigned each facility a technology installation year which varies across facilities and regulatory options based on facility characteristics and type of technology being installed. Facilities installing impingement only technology have technology installation years ranging from 2018 to 2022, non-nuclear electric generating facilities and manufacturing facilities installing towers have technology installation years ranging from 2020 to 2024, and nuclear generating facilities installing towers have technology installation years ranging from 2026 to 2030. EPA estimates that a small number of manufacturers could be required to install both IM&E technology and towers. EPA assumed that these facilities would install both technologies at the same time, during the 5-year window of 2021 through 2025. Compliance is assumed to continue until the year 2059 for all facilities. See Chapter 3 of the EA report for more detail.

A biological time lag occurs between installation of technologies to reduce IM&E and realization of commercial and recreational angling benefits because these fish may require several years to grow and mature before commercial and recreational anglers can harvest them. For example, a larval fish spared from entrainment (in effect, at age zero) may be caught by a recreational angler at age three. A three-year time lag then arises between the installation of technologies to reduce IM&E and the realization of the estimated recreational benefit. Likewise, if a one-year-old fish is spared from impingement and is then harvested by a commercial fisherman at age two, there is a one-year lag between the installation of technologies to reduce IM&E and the subsequent commercial fishery benefit. In general, there will be relatively short time lags between implementation of technologies to reduce IM&E and the subsequent timing of changes in catch for fish that tend to be harvested at young ages. In contrast, for long-lived fish that tend to be caught at relatively older ages, there would be longer time lags and, hence, the effects of discounting would be larger, resulting in lower present values.

To model the biological time lags, EPA collected species-specific information on ages of fish at harvest to estimate the average time required for a fish spared from IM&E, to reach a harvestable age. The estimated time lags vary, depending on the life history of each fish species affected. EPA used this information, along with information about the estimated age and species composition of IM&E in each study region, to develop a benefits schedule for facilities in each region.[93] EPA used these lags in analyses for both existing and new units.

EPA assumes that once facilities have installed technology, commercial and recreational fishing benefits from facilities in most regions (the California, North Atlantic, Mid-Atlantic, and South Atlantic regions) increase over a seven-year period to a long-term, steady-state average. This average is equal to the approximated per-facility benefit value discussed above, according to a numerical profile of <0.0, 0.1, 0.2, 0.8, 0.9, 0.95, 1.0>. This profile is the fraction of the steady-state benefit value (i.e., the percentage of commercial and recreational fish spared from IM&E that reach a harvestable age) that is realized in each of the first seven years following a facility installing technology.

For regions with a relatively high contribution of impingement to total IM&E (the Inland, Great Lakes, and Gulf of Mexico regions), EPA used an adjusted profile of <0.1, 0.2, 0.8, 0.9, 0.95, 1.0> for commercial and recreational fishing benefits. This adjusted profile reflects the fact that impinged fish are usually larger and older than entrained fish, and thus benefits will be realized sooner in these three regions. These profile values are approximations based on a review of the age-specific fishing mortality rates that EPA used in the IM&E analysis and best professional judgment.[94]

In all regions, this fraction remains 1.0 until the final year of compliance, 2059. The commercial and recreational fishing benefits profile declines at the end of the compliance period in the same fashion that it increases after technology installation. This reflects the fact that the fish saved by technology would survive and could still be harvested beyond the end of the compliance period. Specifically, at the end of the compliance period, benefit values decline following a profile of <0.9, 0.8, 0.2, 0.1, 0.05, 0.0>, with the last benefits occurring in 2064. Therefore, the benefits analysis encompasses a 51-year period from rule promulgation and first incidence of compliance-related costs in 2014, until the final benefits are realized in 2064. The number of years when benefits do not equal zero varies among the regulated facilities, depending on the year that it installs technology.

EPA assumes no initial biological lag for nonuse benefits (including benefit transfer and preliminary benefits based on the 316(b) SP survey) at the start of the compliance period because nonuse benefits are not based on the harvest of fish spared from IM&E. EPA assumes that benefits begin accruing immediately when a facility installs technology, and continue being generated in full until the year 2059. The nonuse benefit transfer includes a linear decline in benefits starting at the end of the compliance period following a profile of <1.0, 0.82, 0.62, 0.37, 0.20, 0.06, 0.0> with the last benefits occurring in 2064. This profile reflects NMFS estimates of age-specific and fisheries-related mortality. For the analysis for the 316(b) SP survey, EPA assumes that benefits end in 2059, the final year of the compliance period, and does not include a declining profile beyond this year. This is consistent with the definition of the fish saved attribute which was used to generate preliminary benefits estimates based on

93 The benefits profile aggregated across all facilities in a region or nationwide was calculated using facility-level sample weights. These facility-level sample weights were designed so that the weighted actual regional intake flow for the sample facilities is the same as the estimated actual regional intake flow for the entire universe of facilities. These sample weights are described in more detail in Appendix A.

94 EPA applied biological lags consistent with the Inland, Great Lakes, and Gulf Mexico regions when estimating commercial, recreational, and T&E species benefits for new units because these regions account for the majority of national benefits for these categories.

the 316(b) SP survey. EPA does not include any lags in its analysis of benefits associated with changes in GHG emissions.

D.3 Discounting and Annualization

Using the time profile of benefits discussed above, EPA discounted the total benefits generated in each year of the analysis to 2013 using the following formula:

$$\text{Present Value} = \sum_t \frac{\text{Benefits}_t}{(1+r)^{t-2013}} \quad \text{(D-1)}$$

where:

Benefits_t = benefits in year t
r = discount rate (3 percent and 7 percent)
t = year in which benefits are incurred

After calculating the present value (PV) of these benefit streams, EPA calculated a constant annual equivalent value (annualized value) using the annualization formula presented below, again using two discount rates, 3 percent and 7 percent.[95] Although the analysis period extends further, EPA annualized benefits over the assumed period of compliance for regulated facilities. EPA followed this same annualization concept and period of annualization in the cost analysis, although the time horizon for calculating the present value is shorter than for benefits. Using the same annualization period for both benefits and social costs allows EPA to compare constant annual equivalent values of benefits and costs that have been calculated on a mathematically consistent basis. The annualization formula is as follows:

$$\text{Annualized Benefit} = \text{PV of Benefit} * \left(\frac{r * (1+r)^{(n-1)}}{(1+r)^n - 1} \right) \quad \text{(D-2)}$$

where:

r = discount rate (3 percent and 7 percent)
n = annualization period, 51 years for the benefits analysis

Table D-1 presents a summary of the time profile of benefits discounted at the 3 percent and 7 percent rates for the final rule and the regulatory options considered, on the national scale. The table also presents the total and annualized values that are equivalent to this stream of benefits.

95 The three percent rate represents an estimate of the social rate of time preference.

Table D-1: Time Profile of Discounted National Mean Benefits at Regulated Facilities by Regulatory Option using 3% and 7% Discount Rates (2011$, millions)[a]										
Year	Proposal Option 4		Final Rule – Existing Units		Proposal Option 2		Final Rule –New Units		Final Rule -Existing Units and New Units	
	3%	7%	3%	7%	3%	7%	3%	7%	3%	7%
2013	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
2014	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000	$0.004	$0.004	$0.004	$0.004
2015	$8.147	$7.550	$8.147	$7.550	$0.000	$0.000	$0.008	$0.008	$8.156	$7.557
2016	$8.124	$7.246	$8.124	$7.246	$0.000	$0.000	$0.014	$0.012	$8.138	$7.259
2017	$8.095	$6.951	$8.095	$6.951	$0.000	$0.000	$0.008	$0.007	$8.103	$6.957
2018	-$1.517	-$1.254	-$1.334	-$1.103	$118.959	$98.325	$0.002	$0.002	-$1.332	-$1.101
2019	-$1.488	-$1.184	-$1.302	-$1.036	$121.271	$96.489	-$0.005	-$0.004	-$1.307	-$1.040
2020	-$0.670	-$0.513	-$0.158	-$0.121	$121.582	$93.120	-$0.011	-$0.009	-$0.170	-$0.130
2021	$0.542	$0.399	$1.236	$0.911	-$999.546	-$736.937	-$0.017	-$0.012	$1.219	$0.899
2022	$5.572	$3.955	$6.772	$4.806	-$974.242	-$691.429	-$0.023	-$0.016	$6.749	$4.790
2023	$43.850	$29.958	$45.283	$30.936	-$1,079.211	-$737.294	-$0.029	-$0.020	$45.253	$30.916
2024	$49.786	$32.741	$51.603	$33.936	-$1,052.143	-$691.931	-$0.036	-$0.024	$51.567	$33.913
2025	$51.111	$32.356	$53.031	$33.571	-$1,031.582	-$653.048	-$0.043	-$0.027	$52.988	$33.544
2026	$51.040	$31.103	$52.955	$32.270	-$1,709.258	-$1,041.604	-$0.049	-$0.030	$52.905	$32.240
2027	$50.690	$29.735	$52.582	$30.845	-$1,689.775	-$991.236	-$0.056	-$0.033	$52.526	$30.812
2028	$49.896	$28.175	$51.737	$29.215	-$1,671.154	-$943.666	-$0.063	-$0.035	$51.675	$29.180
2029	$49.052	$26.663	$50.840	$27.635	-$1,651.425	-$897.664	-$0.069	-$0.038	$50.771	$27.597
2030	$48.215	$25.229	$49.951	$26.137	-$1,634.747	-$855.380	-$0.076	-$0.040	$49.875	$26.097
2031	$46.811	$23.578	$48.496	$24.427	-$1,143.475	-$575.955	-$0.079	-$0.040	$48.417	$24.387
2032	$46.005	$22.306	$47.642	$23.099	-$1,131.655	-$548.693	-$0.086	-$0.042	$47.556	$23.058
2033	$15.959	$7.448	$17.547	$8.190	-$1,120.741	-$523.087	-$0.092	-$0.043	$17.455	$8.147
2034	$15.494	$6.961	$17.036	$7.654	-$1,109.610	-$498.532	-$0.098	-$0.044	$16.938	$7.610
2035	$15.043	$6.506	$16.540	$7.153	-$1,098.347	-$475.024	-$0.104	-$0.045	$16.436	$7.108
2036	$14.604	$6.080	$16.058	$6.685	-$1,086.843	-$452.477	-$0.110	-$0.046	$15.948	$6.640
2037	$14.179	$5.682	$15.591	$6.248	-$1,074.992	-$430.812	-$0.116	-$0.046	$15.475	$6.202
2038	$13.766	$5.311	$15.136	$5.839	-$1,062.923	-$410.051	-$0.122	-$0.047	$15.015	$5.792
2039	$13.365	$4.963	$14.696	$5.457	-$1,050.571	-$390.135	-$0.127	-$0.047	$14.568	$5.410
2040	$12.976	$4.639	$14.268	$5.100	-$1,038.033	-$371.068	-$0.133	-$0.047	$14.135	$5.053
2041	$12.598	$4.335	$13.852	$4.767	-$1,025.492	-$352.881	-$0.138	-$0.047	$13.714	$4.719
2042	$12.231	$4.051	$13.449	$4.455	-$1,012.802	-$335.486	-$0.143	-$0.047	$13.305	$4.407
2043	$11.875	$3.786	$13.057	$4.163	-$999.981	-$318.856	-$0.148	-$0.047	$12.909	$4.116
2044	$11.529	$3.539	$12.677	$3.891	-$987.047	-$302.967	-$0.153	-$0.047	$12.524	$3.844
2045	$11.193	$3.307	$12.307	$3.636	-$974.019	-$287.791	-$0.158	-$0.047	$12.150	$3.590
2046	$10.867	$3.091	$11.949	$3.399	-$960.912	-$273.305	-$0.162	-$0.046	$11.787	$3.352
2047	$10.551	$2.889	$11.601	$3.176	-$947.742	-$259.482	-$0.167	-$0.046	$11.434	$3.131

Table D-1: Time Profile of Discounted National Mean Benefits at Regulated Facilities by Regulatory Option using 3% and 7% Discount Rates (2011$, millions)[a]

Year	Proposal Option 4		Final Rule – Existing Units		Proposal Option 2		Final Rule –New Units		Final Rule -Existing Units and New Units	
	3%	7%	3%	7%	3%	7%	3%	7%	3%	7%
2048	$10.243	$2.700	$11.263	$2.968	-$934.525	-$246.298	-$0.171	-$0.045	$11.092	$2.923
2049	$9.945	$2.523	$10.935	$2.774	-$921.273	-$233.729	-$0.175	-$0.044	$10.760	$2.730
2050	$9.655	$2.358	$10.616	$2.593	-$908.001	-$221.750	-$0.179	-$0.044	$10.438	$2.549
2051	$9.374	$2.204	$10.307	$2.423	-$894.911	-$210.383	-$0.182	-$0.043	$10.125	$2.380
2052	$9.101	$2.060	$10.007	$2.265	-$881.999	-$199.596	-$0.186	-$0.042	$9.821	$2.222
2053	$8.836	$1.925	$9.715	$2.116	-$869.263	-$189.360	-$0.190	-$0.041	$9.526	$2.075
2054	$8.579	$1.799	$9.433	$1.978	-$856.700	-$179.647	-$0.193	-$0.040	$9.240	$1.937
2055	$8.329	$1.681	$9.158	$1.849	-$844.308	-$170.430	-$0.196	-$0.040	$8.961	$1.809
2056	$8.086	$1.571	$8.891	$1.728	-$832.085	-$161.684	-$0.200	-$0.039	$8.692	$1.689
2057	$7.851	$1.468	$8.632	$1.615	-$820.030	-$153.385	-$0.203	-$0.038	$8.429	$1.577
2058	$7.622	$1.372	$8.381	$1.509	-$808.141	-$145.510	-$0.206	-$0.037	$8.175	$1.472
2059	$7.400	$1.283	$8.137	$1.410	-$796.414	-$138.038	-$0.209	-$0.036	$7.928	$1.374
2060	$6.459	$1.078	$7.086	$1.182	$35.306	$5.891	$0.065	$0.011	$7.151	$1.193
2061	$5.567	$0.894	$6.093	$0.979	$29.154	$4.682	$0.054	$0.009	$6.146	$0.987
2062	$1.384	$0.214	$1.586	$0.245	$13.337	$2.062	$0.027	$0.004	$1.613	$0.249
2063	$0.680	$0.101	$0.795	$0.118	$7.937	$1.181	$0.016	$0.002	$0.811	$0.121
2064	$0.330	$0.047	$0.387	$0.055	$3.942	$0.565	$0.008	$0.001	$0.395	$0.057
Total Present Value[b]										
-	$828.931	$402.860	$880.882	$424.898	-$41,234.429	-$16,994.287	-$4.694	-$1.492	$876.188	$423.406
Annualized Value[c]										
-	$31.012	$27.219	$32.955	$28.708	-$1,542.641	-$1,148.205	-$0.176	-$0.101	$32.779	$28.607

[a] Values presented here are based on 3 percent average SCC values.
[b] The total present value is equal to the sum of the values of the benefits realized in all years of the analysis, discounted to 2013.
[c] The annualized value represents the total present value of the benefits of the rule, distributed over a 51-year period.
Source: U.S. EPA analysis for this report.

Appendix E: List of T&E Species Overlapping CWIS

Table E-1: List of 99 T&E Species Overlapping One or More Regulated CWIS	
Latin Name	**Common Name**
Acipenser brevirostrum	Shortnose Sturgeon
Acipenser medirostris	Green Sturgeon
Acipenser oxyrinchus desotoi	Gulf Sturgeon
Acipenser oxyrinchus oxyrinchus	Atlantic Sturgeon
Alasmidonta heterodon	Dwarf Wedgemussel
Amblema neislerii	Fat Threeridge
Amblyopsis rosae	Ozark Cavefish
Arkansia wheeleri	Ouachita Rock Pocketbook
Athearnia anthonyi	Anthony's Riversnail
Campeloma decampi	Slender Campeloma
Caretta caretta	Loggerhead Sea Turtle
Chelonia mydas	Green Sea Turtle
Cottus Paulus	Pygmy Sculpin
Cyprinella caerulea	Blue Shiner
Cyprogenia stegaria	Fanshell
Dermochelys coriacea	Leatherback Sea Turtle
Dromus dromas	Dromedary Pearlymussel
Elliptio chipolaensis	Chipola Slabshell
Elliptio spinosa	Altamaha Spinymussel
Elliptio steinstansana	Tar River Spinymussel
Elliptoideus sloatianus	Purple Bankclimber
Epioblasma brevidens	Cumberlandian Combshell
Epioblasma capsaeformis	Oyster Mussel
Epioblasma florentina florentina	Yellow (Pearlymussel) Blossom
Epioblasma florentina walkeri	Tan Riffleshell
Epioblasma obliquata obliquata	Catspaw (Purple Cat's Paw Pearlymussel)
Epioblasma obliquata perobliqua	White (Pearlymussel) Catspaw
Epioblasma torulosa gubernaculum	Green (Pearlymussel) Blossom
Epioblasma torulosa rangiana	Northern Riffleshell
Epioblasma torulosa torulosa	Tubercled (Pearlymussel) Blossom
Epioblasma turgidula	Turgid (Pearlymussel) Blossom
Eretmochelys imbricata	Hawksbill Sea Turtle
Etheostoma etowahae	Etowah Darter
Etheostoma percnurum	Duskytail Darter
Etheostoma scotti	Cherokee Darter
Etheostoma wapiti	Boulder Darter
Fusconaia cor	Shiny Pigtoe
Fusconaia cuneolus	Finerayed Pigtoe
Gasterosteus aculeatus williamsoni	Unarmored Threespine Stickleback
Gila bicolor mohavensis	Mohave Tui Chub
Hemistena lata	Cracking Pearlymussel
Hypomesus transpacificus	Delta Smelt
Lampsilis abrupta	Pink (Pearlymussel) Mucket

Table E-1: List of 99 T&E Species Overlapping One or More Regulated CWIS

Latin Name	Common Name
Lampsilis higginsii	Higgins Eye (Pearlymussel)
Lampsilis powellii	Arkansas Fatmucket
Lampsilis subangulata	Shinyrayed Pocketbook
Lampsilis virescens	Alabama Lampmussel
Lepidochelys kempii	Kemp's Ridley Sea Turtle
Lepidochelys olivacea	Olive Ridley Sea Turtle
Leptodea leptodon	Scaleshell Mussel
Leptoxis ampla	Round Rocksnail
Leptoxis foreman	Interrupted (Georgia) Rocksnail
Leptoxis plicata	Plicate Rocksnail
Leptoxis taeniata	Painted Rocksnail
Margaritifera hembeli	Louisiana Pearlshell
Medionidus penicillatus	Gulf Moccasinshell
Medionidus simpsonianus	Ochlockonee Moccasinshell
Notropis albizonatus	Palezone Shiner
Noturus placidus	Neosho Madtom
Noturus stanauli	Pygmy Madtom
Obovaria retusa	Ring Pink (Mussel)
Oncorhynchus clarki stomias	Greenback Cutthroat
Oncorhynchus keta	Chum Salmon
Oncorhynchus kisutch	Coho Salmon
Oncorhynchus mykiss	Steelhead Trout
Oncorhynchus tshawytscha	Chinook Salmon
Oregonichthys crameri	Oregon Chub
Pegias fabula	Littlewing Pearlymussel
Percina rex	Roanoke Logperch
Percina tanasi	Snail Darter
Phoxinus cumberlandensis	Blackside Dace
Plethobasus cicatricosus	White (Pearlymussel) Wartyback
Plethobasus cooperianus	Orangefoot (Pearlymussel) Pimpleback
Pleurobema clava	Clubshell
Pleurobema collina	James Spinymussel
Pleurobema curtum	Black Clubshell
Pleurobema hanleyianum	Georgia Pigtoe
Pleurobema marshalli	Flat Pigtoe
Pleurobema plenum	Rough Pigtoe
Pleurobema pyriforme	Oval Pigtoe
Pleurobema taitianum	Heavy Pigtoe
Pleurocera foremani	Rough Hornsnail
Potamilus capax	Fat Pocketbook
Potamilus inflatus	Alabama (Inflated) Heelsplitter
Ptychocheilus lucius	Colorado Pikeminnow (Squawfish)
Quadrula cylindrica strigillata	Rough Rabbitsfoot
Quadrula fragosa	Winged Mapleleaf
Quadrula intermedia	Cumberland (Pearlymussel) Monkeyface
Quadrula sparsa	Appalachian (Pearlymussel) Monkeyface
Quadrula stapes	Stirrupshell

Table E-1: List of 99 T&E Species Overlapping One or More Regulated CWIS

Latin Name	Common Name
Salmo salar	Atlantic Salmon
Salvelinus confluentus	Bull Trout
Scaphirhynchus albus	Pallid Sturgeon
Scaphirhynchus suttkusi	Alabama Sturgeon
Speoplatyrhinus poulsoni	Alabama Cavefish
Toxolasma cylindrellus	Pale (Pearlymussel) Lilliput
Villosa perpurpurea	Purple Bean
Villosa trabalis	Cumberland (Pearlymussel) Bean
Xyrauchen texanus	Razorback Sucker
Source: U.S. EPA analysis for this report	

Appendix F: Detailed Methodologies for Estimating Benefits to Threatened and Endangered Species

F.1 IM&E of Sea Turtles

Six species of sea turtles are found in waters of the United States: Green, Hawksbill, Kemp's Ridley, Leatherback, Loggerhead, and Olive Ridley sea turtles. All have extensive ranges, migrate long distances during their lifetime, and are listed as either T&E under the ESA. Because of these large ranges, there is substantial overlap between sea turtle habitat and CWIS for regulated facilities. Moreover, because individuals of all ages and sizes are susceptible to impingement and entrainment (Norem 2005), there are more than 730 locations of potential interactions between species ranges and CWIS that may result in the injury or death of these T&E species.

Power plants are known to entrain and impinge all species of sea turtles, with individual incidences of mortality reported from California, Texas, Florida, South Carolina, North Carolina, and New Jersey (Plotkin 1995). Although the cumulative impact of this mortality is unclear, it may be relatively small compared to fishing mortality. Although quantitative reports are available from a few power stations (Table F-1), high-quality data is available from only one source, the St. Lucie Nuclear Power Plant, at Hutchinson Island, Florida, where annual capture rates range from 350 to 1,000 turtles. Although estimated mortality rates due to entrainment are < 3 percent, approximately 85 percent of entrained organisms show evidence of injury as a result of entrainment (Norem 2005). As such, true mortality rates from CWIS may be higher than reported, particularly for individuals who are recaptured repeatedly (37 percent of Green and 13 percent of Loggerhead sea turtles entrained between May and December 2000 were recaptured individuals) (Norem 2005).

In addition to research sponsored by the National Science Foundation, federal and state governmental spending on sea turtles under the ESA totaled $33.8 million in FY2008 (USFWS 2009). Moreover, the number of volunteer organizations dedicated to sea turtle recovery (Table F-2) provides further evidence of the high nonuse values placed upon the survival of these animals by the public.

Table F-1: Reported Numbers of Sea Turtle Entrainment Incidences

Facility(s)	Species	Takes		Dates	Takes / yr		Source
		Non-lethal	Lethal		Non-lethal	Lethal	
Crystal River, FL	Kemp's Ridley, Loggerhead	40	5	1998	40	5	TEWG (2000)
Brunswick, NC	Loggerhead, Kemp's Ridley, Green	50	11	2000	50	11	NMFS (2001)
Oyster Creek, NJ; Salem, NJ; and Hope, NJ	Loggerhead	40	8	1999	40	8	NMFS (2001)
	Kemp's Ridley	7	3	1999	7	3	
	Green	8	2	1999	8	2	
Salem, NJ	Loggerhead, Kemp's Ridley, Green	23	2	1991	23	2	Eggers (2001)
Salem, NJ	Loggerhead	18	8	1980-1988	2.25	1	Eggers (1989)
Salem, NJ	Kemp's Ridley	6	6	1980-1988	0.75	0.75	
St. Lucie, FL	Loggerhead	6313	169	1976-2005	225.5	6	NMFS (2009)
San Diego, Edison	Olive Ridley	QR	QR	QR	QR	QR	(NMFS and USFWS 1998b)
San Diego, Encina, Edison	Green	QR	QR	QR	QR	QR	(NMFS and USFWS 1998a)
St. Lucie, FL	Leatherback	20		1976-1998	0.95		Bresette et al (1998)
St. Lucie, FL	Hawksbill	19		1976-1998	0.90		Bresette et al (1998)
St. Lucie, FL	Green	2297		1976-1998	109.38		Ernest et al (1988)
St. Lucie, FL	Kemp's Ridley	34		1976-1998	1.62		Bresette et al (1998)
All US Waters	Loggerhead	-	5-50	Annual Estimate	-	5-50	Plotkin (1995)

Notes:
QR = qualitative resports only
"-" = value not available

Table F-2: Subset of Nongovernmental Organizations Based in the United States Dedicated to Sea Turtle Research and Conservation

Name	Group Type	Web Address
Amelia Island Sea Turtle Watch, Inc.	Volunteer	www.ameliaislandseaturtlewatch.com/
Archie Carr Center for Sea Turtle Research	Academic	accstr.ufl.edu/
Bald Head Island Conservancy	Volunteer	www.bhic.org/STPP.shtml
California Turtle & Tortoise Club	Volunteer	www.tortoise.org/
Caribbean Conservation Corporation	Nonprofit	www.helpingseaturtles.org/
Chelonian Research Foundation	Academic	www.chelonian.org/
Clearwater Marine Aquarium	Nonprofit/Volunteer	www.seewinter.com/what-we-do/nesting
Coastal Research and Education Society of Long Island, Inc., New York State Sea Turtle Program	Nonprofit/Volunteer	www.cresli.org/cresli/turtles/turtpage.html
Conservation International Sea Turtle Flagship Program	Nonprofit	www.conservation.org/discover/centers_programs/sea_turtles/Pages/seaturtles.aspx
Earthwatch	Nonprofit/Ecotourism	www.earthwatch.org
Gulf Coast Turtle and Tortoise Society	Volunteer	www.gctts.org/
Hawksbill Sea Turtle Recovery Project	Government/Volunteer	www.fpir.noaa.gov/PRD/prd_volunteer_opps.html
Malama na Honu	Nonprofit/Volunteer	malamanahonu.org/
Marine Turtle Specialist Group	Academic	www.iucn-mtsg.org/
Maryland Marine Mammal and Sea Turtle Stranding Network	Government/Volunteer	www.dnr.state.md.us/fisheries/oxford/research/fwh/strandingprogram.html
National Aquarium in Baltimore, Marine Animal Rescue Program	Nonprofit/Volunteer	www.aqua.org/oceanhealth_marp.html
National Save the Sea Turtle Foundation	Nonprofit	savetheseaturtle.org/
Network for Endangered Seaturtles	Volunteer	www.nestonline.org/
Ocean Conservancy	Nonprofit	www.oceanconservancy.org/
Riverhead Foundation for Marine Research and Preservation	Nonprofit/Volunteer	www.riverheadfoundation.org/index.asp
Sanibel-Captiva Conservation Foundation	Nonprofit/Volunteer	www.sccf.org/
Sea Turtle Restoration Project	Nonprofit	www.seaturtles.org
Share the Beach, Sea Turtle Volunteering Program	Volunteer	www.alabamaseaturtles.com/
The Leatherback Trust	Nonprofit	leatherback.org/
The Turtle Foundation	Nonprofit	www.turtle-foundation.org

Source: U.S. EPA analysis for this report

F.2 Application of Whitehead's (1993) Benefit Transfer Approach for Estimating WTP for T&E Sea Turtle Species

EPA identified a study that used a stated preference valuation approach to estimate the total economic value (i.e. use and nonuse values) of a management program designed to reduce the risk of extinction for loggerhead sea turtles (Whitehead 1993). The mail survey asked North Carolina households whether they were willing to pay a bid amount for a management program which reduces the probability that loggerhead sea turtles would be extinct in 25 years. Within the model framework, the baseline extinction risk and change from the management program are expressed in terms of a supply probability. Supply probability reflects the probability that "the wildlife resource will continue to exist so it can be enjoyed by recreational users and nonusers (p.121)" (Whitehead 1993).

The household value is expressed as the option price, or WTP to pay under conditions of future supply and demand uncertainty. The option price is estimated by solving for the dollar amount which would make the respondent indifferent to utility with and without the management program. The function used to estimate the option price (Model B from Whitehead (1993)) is:

$$OP\ (1991\$) = 1.272\ [p_2(r_2 - q_2)]\ /\ 0.029 \quad \text{Equation F-1}$$

Variable definitions for the parameters in the function are described in Table F-3.

EPA used Whitehead (1993) to assess the range of benefits potentially resulting from the final rule and regulatory options considered. EPA reviewed available data sources and biological models to assess the potential impact of baseline losses and reductions on sea turtle supply probability (r_2-q_2). While analyses of sea turtle extinction risk have been conducted (e.g., Conant et al. 2009), EPA was unable to identify an existing model or analysis which could be readily used in conjunction with available mortality data to estimate the marginal impacts of CWIS on sea turtle extinction risk.

Estimates from the literature suggest that IM&E is of relatively low importance compared to other human-induced mortality such as shrimp trawling and other fisheries (Plotkin 1995). However, Crouse et al. (1987) found that mortality at juvenile and subadult life stages can have a substantial effect on population growth, suggesting that small changes in survival at these age classes could have a measurable impact on extinction risk. As such, the marginal change in supply probability of loggerhead sea turtles due to the final rule and proposed options is unlikely to be lower than 0.01 (i.e., a 1 percent decrease in the probability of extinction over 25 years).

EPA specified a marginal improvement of 0.01 within Whitehead's (1993) modeling framework to bound household values for changes in extinction risk for loggerhead sea turtles as a consequence of the final rule. Although this assessment is not based on formal quantitative analysis of extinction risk, EPA intends it to illustrate the range of potential benefits associated with reductions in sea turtle losses. Using the author's mean values for demand probability (p_2) and supply probability without the management program (q_2) (Table F-3), EPA calculated an annual household value of $0.37 (2011$). Estimates were converted to 2011 dollars using the consumer price index (USBLS 2011).

Table F-3: Variable Descriptions and Values used for EPA's Benefits Transfer Application

Variable	Description	Value Used in EPA's Application
OP	Option Price - the amount a household would be willing to pay under conditions of supply and demand uncertainty.	Estimated by the model
p_2	Demand Probability - for wildlife users, demand uncertainty occurs when it is indeterminate whether recreational use of the wildlife resource will be pursued because of uncertain travel costs, income, and tastes. For nonusers, demand uncertainty depends on uncertain tastes.	0.51
q_2[a]	Supply Probability without the Management Program - probability that the resource will continue to exist in 25 years without implementation of the management program.	0.43
r_2	Supply Probability with the Management Program - probability that the resource will continue to exist in 25 years with implementation of the management program.	0.44
(r_2-q_2)[b]	Marginal increase in supply probability resulting from the management program.	0.01

[a] The model results are linear for marginal improvements in supply probability.

[b] EPA notes that a marginal change in supply probability of 0.01 is substantially less than changes used by Whitehead (1993) for model estimation. Whitehead (1993) estimated an annual household willingness to pay value of $10.98 (1991$) for a mean increase in supply probability of 0.47 in 25 years.

Sources: Whitehead (1993), U.S. EPA analysis for this report

Appendix G: Estimation of Price Changes for Consumer Surplus

G.1 Introduction

EPA considered estimating consumer surplus values associated with reductions in IM&E, but found that dockside prices would change too little to produce measurable shifts in consumer surplus. This Appendix presents the details of this analysis and the estimated price changes by region and species.

G.2 Methodology and Results

To properly estimate price changes, it is necessary to consider the contribution of the species to the overall market. Because individual demand functions incorporating substitutes are not available for most species, EPA estimated price changes in the following way. . The Agency estimated the total baseline harvest for relevant species (commercial species of similar types to those affected by IM&E) using National Marine Fisheries Service (NMFS) landings data from 2007 to 2011(NMFS 2012) in three categories: finfish, shrimp, and crabs.[96,] The totals for finfish were summed for the East Coast and Gulf, and for the West Coast, while totals for shrimp and crabs were summed across all coastal regions.[97] EPA summed estimated harvest increases from the elimination of baseline IM&E according to the same species and regional categories. Next, EPA calculated the percentage change in harvest if baseline IM&E were to be eliminated, by dividing the total increase in harvest from elimination of baseline IM&E, by the total harvest. EPA then estimated the percentage change in price for each region and species by dividing the percentage change in harvest by the elasticity for the species group (finfish, shrimp, or crabs).

This last step requires estimates of elasticities. The price elasticity of demand for fish measures the percentage change in demand in response to a percentage change in fish price. Thus, the inverse elasticity, or price flexibility, measures the percentage change in price for a given percentage change in quantity. EPA's review of the economics literature identified several potentially relevant studies, including Asche, Bjorndal, and Gordon (2005); Capps and Lambrgets (1991); Cheng and Capps (1988); Tsoa, Schrank, and Roy (1982); Davis, Yen, and Hwan-Lin (2007); and Lin, Richards, and Terry (1988).

Table G-1 presents the own-price elasticities identified in the literature review for those commercial species where IM&E was estimated. Because elasticities can vary by species, the Agency grouped the own-price elasticities found in the literature review into three categories: (1) saltwater fish, (2) shrimp, and (3) crabs. The median elasticities within each of these groups, presented in the fourth column of Table G-1, are the elasticities used in this analysis. Table G-1 shows that there is a substantial amount of variation in the elasticity estimates, so by selecting the median elasticity rather than taking an average, the influence of the more extreme estimates is reduced.[98]

96 For example, offshore species such as tuna and swordfish, baitfish species, and shellfish were not included.

97 Harvests for Alaska and Hawaii were not included in the totals.

98 Only two studies were available for crabs, so EPA used the mean elasticity for crabs. The Agency did not distinguish between finfish elasticities for the East and West Coast, because some sources provide elasticities based on models that include both regions.

Table G-1: Own-Price Elasticity Estimates from Literature Review

Species Group	Species	Study Elasticity	Median Species Group Elasticity	Study	Notes
Saltwater	Cod	-0.54	-1.89	Cheng and Capps (1988)	
Saltwater	Cod	-3.15	-1.89	Bell (1986) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Cod(Blocks)	-3.16	-1.89	Mazany, Roy and Schrank (1996) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Cod(Fillets)	-0.46	-1.89	Tsoa, Schrank and Roy (1982)	Long run estimate.
Saltwater	Cod(Fillets)	-1.89	-1.89	Asche, Bjorndal and Gordon (2005)	
Saltwater	Flounder	-1.63	-1.89	Mazany, Roy and Schrank (1996) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Flounder/Sole	-0.45	-1.89	Cheng and Capps (1988)	
Saltwater	Flounder/Sole	-1.04	-1.89	Tsoa, Schrank and Roy (1982)	Long run estimate.
Saltwater	Halibut	-5.56	-1.89	Lin, Richards and Terry (1988) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Perch	-0.70	-1.89	Cheng and Capps (1988)	
Saltwater	Perch	-3.09	-1.89	Capps and Lambrgets (1991)	
Saltwater	Perch	-0.60	-1.89	Tsoa, Schrank and Roy (1982)	Long run estimate.
Saltwater	Perch	-215.00	-1.89	Bell (1986) as cited in Asche, Bjorndal and Gordon (2005)	
Saltwater	Rockfish	-3.55	-1.89	Capps and Lambrgets (1991)	
Saltwater	Whitefish	-5.24	-1.89	Capps and Lambrgets (1991)	
Shrimp	Shrimp	-0.70	-0.63	Cheng and Capps (1988)	
Shrimp	Shrimp	-1.08	-0.63	Davis, Yen and Hwan-Lin (2007)	Low income estimate.
Shrimp	Shrimp	-0.30	-0.63	Davis, Yen and Hwan-Lin (2007)	High income estimate.
Shrimp	Shrimp	-2.84	-0.63	Capps and Lambrgets (1991)	
Shrimp	Shrimp	-0.63	-0.63	Doll (1972) as cited in Cheng and Capps (1988)	
Shrimp	Shrimp	0.28	-0.63	Cleary (1969) as cited in Cheng and Capps (1988)	
Shrimp	Shrimp	-0.57	-0.63	Sun (1995) as cited in Asche, Bjorndal and Gordon (2005)	
Crabs	Crabs	-0.77	-1.31	Cheng and Capps (1988)	
Crabs	Crabs	-1.84	-1.31	Capps and Lambrgets (1991)	

Table G-2 shows the results of the calculations of percentage changes in price. EPA applied these percentage changes to the baseline prices to develop estimates of prices for the increased harvests that would result from eliminating baseline IM&E. For example, the table shows that a 0.39 percent change in total harvest in California is predicted to lead to a 0.21 percent change in finfish prices. These prices changes translate into very small changes (generally one to two cents) in ex-vessel prices per pound for the species affected by IM&E. Tables G-3 to G-7 show the projected prices after eliminating baseline IM&E.

EPA did not include estimates of changes in consumer surplus for commercial species. Prices must change in order for consumer surplus to change. Most species of fish have numerous close substitutes. The literature suggests that when there are plentiful substitute fish products, lots of fishers, and a strong ex-vessel market, individual fishers are generally price takers. Although there are exceptions, fisheries economics studies often make these assumptions in analyzing regional effects from harvest changes (e.g., Herrmann 1996; Thunberg et al. 1995) and international markets (e.g., Clarke et al. 1992) . Consumer surplus measures that have been estimated by NMFS for past environmental impact statements tend to be quite low. NMFS fisheries analyses incorporate price changes for large changes in regional or national harvest, such as stock rebuilding. However, for small changes in landings, such as those expected under the final rule, it is standard to assume that prices are fixed. [99]

Table G-2: Estimated Average Percentage Change in Ex-Vessel Price by Region and Species Group from the Elimination of Baseline IM&E

Region	Species Group	Increase in Harvest from Elimination of Baseline IM&E[a] (lbs)	Total Average Annual Harvest[a]	Percentage Change in Harvest	Elasticity	Percentage Change in Price[b]
California	Finfish	1,920,625	489,705,990	0.39%	-1.89	-0.21%
East Coast and Gulf	Finfish	12,548,060	265,617,830	4.72%	-1.89	-2.50%
All Regions	Crabs	1,373,553	258,973,619	0.53%	-1.31	-0.40%
All Regions	Shrimp	369,750	279,365,691	0.13%	-0.63	-0.21%

[a] Sum of total landings for all relevant species.
[b] Percentage changes in price reflect the average across all species within the species group and region.
Sources: U.S. EPA analysis for this report, NMFS (2012a)

Table G-3: Estimated Price Changes for the California Region

Species	Average Annual Harvest 2007-2011 (thousand lbs)	Price Per Pound (2011$)	Increase in Harvest from Elimination of Baseline IM&E (thousand lbs)[a]	Percentage Change in Price	New Price Per Pound (2011$)
American Shad	57.9	$1.07	0.0	-0.21%	$1.07
Anchovies	13,637.3	$0.06	0.9	-0.21%	$0.06
Cabezon	53.7	$5.89	76.1	-0.21%	$5.88
California Halibut	495.5	$4.73	176.9	-0.21%	$4.72
California Scorpionfish	7.9	$3.83	0.0	-0.21%	$3.82
Commercial Crabs	1,386.3	$1.37	2.2	-0.40%	$1.36
Commercial Shrimp	4,272.1	$1.40	0.0	-0.21%	$1.39
Drums and Croakers	53.8	$0.56	6.9	-0.21%	$0.55
Dungeness Crabs	15,495.5	$2.31	6.1	-0.40%	$2.30
Flounders	381.3	$0.42	14.2	-0.21%	$0.42
Other	47,410.9	$1.16	6.6	-0.21%	$1.16
Rockfishes	2,741.3	$1.25	1,634.5	-0.21%	$1.25
Sculpins	3.8	$3.53	3.7	-0.21%	$3.52
Sea Basses	6.4	$2.76	0.0	-0.21%	$2.75
Smelts	323.0	$0.41	0.2	-0.21%	$0.41
Surfperches	17.5	$1.90	0.7	-0.21%	$1.90
Total	**86,344.2**	**.**	**1,928.9**	**.**	**.**

[a] Values of 0.0 for increased harvest from elimination of baseline IM&E may include increases less than 0.1 thousand lbs.
Sources: U.S. EPA analysis for this report, NMFS (2012c)

99 Personal communications with NMFS economists Cindy Thomson (2008), Eric Thunberg (2008), Steve Freese (2008), and Sabrina Lovell (2013).

Table G-4: Estimated Price Changes for the North Atlantic Region					
Species	**Average Annual Harvest 2007-2011 (thousand lbs)**	**Price Per Pound (2011$)**	**Increase in Harvest from Elimination of Baseline IM&E (thousand lbs)[a]**	**Percentage Change in Price**	**New Price Per Pound (2011$)**
American Shad	30.3	$0.86	0.0	-2.50%	$0.84
Atlantic Cod	18,152.5	$1.64	2.3	-2.50%	$1.60
Atlantic Herring	168,023.6	$0.13	17.4	-2.50%	$0.13
Atlantic Menhaden	7,346.1	$0.12	4.8	-2.50%	$0.12
Bluefish	1,038.3	$0.57	0.0	-2.50%	$0.56
Butterfish	784.5	$0.68	0.2	-2.50%	$0.66
Commercial Crabs	16,083.4	$0.62	0.3	-2.50%	$0.61
Flounders	16,026.1	$1.95	373.1	-2.50%	$1.91
Mackerels	29,268.6	$0.17	2.2	-0.40%	$0.16
Other	332,156.1	$0.42	3.8	-2.50%	$0.41
Pollock	16,818.4	$0.64	0.0	-2.50%	$0.62
Red Hake	926.7	$0.39	0.0	-2.50%	$0.38
Sculpins	1.0	$0.11	3.2	-2.50%	$0.11
Scup	5,362.2	$0.75	0.1	-2.50%	$0.73
Searobin	53.3	$0.17	0.1	-2.50%	$0.16
Silver Hake	11,108.1	$0.59	0.6	-2.50%	$0.58
Skate Species	35,198.9	$0.22	0.5	-2.50%	$0.21
Tautog	142.6	$2.43	4.7	-2.50%	$2.37
Weakfish	11.1	$1.67	0.2	-2.50%	$1.63
White Perch	4.8	$1.20	0.0	-2.50%	$1.17
Total	**658,536.4**	**.**	**413.6**	**.**	**.**

[a] Values of 0.0 for increased harvest from elimination of baseline IM&E may include increases less than 0.1 thousand lbs.
Sources: U.S. EPA analysis for this report, NMFS (2012c)

Table G-5: Estimated Price Changes for the Mid-Atlantic Region					
Species	**Average Annual Harvest 2007-2011 (thousand lbs)**	**Price Per Pound (2011$)**	**Increase in Harvest from Elimination of Baseline IM&E (thousand lbs)[a]**	**Percentage Change in Price**	**New Price Per Pound (2011$)**
Alewife	343.8	$0.29	0.3	-2.50%	$0.28
American Shad	57.5	$0.83	0.9	-2.50%	$0.81
Atlantic Herring	6,658.6	$0.12	0.1	-2.50%	$0.11
Atlantic Menhaden	452,353.9	$0.07	3,700.8	-2.50%	$0.07
Black Drum	89.8	$2.20	0.2	-2.50%	$2.14
Blue Crab	85,836.4	$1.11	640.9	-0.40%	$1.10
Bluefish	2,996.3	$0.49	0.1	-2.50%	$0.48
Butterfish	494.1	$0.84	0.0	-2.50%	$0.82
Commercial Crabs	2,490.9	$0.54	0.3	-0.40%	$0.54
Drums and Croakers	10,159.5	$0.64	960.3	-2.50%	$0.63
Flounders	6,308.5	$2.08	6.1	-2.50%	$2.03
Other	602,868.9	$0.31	820.1	-2.50%	$0.30
Red Hake	360.0	$0.46	0.6	-2.50%	$0.44
Scup	4,121.8	$0.81	0.0	-2.50%	$0.79
Searobin	37.3	$0.21	0.0	-2.50%	$0.21
Silver Hake	4,877.3	$0.64	0.1	-2.50%	$0.63
Spot	3,478.4	$0.85	1,064.6	-2.50%	$0.82
Striped Bass	5,609.6	$2.12	55.9	-2.50%	$2.07
Striped Mullet	26.2	$0.45	0.2	-2.50%	$0.44
Tautog	135.3	$2.98	0.0	-2.50%	$2.90
Weakfish	267.4	$1.32	503.7	-2.50%	$1.29
White Perch	1,588.5	$0.79	2.6	-2.50%	$0.77
Total	**1,191,159.9**	**.**	**7,757.9**	**.**	**.**

[a] Values of 0.0 for increased harvest from elimination of baseline IM&E may include increases less than 0.1 thousand lbs.
Sources: U.S. EPA analysis for this report, NMFS (2012c)

Table G-6: Estimated Price Changes for the South Atlantic Region					
Species	**Average Annual Harvest 2007-2011 (thousand lbs)**	**Price Per Pound (2011$)**	**Increase in Harvest from Elimination of Baseline IM&E (thousand lbs)[a]**	**Percentage Change in Price**	**New Price Per Pound (2011$)**
Atlantic Menhaden	1,828.1	$0.12	42.9	-2.50%	$0.11
Blue Crab	39,786.5	$0.95	3.2	-0.40%	$0.95
Commercial Crabs	583.7	$1.65	0.0	-0.40%	$1.65
Drums and Croakers	6,347.6	$0.51	12.5	-2.50%	$0.50
Other	94,277.5	$1.28	2.3	-2.50%	$1.25
Spot	854.3	$0.70	16.1	-2.50%	$0.68
Stone Crab	145.2	$4.01	0.4	-0.40%	$3.99
Weakfish	144.6	$1.02	0.6	-2.50%	$0.99
Total	**143,967.5**	**.**	**78.1**	**.**	**.**

[a] Values of 0.0 for increased harvest from elimination of baseline IM&E may include increases less than 0.1 thousand lbs.
Sources: U.S. EPA analysis for this report, NMFS (2012c)

Table G-7: Estimated Price Changes for the Gulf of Mexico Region

Species	Average Annual Harvest 2007-2011 (thousand lbs)	Price Per Pound (2011$)	Increase in Harvest from Elimination of Baseline IM&E (thousand lbs)[a]	Percentage Change in Price	New Price Per Pound (2011$)
Atlantic Menhaden	1,088,022.8	$0.07	1,173.2	-2.50%	$0.07
Black Drum	4,621.9	$0.83	1,945.0	-2.50%	$0.81
Blue Crab	53,055.9	$0.87	244.0	-0.40%	$0.87
Drums and Croakers	111.8	$5.19	47.8	-2.50%	$5.06
Leatherjacket	61.0	$1.51	107.1	-2.50%	$1.47
Mackerels	3,898.1	$1.16	0.4	-2.50%	$1.13
Other	1,384,185.9	$0.39	281.9	-2.50%	$0.38
Pink Shrimp	6,973.0	$2.00	369.7	-0.21%	$2.00
Sea Basses	179.4	$0.97	0.0	-2.50%	$0.95
Sheepshead	1,393.0	$0.44	0.0	-2.50%	$0.43
Spot	16.9	$0.51	46.3	-2.50%	$0.50
Stone Crab	5,587.9	$4.13	474.4	-0.40%	$4.11
Striped Mullet	10,800.3	$0.64	1,343.6	-2.50%	$0.62
Total	**2,558,908.0**	**.**	**6,033.5**	**.**	**.**

[a] Values of 0.0 for increased harvest from elimination of baseline IM&E may include increases less than 0.1 thousand lbs.

Sources: U.S. EPA analysis for this report, NMFS (2012c)

Appendix H: Details of Regional Commercial Fishing Benefits

Table H-1: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the California Region, by Species and Regulatory Option (2011$)

Species Name	Average Annual Harvest 2007-2011 (1,000 lbs)	Price per Pound	Annual Increase in Commercial Harvest (1,000 lbs)				Annual Benefits from Increase in Commercial Harvest (2011$, 1,000s)			
			Proposal Option 4	Final Rule	Proposal Option 2	Baseline	Proposal Option 4	Final Rule	Proposal Option 2	Baseline
American Shad	57.9	$1.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anchovies	13,637.3	$0.06	0.5	0.5	0.6	0.9	0.0	0.0	0.0	0.0
Cabezon	53.7	$5.89	0.1	0.1	46.4	76.1	0.2	0.3	143.6	235.4
California Halibut	495.5	$4.73	0.2	0.2	107.9	176.9	0.6	0.7	297.2	487.1
California Scorpionfish	7.9	$3.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Commercial Crabs	1,386.3	$1.37	0.0	0.0	1.3	2.2	0.0	0.0	1.4	2.2
Commercial Shrimp	4,272.1	$1.40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drums and Croakers	53.8	$0.56	0.7	0.8	4.3	6.9	0.2	0.2	1.0	1.6
Dungeness Crabs	15,495.5	$2.31	0.4	0.4	3.8	6.1	0.6	0.7	6.4	10.3
Flounders	381.3	$0.42	0.9	0.9	8.7	14.2	0.2	0.2	2.3	3.8
Other	47,410.9	$1.16	0.6	0.7	4.1	6.6	0.4	0.4	2.5	4.0
Rockfishes	2,741.3	$1.25	2.5	2.7	997.3	1,634.5	2.0	2.1	775.9	1,271.7
Sculpins	3.8	$3.53	0.1	0.1	2.2	3.7	0.2	0.2	5.1	8.3
Sea Basses	6.4	$2.76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Smelts	323.0	$0.41	0.1	0.1	0.1	0.2	0.0	0.0	0.0	0.1
Surfperches	17.5	$1.90	0.4	0.5	0.5	0.7	0.3	0.3	0.4	0.5
Total (Undiscounted)	**86,344.2**	**.**	**6.5**	**7.0**	**1,177.4**	**1,928.9**	**4.8**	**5.2**	**1,235.8**	**2,025.1**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**3.0**	**3.3**	**650.8**	**1,698.4**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**2.2**	**2.4**	**422.5**	**1,518.8**

Source: U.S. EPA analysis for this report.

Table H-2: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the North Atlantic Region, by Species and Regulatory Option (2011$)

Species Name	Average Annual Harvest 2007-2011 (1,000 lbs)	Price per Pound	Annual Increase in Commercial Harvest (1,000 lbs)				Annual Benefits from Increase in Commercial Harvest (2011$, 1,000s)			
			Proposal Option 4	Final Rule	Proposal Option 2	Baseline	Proposal Option 4	Final Rule	Proposal Option 2	Baseline
American Shad	30.3	$0.86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Atlantic Cod	18,152.5	$1.64	0.1	0.1	1.8	2.3	0.1	0.1	2.0	2.5
Atlantic Herring	168,023.6	$0.13	0.4	0.5	13.4	17.4	0.0	0.1	1.4	1.8
Atlantic Menhaden	7,346.1	$0.12	0.0	0.1	3.7	4.8	0.0	0.0	0.3	0.4
Bluefish	1,038.3	$0.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Butterfish	784.5	$0.68	0.1	0.1	0.2	0.2	0.0	0.0	0.1	0.1
Commercial Crabs	16,083.4	$0.62	0.2	0.2	0.3	0.3	0.1	0.1	0.1	0.1
Flounders	16,026.1	$1.95	1.2	4.6	286.0	373.1	1.5	5.7	355.5	463.8
Mackerels	29,268.6	$0.17	0.0	0.0	1.7	2.2	0.0	0.0	0.2	0.3
Other	332,156.1	$0.42	0.2	0.2	2.9	3.8	0.0	0.1	0.7	0.9
Pollock	16,818.4	$0.64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Red Hake	926.7	$0.39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sculpins	1.0	$0.11	0.0	0.2	3.2	3.2	0.0	0.0	0.0	0.0
Scup	5,362.2	$0.75	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1
Searobin	53.3	$0.17	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Silver Hake	11,108.1	$0.59	0.1	0.1	0.5	0.6	0.0	0.1	0.2	0.2
Skate Species	35,198.9	$0.22	0.3	0.3	0.5	0.5	0.0	0.1	0.1	0.1
Tautog	142.6	$2.43	0.0	0.0	3.6	4.7	0.0	0.1	4.0	5.2
Weakfish	11.1	$1.67	0.0	0.0	0.2	0.2	0.0	0.0	0.2	0.3
White Perch	4.8	$1.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (Undiscounted)	**658,536.4**	**.**	**2.7**	**6.7**	**318.0**	**413.6**	**1.9**	**6.2**	**364.7**	**475.8**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**1.2**	**4.0**	**202.3**	**399.0**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**0.9**	**3.0**	**135.9**	**356.8**

Source: U.S. EPA analysis for this report.

Table H-3: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the Mid-Atlantic Region, by Species and Regulatory Option (2011$)

Species Name	Average Annual Harvest 2007-2011 (1,000 lbs)	Price per Pound	Annual Increase in Commercial Harvest (1,000 lbs)				Annual Benefits from Increase in Commercial Harvest (2011$, 1,000s)			
			Proposal Option 4	Final Rule	Proposal Option 2	Baseline	Proposal Option 4	Final Rule	Proposal Option 2	Baseline
Alewife	343.8	$0.29	0.2	0.2	0.3	0.3	0.1	0.1	0.1	0.1
American Shad	57.5	$0.83	0.0	0.0	0.8	0.9	0.0	0.0	0.6	0.6
Atlantic Herring	6,658.6	$0.12	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Atlantic Menhaden	452,353.9	$0.07	2,503.2	2,674.8	3,398.8	3,700.8	126.4	135.0	171.6	186.8
Black Drum	89.8	$2.20	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4
Blue Crab	85,836.4	$1.11	8.8	9.8	559.0	640.9	5.6	6.2	354.4	406.3
Bluefish	2,996.3	$0.49	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Butterfish	494.1	$0.84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commercial Crabs	2,490.9	$0.54	0.2	0.2	0.3	0.3	0.1	0.1	0.1	0.1
Drums and Croakers	10,159.5	$0.64	14.1	15.7	837.7	960.3	6.7	7.5	398.8	457.1
Flounders	6,308.5	$2.08	2.6	2.8	5.5	6.1	3.6	3.8	7.8	8.6
Other	602,868.9	$0.31	98.1	105.3	721.4	820.1	21.9	23.5	160.7	182.7
Red Hake	360.0	$0.46	0.5	0.5	0.6	0.6	0.1	0.1	0.2	0.2
Scup	4,121.8	$0.81	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Searobin	37.3	$0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Silver Hake	4,877.3	$0.64	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Spot	3,478.4	$0.85	93.6	100.8	1,064.6	1,064.6	66.5	71.7	756.9	756.9
Striped Bass	5,609.6	$2.12	0.4	0.5	48.7	55.9	0.6	0.7	68.8	78.9
Striped Mullet	26.2	$0.45	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Tautog	135.3	$2.98	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weakfish	267.4	$1.32	150.4	160.9	449.3	503.7	150.9	161.4	450.8	505.3
White Perch	1,588.5	$0.79	0.2	0.3	2.2	2.6	0.2	0.2	1.5	1.7
Total (Undiscounted)	**1,191,159.9**	**.**	**2,872.9**	**3,072.5**	**7,090.1**	**7,757.9**	**382.9**	**410.7**	**2,372.6**	**2,586.0**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**242.1**	**259.7**	**1,206.2**	**2,168.8**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**177.1**	**190.1**	**769.7**	**1,939.4**

Source: U.S. EPA analysis for this report.

Table H-4: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the South Atlantic Region, by Species and Regulatory Option (2011$)

Species Name	Average Annual Harvest 2007-2011 (1,000 lbs)	Price per Pound	Annual Increase in Commercial Harvest (1,000 lbs)				Annual Benefits from Increase in Commercial Harvest (2011$, 1,000s)			
			Proposal Option 4	Final Rule	Proposal Option 2	Baseline	Proposal Option 4	Final Rule	Proposal Option 2	Baseline
Atlantic Menhaden	1,828.1	$0.12	25.7	27.5	42.2	42.9	2.2	2.4	3.7	3.8
Blue Crab	39,786.5	$0.95	2.2	2.3	3.2	3.2	1.2	1.3	1.7	1.7
Commercial Crabs	583.7	$1.65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drums and Croakers	6,347.6	$0.51	0.2	0.2	11.7	12.5	0.1	0.2	3.2	3.4
Other	94,277.5	$1.28	1.3	1.3	2.3	2.3	1.0	1.0	1.7	1.8
Spot	854.3	$0.70	7.0	7.5	15.6	16.1	3.4	3.8	7.6	7.9
Stone Crab	145.2	$4.01	0.3	0.3	0.4	0.4	0.6	0.7	0.9	1.0
Weakfish	144.6	$1.02	0.3	0.3	0.6	0.6	0.2	0.2	0.4	0.4
Total (Undiscounted)	**143,967.5**	**.**	**36.9**	**39.6**	**76.0**	**78.1**	**8.7**	**9.7**	**19.3**	**19.9**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**5.8**	**6.4**	**10.4**	**16.7**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**4.4**	**4.9**	**7.0**	**14.9**

Source: U.S. EPA analysis for this report.

Table H-5: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the Gulf of Mexico Region, by Species and Regulatory Option (2011$)

Species Name	Average Annual Harvest 2007-2011 (1,000 lbs)	Price per Pound	Annual Increase in Commercial Harvest (1,000 lbs)				Annual Benefits from Increase in Commercial Harvest (2011$, 1,000s)			
			Proposal Option 4	Final Rule	Proposal Option 2	Baseline	Proposal Option 4	Final Rule	Proposal Option 2	Baseline
Atlantic Menhaden	1,088,022.8	$0.07	841.3	873.2	1,053.6	1,173.2	44.7	46.3	55.9	62.3
Black Drum	4,621.9	$0.83	5.1	5.2	1,150.0	1,945.0	2.9	3.0	662.9	1,121.1
Blue Crab	53,055.9	$0.87	45.3	47.0	163.4	244.0	28.1	29.2	101.6	151.7
Drums and Croakers	111.8	$5.19	34.6	35.9	43.1	47.8	97.0	100.7	120.8	134.2
Leatherjacket	61.0	$1.51	74.3	77.2	95.1	107.1	0.0	0.0	0.0	0.0
Mackerels	3,898.1	$1.16	0.3	0.3	0.3	0.4	0.2	0.2	0.3	0.3
Other	1,384,185.9	$0.39	185.1	192.1	245.8	281.9	33.6	34.9	44.6	51.2
Pink Shrimp	6,973.0	$2.00	173.5	180.1	292.7	369.7	150.7	156.4	254.2	321.1
Sea Basses	179.4	$0.97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sheepshead	1,393.0	$0.44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spot	16.9	$0.51	27.8	28.9	39.3	46.3	7.7	7.9	10.8	12.7
Stone Crab	5,587.9	$4.13	117.2	121.6	330.2	474.4	344.9	358.0	972.0	1,396.2
Striped Mullet	10,800.3	$0.64	137.3	142.5	851.9	1,343.6	69.0	71.6	428.1	675.3
Total (Undiscounted)	**2,558,908.0**	**.**	**1,641.8**	**1,704.0**	**4,265.5**	**6,033.5**	**778.9**	**808.3**	**2,651.3**	**3,926.1**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**496.8**	**515.5**	**1,702.5**	**3,426.9**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**365.2**	**378.9**	**1,255.7**	**3,160.8**

Source: U.S. EPA analysis for this report.

Table H-6: Commercial Fishing Benefits from Eliminating or Reducing Baseline IM&E at Regulated Facilities in the Great Lakes Region, by Species and Regulatory Option (2011$)

Species Name	Average Annual Harvest 2007-2011 (1,000 lbs)	Price per Pound	Annual Increase in Commercial Harvest (1,000 lbs)				Annual Benefits from Increase in Commercial Harvest (2011$, 1,000s)			
			Proposal Option 4	Final Rule	Proposal Option 2	Baseline	Proposal Option 4	Final Rule	Proposal Option 2	Baseline
Bullhead	679.1	$0.40	17.9	19.7	22.8	23.5	2.1	2.3	2.6	2.7
Freshwater Drum	585.9	$0.18	73.8	81.4	203.3	209.1	3.9	4.3	10.8	11.2
Other	14,356.7	$1.03	320.0	352.2	451.4	481.3	95.8	105.5	135.2	144.1
Sculpins	14,356.7	$1.03	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Smelts	380.5	$1.60	61.3	67.5	87.0	92.9	28.4	31.3	40.4	43.1
White Bass	523.6	$0.73	248.1	248.1	248.1	248.1	52.6	52.6	52.6	52.6
Whitefish	9,785.3	$0.99	59.4	65.4	74.5	76.4	17.1	18.8	21.4	22.0
Yellow Perch	1,543.6	$2.14	3.8	4.1	5.2	5.5	2.3	2.6	3.2	3.4
Total (Undiscounted)	**42,211.3**	**.**	**784.2**	**838.5**	**1,092.4**	**1,136.9**	**202.2**	**217.3**	**266.2**	**279.0**
Total (3% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**134.6**	**144.9**	**162.5**	**243.6**
Total (7% Discount Rate)	**.**	**.**	**.**	**.**	**.**	**.**	**101.9**	**109.8**	**116.2**	**224.6**

Source: U.S. EPA analysis for this report.

Appendix I: Details of Regional Recreational Fishing Benefits

I.1 California Region

Table I-1: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 4 in the California Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
California halibut	69.0	$5.35	$10.21	$19.49	0.0	0.8	1.5
Flounders	21.0	$5.35	$10.21	$19.49	0.0	0.2	0.5
Total (Flatfish)	**90.0**	**$5.35**	**$10.21**	**$19.49**	**0.0**	**1.0**	**2.0**
Striped bass	0.0	$4.40	$7.60	$13.01	0.0	0.0	0.0
Total (Small Game)	**0.0**	**$4.40**	**$7.60**	**$13.01**	**0.0**	**0.0**	**0.0**
Cabezon	10.0	$1.87	$3.09	$5.11	0.0	0.0	0.1
California scorpionfish	49.0	$1.87	$3.09	$5.11	0.1	0.2	0.3
Croakers	4,564.0	$1.87	$3.09	$5.11	8.5	14.1	23.4
Rockfish	618.0	$1.87	$3.09	$5.11	1.2	1.9	3.2
Sculpin	3,192.0	$1.87	$3.09	$5.11	5.9	9.8	16.3
Sea bass	276.0	$1.87	$3.09	$5.11	0.5	0.9	1.4
Smelts	16.0	$1.87	$3.09	$5.11	0.0	0.0	0.1
Sunfish	1.0	$1.87	$3.09	$5.11	0.0	0.0	0.0
Surfperch	25,654.0	$1.87	$3.09	$5.11	47.8	79.1	131.3
Total (Other Saltwater)	**34,381.0**	**$1.87**	**$3.09**	**$5.11**	**64.0**	**106.0**	**176.0**
Total (Unidentified)	**949.0**	**$1.95**	**$3.25**	**$5.42**	**2.0**	**3.0**	**5.0**
Total (Undiscounted)	**35,420.0**	**.**	**.**	**.**	**67.0**	**110.0**	**183.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**42.0**	**69.0**	**114.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**30.0**	**50.0**	**83.0**

Source: U.S. EPA analysis for this report.

Table I-2: Recreational Fishing Benefits from Reducing at Regulated Facilities under the Final Rule in the California Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
California halibut	74.0	$5.35	$10.21	$19.49	0.8	0.8	1.5
Flounders	23.0	$5.35	$10.21	$19.49	0.2	0.2	0.5
Total (Flatfish)	**97.0**	**$5.35**	**$10.21**	**$19.49**	**1.0**	**1.0**	**2.0**
Striped bass	0.0	$4.40	$7.60	$13.01	0.0	0.0	0.0
Total (Small Game)	**0.0**	**$4.40**	**$7.60**	**$13.01**	**0.0**	**0.0**	**0.0**
Cabezon	11.0	$1.87	$3.09	$5.11	0.0	0.0	0.1
California scorpionfish	53.0	$1.87	$3.09	$5.11	0.1	0.2	0.3
Croakers	4,917.0	$1.87	$3.09	$5.11	9.2	15.3	25.1
Rockfish	665.0	$1.87	$3.09	$5.11	1.2	2.1	3.4
Sculpin	3,439.0	$1.87	$3.09	$5.11	6.4	10.7	17.5
Sea bass	297.0	$1.87	$3.09	$5.11	0.6	0.9	1.5
Smelts	18.0	$1.87	$3.09	$5.11	0.0	0.1	0.1
Sunfish	1.0	$1.87	$3.09	$5.11	0.0	0.0	0.0
Surfperch	27,638.0	$1.87	$3.09	$5.11	51.5	85.8	141.0
Total (Other Saltwater)	**37,040.0**	**$1.87**	**$3.09**	**$5.11**	**69.0**	**115.0**	**189.0**
Total (Unidentified)	**1,022.0**	**$1.95**	**$3.25**	**$5.42**	**2.0**	**3.0**	**6.0**
Total (Undiscounted)	**38,159.0**	**.**	**.**	**.**	**72.0**	**119.0**	**197.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**45.0**	**74.0**	**123.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**33.0**	**54.0**	**89.0**

Source: U.S. EPA analysis for this report.

Table I-3: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 2 in the California Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
California halibut	32,791.0	$5.35	$10.21	$19.49	175.9	334.8	638.9
Flounders	213.0	$5.35	$10.21	$19.49	1.1	2.2	4.1
Total (Flatfish)	**33,004.0**	**$5.35**	**$10.21**	**$19.49**	**177.0**	**337.0**	**643.0**
Striped bass	1,032.0	$4.40	$7.60	$13.01	5.0	8.0	13.0
Total (Small Game)	**1,032.0**	**$4.40**	**$7.60**	**$13.01**	**5.0**	**8.0**	**13.0**
Cabezon	6,110.0	$1.87	$3.09	$5.11	11.4	18.9	31.3
California scorpionfish	56.0	$1.87	$3.09	$5.11	0.1	0.2	0.3
Croakers	28,043.0	$1.87	$3.09	$5.11	52.5	86.8	143.4
Rockfish	243,212.0	$1.87	$3.09	$5.11	455.2	752.6	1,244.0
Sculpin	95,822.0	$1.87	$3.09	$5.11	179.3	296.5	490.1
Sea bass	437,354.0	$1.87	$3.09	$5.11	818.6	1,353.3	2,237.0
Smelts	20.0	$1.87	$3.09	$5.11	0.0	0.1	0.1
Sunfish	12.0	$1.87	$3.09	$5.11	0.0	0.0	0.1
Surfperch	29,282.0	$1.87	$3.09	$5.11	54.8	90.6	149.8
Total (Other Saltwater)	**839,911.0**	**$1.87**	**$3.09**	**$5.11**	**1,572.0**	**2,599.0**	**4,296.0**
Total (Unidentified)	**3,227.0**	**$1.95**	**$3.25**	**$5.42**	**6.0**	**10.0**	**17.0**
Total (Undiscounted)	**877,174.0**	**.**	**.**	**.**	**1,759.0**	**2,954.0**	**4,970.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**919.0**	**1,543.0**	**2,595.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**592.0**	**994.0**	**1,673.0**

Source: U.S. EPA analysis for this report.

Table I-4: Recreational Fishing Benefits from Eliminating Baseline IM&E at Regulated Facilities in the California Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
California halibut	53,746.0	$5.35	$10.21	$19.49	287.2	548.5	1,047.3
Flounders	345.0	$5.35	$10.21	$19.49	1.8	3.5	6.7
Total (Flatfish)	**54,091.0**	**$5.35**	**$10.21**	**$19.49**	**289.0**	**552.0**	**1,054.0**
Striped bass	1,692.0	$4.40	$7.60	$13.01	7.0	13.0	22.0
Total (Small Game)	**1,692.0**	**$4.40**	**$7.60**	**$13.01**	**7.0**	**13.0**	**22.0**
Cabezon	10,015.0	$1.87	$3.09	$5.11	18.7	31.0	51.2
California scorpionfish	82.0	$1.87	$3.09	$5.11	0.2	0.3	0.4
Croakers	45,086.0	$1.87	$3.09	$5.11	84.4	139.5	230.6
Rockfish	398,609.0	$1.87	$3.09	$5.11	745.9	1,233.4	2,038.6
Sculpin	156,471.0	$1.87	$3.09	$5.11	292.8	484.2	800.2
Sea bass	716,959.0	$1.87	$3.09	$5.11	1,341.5	2,218.5	3,666.7
Smelts	30.0	$1.87	$3.09	$5.11	0.1	0.1	0.2
Sunfish	19.0	$1.87	$3.09	$5.11	0.0	0.1	0.1
Surfperch	43,011.0	$1.87	$3.09	$5.11	80.5	133.1	220.0
Total (Other Saltwater)	**1,370,282.0**	**$1.87**	**$3.09**	**$5.11**	**2,564.0**	**4,240.0**	**7,008.0**
Total (Unidentified)	**5,106.0**	**$1.95**	**$3.25**	**$5.42**	**10.0**	**17.0**	**28.0**
Total (Undiscounted)	**1,431,170.0**	**.**	**.**	**.**	**2,871.0**	**4,822.0**	**8,112.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**2,408.0**	**4,044.0**	**6,803.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**2,153.0**	**3,616.0**	**6,084.0**

Source: U.S. EPA analysis for this report.

I.2 North Atlantic Region

Table I-5: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 4 in the North Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Winter flounder	765.0	$3.98	$6.24	$9.86	3.0	5.0	8.0
Total (flatfish)	**765.0**	**$3.98**	**$6.24**	**$9.86**	**3.0**	**5.0**	**8.0**
Atlantic mackerel	0.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Bluefish	1.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Striped bass	0.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Weakfish	0.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Total (small game)	**1.0**	**$2.23**	**$6.22**	**$17.53**	**0.0**	**0.0**	**0.0**
Atlantic Cod	37.0	$1.87	$3.12	$5.20	0.1	0.1	0.2
Cunner	18.0	$1.87	$3.12	$5.20	0.0	0.0	0.1
Pollock	1.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Sculpin	316.0	$1.87	$3.12	$5.20	0.7	0.7	1.4
Scup	8.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Searobin	41.0	$1.87	$3.12	$5.20	0.1	0.1	0.2
Tautog	15.0	$1.87	$3.12	$5.20	0.0	0.0	0.1
White Perch	0.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Total (other saltwater)	**436.0**	**$1.87**	**$3.12**	**$5.20**	**1.0**	**1.0**	**2.0**
Total (unidentified)	**166.0**	**$1.88**	**$3.15**	**$5.26**	**0.0**	**1.0**	**1.0**
Total (Undiscounted)	**1,367.0**	**.**	**.**	**.**	**4.0**	**7.0**	**11.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**3.0**	**4.0**	**7.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**2.0**	**3.0**	**5.0**

Source: U.S. EPA analysis for this report.

Table I-6: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under the Final Rule in the North Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Winter flounder	3,471.0	$3.98	$6.24	$9.86	14.0	22.0	34.0
Total (flatfish)	**3,471.0**	**$3.98**	**$6.24**	**$9.86**	**14.0**	**22.0**	**34.0**
Atlantic mackerel	8.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Bluefish	1.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Striped bass	0.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Weakfish	0.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Total (small game)	**9.0**	**$2.23**	**$6.22**	**$17.53**	**0.0**	**0.0**	**0.0**
Atlantic Cod	50.0	$1.87	$3.12	$5.20	0.1	0.2	0.3
Cunner	941.0	$1.87	$3.12	$5.20	1.8	2.8	4.8
Pollock	1.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Sculpin	3,107.0	$1.87	$3.12	$5.20	5.8	9.4	15.9
Scup	9.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Searobin	51.0	$1.87	$3.12	$5.20	0.1	0.2	0.3
Tautog	139.0	$1.87	$3.12	$5.20	0.3	0.4	0.7
White Perch	0.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Total (other saltwater)	**4,298.0**	**$1.87**	**$3.12**	**$5.20**	**8.0**	**13.0**	**22.0**
Total (unidentified)	**198.0**	**$1.88**	**$3.15**	**$5.26**	**0.0**	**1.0**	**1.0**
Total (Undiscounted)	**7,975.0**	**.**	**.**	**.**	**22.0**	**36.0**	**58.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**14.0**	**23.0**	**36.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**10.0**	**16.0**	**27.0**

Source: U.S. EPA analysis for this report.

Table I-7: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 2 in the North Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Winter flounder	229,386.0	$3.98	$6.24	$9.86	914.0	1,430.0	2,261.0
Total (flatfish)	**229,386.0**	**$3.98**	**$6.24**	**$9.86**	**914.0**	**1,430.0**	**2,261.0**
Atlantic mackerel	666.0	$2.23	$6.22	$17.53	1.9	3.8	11.5
Bluefish	1.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Striped bass	0.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Weakfish	25.0	$2.23	$6.22	$17.53	0.1	0.1	0.4
Total (small game)	**692.0**	**$2.23**	**$6.22**	**$17.53**	**2.0**	**4.0**	**12.0**
Atlantic Cod	955.0	$1.87	$3.12	$5.20	1.8	3.0	5.0
Cunner	79,272.0	$1.87	$3.12	$5.20	148.2	247.3	412.3
Pollock	3.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Sculpin	238,602.0	$1.87	$3.12	$5.20	445.9	744.4	1,241.0
Scup	96.0	$1.87	$3.12	$5.20	0.2	0.3	0.5
Searobin	618.0	$1.87	$3.12	$5.20	1.2	1.9	3.2
Tautog	10,583.0	$1.87	$3.12	$5.20	19.8	33.0	55.0
White Perch	0.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Total (other saltwater)	**330,130.0**	**$1.87**	**$3.12**	**$5.20**	**617.0**	**1,030.0**	**1,717.0**
Total (unidentified)	**2,098.0**	**$1.88**	**$3.15**	**$5.26**	**4.0**	**7.0**	**11.0**
Total (Undiscounted)	**562,305.0**	**.**	**.**	**.**	**1,537.0**	**2,471.0**	**4,001.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**852.0**	**1,371.0**	**2,219.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**573.0**	**921.0**	**1,491.0**

Source: U.S. EPA analysis for this report.

Table I-8: Recreational Fishing Benefits from Eliminating Baseline IM&E at Regulated Facilities in the North Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Winter flounder	299,352.0	$3.98	$6.24	$9.86	1,192.0	1,867.0	2,951.0
Total (flatfish)	**299,352.0**	**$3.98**	**$6.24**	**$9.86**	**1,192.0**	**1,867.0**	**2,951.0**
Atlantic mackerel	870.0	$2.23	$6.22	$17.53	1.9	5.8	15.4
Bluefish	1.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Striped bass	0.0	$2.23	$6.22	$17.53	0.0	0.0	0.0
Weakfish	32.0	$2.23	$6.22	$17.53	0.1	0.2	0.6
Total (small game)	**903.0**	**$2.23**	**$6.22**	**$17.53**	**2.0**	**6.0**	**16.0**
Atlantic Cod	1,235.0	$1.87	$3.12	$5.20	2.3	3.9	6.4
Cunner	103,533.0	$1.87	$3.12	$5.20	193.6	323.1	538.5
Pollock	4.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Sculpin	311,537.0	$1.87	$3.12	$5.20	582.5	972.1	1,620.4
Scup	123.0	$1.87	$3.12	$5.20	0.2	0.4	0.6
Searobin	794.0	$1.87	$3.12	$5.20	1.5	2.5	4.1
Tautog	13,817.0	$1.87	$3.12	$5.20	25.8	43.1	71.9
White Perch	0.0	$1.87	$3.12	$5.20	0.0	0.0	0.0
Total (other saltwater)	**431,044.0**	**$1.87**	**$3.12**	**$5.20**	**806.0**	**1,345.0**	**2,242.0**
Total (unidentified)	**2,686.0**	**$1.88**	**$3.15**	**$5.26**	**5.0**	**8.0**	**14.0**
Total (Undiscounted)	**733,985.0**	**.**	**.**	**.**	**2,006.0**	**3,226.0**	**5,223.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,682.0**	**2,705.0**	**4,380.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**1,504.0**	**2,419.0**	**3,917.0**

Source: U.S. EPA analysis for this report.

I.3 Mid-Atlantic Region

Table I-9: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 4 in the Mid-Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Summer Flounder	3,096.0	$3.92	$5.88	$8.92	12.4	17.8	27.6
Winter Flounder	386.0	$3.92	$5.88	$8.92	1.6	2.2	3.4
Total (Flatfish)	**3,482.0**	**$3.92**	**$5.88**	**$8.92**	**14.0**	**20.0**	**31.0**
Black Crappie	2.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Bluegill	9.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Brown bullhead	604.0	$0.55	$1.11	$2.20	0.2	0.7	1.2
Bullhead	6.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Channel catfish	1,686.0	$0.55	$1.11	$2.20	0.7	2.1	3.5
Crappie	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Menhaden	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Sunfish	129.0	$0.55	$1.11	$2.20	0.1	0.2	0.3
Total (Panfish)	**2,438.0**	**$0.55**	**$1.11**	**$2.20**	**1.0**	**3.0**	**5.0**
Bluefish	74.0	$2.37	$6.17	$16.23	0.2	0.5	1.2
Red drum	1,555.0	$2.37	$6.17	$16.23	3.7	9.6	25.2
Spotted seatrout	1,031.0	$2.37	$6.17	$16.23	2.4	6.4	16.7
Striped bass	773.0	$2.37	$6.17	$16.23	1.8	4.8	12.6
Weakfish	93,196.0	$2.37	$6.17	$16.23	220.9	575.8	1,513.3
Total (Small Game)	**96,628.0**	**$2.37**	**$6.17**	**$16.23**	**229.0**	**597.0**	**1,569.0**
Atlantic croaker	16,563.0	$1.94	$3.05	$4.82	32.1	50.6	79.8
Atlantic herring	33.0	$1.94	$3.05	$4.82	0.1	0.1	0.2
Black drum	149.0	$1.94	$3.05	$4.82	0.3	0.5	0.7
Cunner	0.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Scup	1.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Searobin	4.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Silver perch	1.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Smallmouth bass	34.0	$1.94	$3.05	$4.82	0.1	0.1	0.2
Spot	248,039.0	$1.94	$3.05	$4.82	481.1	757.9	1,194.5
Striped mullet	7.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Tautog	0.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
White perch	1,972.0	$1.94	$3.05	$4.82	3.8	6.0	9.5
Whitefish	248.0	$1.94	$3.05	$4.82	0.5	0.8	1.2
Total (Other Saltwater)	**267,049.0**	**$1.94**	**$3.05**	**$4.82**	**518.0**	**816.0**	**1,286.0**
Total (Unidentified)	**58,327.0**	**$2.00**	**$3.39**	**$6.00**	**117.0**	**198.0**	**350.0**
Total (Undiscounted)	**427,924.0**	**.**	**.**	**.**	**878.0**	**1,633.0**	**3,241.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**531.0**	**988.0**	**1,961.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**376.0**	**700.0**	**1,389.0**

Source: U.S. EPA analysis for this report.

Table I-10: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under the Final Rule in the Mid-Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Summer Flounder	3,308.0	$3.92	$5.88	$8.92	13.3	19.5	29.3
Winter Flounder	414.0	$3.92	$5.88	$8.92	1.7	2.4	3.7
Total (Flatfish)	**3,723.0**	**$3.92**	**$5.88**	**$8.92**	**15.0**	**22.0**	**33.0**
Black Crappie	2.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Bluegill	10.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Brown bullhead	647.0	$0.55	$1.11	$2.20	0.2	0.7	1.5
Bullhead	7.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Channel catfish	1,801.0	$0.55	$1.11	$2.20	0.7	2.1	4.1
Crappie	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Menhaden	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Sunfish	138.0	$0.55	$1.11	$2.20	0.1	0.2	0.3
Total (Panfish)	**2,607.0**	**$0.55**	**$1.11**	**$2.20**	**1.0**	**3.0**	**6.0**
Bluefish	79.0	$2.37	$6.17	$16.23	0.2	0.5	1.3
Red drum	1,661.0	$2.37	$6.17	$16.23	3.9	10.3	27.0
Spotted seatrout	1,101.0	$2.37	$6.17	$16.23	2.6	6.8	17.9
Striped bass	897.0	$2.37	$6.17	$16.23	2.1	5.5	14.6
Weakfish	99,705.0	$2.37	$6.17	$16.23	236.1	615.9	1,618.3
Total (Small Game)	**103,444.0**	**$2.37**	**$6.17**	**$16.23**	**245.0**	**639.0**	**1,679.0**
Atlantic croaker	18,458.0	$1.94	$3.05	$4.82	35.8	56.3	88.9
Atlantic herring	35.0	$1.94	$3.05	$4.82	0.1	0.1	0.2
Black drum	159.0	$1.94	$3.05	$4.82	0.3	0.5	0.8
Cunner	0.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Scup	1.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Searobin	4.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Silver perch	1.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Smallmouth bass	36.0	$1.94	$3.05	$4.82	0.1	0.1	0.2
Spot	267,172.0	$1.94	$3.05	$4.82	518.1	815.6	1,286.5
Striped mullet	8.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Tautog	0.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
White perch	2,119.0	$1.94	$3.05	$4.82	4.1	6.5	10.2
Whitefish	265.0	$1.94	$3.05	$4.82	0.5	0.8	1.3
Total (Other Saltwater)	**288,258.0**	**$1.94**	**$3.05**	**$4.82**	**559.0**	**880.0**	**1,388.0**
Total (Unidentified)	**62,808.0**	**$2.00**	**$3.39**	**$6.00**	**126.0**	**213.0**	**377.0**
Total (Undiscounted)	**460,839.0**	**.**	**.**	**.**	**945.0**	**1,757.0**	**3,483.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**572.0**	**1,063.0**	**2,108.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**405.0**	**753.0**	**1,493.0**

Source: U.S. EPA analysis for this report.

Table I-11: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 2 in the Mid-Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Summer Flounder	3,781.0	$3.92	$5.88	$8.92	14.9	22.3	33.8
Winter Flounder	2,823.0	$3.92	$5.88	$8.92	11.1	16.7	25.2
Total (Flatfish)	**6,604.0**	**$3.92**	**$5.88**	**$8.92**	**26.0**	**39.0**	**59.0**
Black Crappie	2.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Bluegill	11.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Brown bullhead	2,281.0	$0.55	$1.11	$2.20	1.4	2.7	5.0
Bullhead	8.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Channel catfish	2,059.0	$0.55	$1.11	$2.20	1.2	2.4	4.5
Crappie	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Menhaden	530.0	$0.55	$1.11	$2.20	0.3	0.6	1.2
Sunfish	157.0	$0.55	$1.11	$2.20	0.1	0.2	0.3
Total (Panfish)	**5,049.0**	**$0.55**	**$1.11**	**$2.20**	**3.0**	**6.0**	**11.0**
Bluefish	90.0	$2.37	$6.17	$16.23	0.2	0.6	1.5
Red drum	1,899.0	$2.37	$6.17	$16.23	4.5	11.7	30.8
Spotted seatrout	1,259.0	$2.37	$6.17	$16.23	3.0	7.8	20.4
Striped bass	91,823.0	$2.37	$6.17	$16.23	217.3	566.9	1,490.6
Weakfish	278,408.0	$2.37	$6.17	$16.23	659.0	1,719.0	4,519.6
Total (Small Game)	**373,479.0**	**$2.37**	**$6.17**	**$16.23**	**884.0**	**2,306.0**	**6,063.0**
Atlantic croaker	983,158.0	$1.94	$3.05	$4.82	1,906.3	3,003.0	4,733.8
Atlantic herring	40.0	$1.94	$3.05	$4.82	0.1	0.1	0.2
Black drum	182.0	$1.94	$3.05	$4.82	0.4	0.6	0.9
Cunner	0.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Scup	1.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Searobin	5.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Silver perch	1.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Smallmouth bass	41.0	$1.94	$3.05	$4.82	0.1	0.1	0.2
Spot	3,026,406.0	$1.94	$3.05	$4.82	5,868.1	9,243.9	14,571.9
Striped mullet	9.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Tautog	0.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
White perch	18,793.0	$1.94	$3.05	$4.82	36.4	57.4	90.5
Whitefish	303.0	$1.94	$3.05	$4.82	0.6	0.9	1.5
Total (Other Saltwater)	**4,028,939.0**	**$1.94**	**$3.05**	**$4.82**	**7,812.0**	**12,306.0**	**19,399.0**
Total (Unidentified)	**689,524.0**	**$2.00**	**$3.39**	**$6.00**	**1,378.0**	**2,340.0**	**4,138.0**
Total (Undiscounted)	**5,103,595.0**	**.**	**.**	**.**	**10,102.0**	**16,996.0**	**29,670.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**5,132.0**	**8,634.0**	**15,072.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**3,273.0**	**5,506.0**	**9,612.0**

Source: U.S. EPA analysis for this report.

Table I-12: Recreational Fishing Benefits from Eliminating Baseline IM&E at Regulated Facilities in the Mid-Atlantic Region, by Species (2011$)							
Species	**Annual Increase in Recreational Harvest (harvestable adult fish)**	**Value per Fish**			**Annual Benefits from Increase in Recreational Harvest (2011$, thousands)**		
		5th	**Mean**	**95th**	**5th**	**Mean**	**95th**
Summer Flounder	4,092.0	$3.92	$5.88	$8.92	16.3	24.1	36.4
Winter Flounder	3,209.0	$3.92	$5.88	$8.92	12.7	18.9	28.6
Total (Flatfish)	**7,301.0**	**$3.92**	**$5.88**	**$8.92**	**29.0**	**43.0**	**65.0**
Black Crappie	3.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Bluegill	12.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Brown bullhead	2,569.0	$0.55	$1.11	$2.20	1.4	2.8	5.5
Bullhead	8.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Channel catfish	2,228.0	$0.55	$1.11	$2.20	1.2	2.4	4.8
Crappie	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Menhaden	609.0	$0.55	$1.11	$2.20	0.3	0.7	1.3
Sunfish	170.0	$0.55	$1.11	$2.20	0.1	0.2	0.4
Total (Panfish)	**5,600.0**	**$0.55**	**$1.11**	**$2.20**	**3.0**	**6.0**	**12.0**
Bluefish	97.0	$2.37	$6.17	$16.23	0.2	0.6	1.6
Red drum	2,055.0	$2.37	$6.17	$16.23	4.9	12.7	33.4
Spotted seatrout	1,362.0	$2.37	$6.17	$16.23	3.2	8.4	22.1
Striped bass	105,323.0	$2.37	$6.17	$16.23	249.2	650.3	1,709.8
Weakfish	312,082.0	$2.37	$6.17	$16.23	738.5	1,927.0	5,066.2
Total (Small Game)	**420,920.0**	**$2.37**	**$6.17**	**$16.23**	**996.0**	**2,599.0**	**6,833.0**
Atlantic croaker	1,127,044.0	$1.94	$3.05	$4.82	2,185.2	3,442.4	5,426.8
Atlantic herring	44.0	$1.94	$3.05	$4.82	0.1	0.1	0.2
Black drum	197.0	$1.94	$3.05	$4.82	0.4	0.6	0.9
Cunner	0.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Scup	1.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Searobin	6.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Silver perch	1.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Smallmouth bass	44.0	$1.94	$3.05	$4.82	0.1	0.1	0.2
Spot	3,453,578.0	$1.94	$3.05	$4.82	6,696.1	10,548.3	16,629.1
Striped mullet	9.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
Tautog	0.0	$1.94	$3.05	$4.82	0.0	0.0	0.0
White perch	21,411.0	$1.94	$3.05	$4.82	41.5	65.4	103.1
Whitefish	328.0	$1.94	$3.05	$4.82	0.6	1.0	1.6
Total (Other Saltwater)	**4,602,664.0**	**$1.94**	**$3.05**	**$4.82**	**8,924.0**	**14,058.0**	**22,162.0**
Total (Unidentified)	**786,704.0**	**$2.00**	**$3.39**	**$6.00**	**1,573.0**	**2,669.0**	**4,721.0**
Total (Undiscounted)	**5,823,189.0**	**.**	**.**	**.**	**11,524.0**	**19,375.0**	**33,793.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**9,665.0**	**16,249.0**	**28,341.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**8,643.0**	**14,531.0**	**25,343.0**
Source: U.S. EPA analysis for this report.							

I.4 South Atlantic Region

Table I-13: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 4 in the South Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Flounders	402.0	$4.05	$5.87	$8.66	2.0	2.0	3.0
Total (Flatfish)	**402.0**	**$4.05**	**$5.87**	**$8.66**	**2.0**	**2.0**	**3.0**
Spotted seatrout	0.0	$2.84	$5.99	$12.59	0.0	0.0	0.0
Weakfish	183.0	$2.84	$5.99	$12.59	1.0	1.0	2.0
Total (Small Game)	**183.0**	**$2.84**	**$5.99**	**$12.59**	**1.0**	**1.0**	**2.0**
Croakers	1,440.0	$2.24	$2.98	$3.95	3.3	4.2	5.7
Pinfish	0.0	$2.24	$2.98	$3.95	0.0	0.0	0.0
Silver perch	39.0	$2.24	$2.98	$3.95	0.1	0.1	0.2
Spot	10,409.0	$2.24	$2.98	$3.95	23.6	30.6	41.2
Total (Other Saltwater)	**11,888.0**	**$2.24**	**$2.98**	**$3.95**	**27.0**	**35.0**	**47.0**
Total (Unidentified)	**510.0**	**$2.25**	**$2.99**	**$3.99**	**1.0**	**2.0**	**2.0**
Total (Undiscounted)	**12,983.0**	**.**	**.**	**.**	**30.0**	**40.0**	**55.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**18.0**	**24.0**	**33.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**13.0**	**17.0**	**23.0**

Source: U.S. EPA analysis for this report.

Table I-14: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under the Final Rule (IM Everywhere) in the South Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Flounders	430.0	$4.05	$5.87	$8.66	2.0	3.0	4.0
Total (Flatfish)	**430.0**	**$4.05**	**$5.87**	**$8.66**	**2.0**	**3.0**	**4.0**
Spotted seatrout	84.0	$2.84	$5.99	$12.59	0.3	0.6	1.2
Weakfish	201.0	$2.84	$5.99	$12.59	0.7	1.4	2.8
Total (Small Game)	**284.0**	**$2.84**	**$5.99**	**$12.59**	**1.0**	**2.0**	**4.0**
Croakers	5,705.0	$2.24	$2.98	$3.95	12.8	17.0	22.6
Pinfish	67.0	$2.24	$2.98	$3.95	0.1	0.2	0.3
Silver perch	42.0	$2.24	$2.98	$3.95	0.1	0.1	0.2
Spot	11,607.0	$2.24	$2.98	$3.95	26.0	34.6	46.0
Total (Other Saltwater)	**17,421.0**	**$2.24**	**$2.98**	**$3.95**	**39.0**	**52.0**	**69.0**
Total (Unidentified)	**589.0**	**$2.25**	**$2.99**	**$3.99**	**1.0**	**2.0**	**2.0**
Total (Undiscounted)	**18,725.0**	**.**	**.**	**.**	**43.0**	**58.0**	**78.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**26.0**	**35.0**	**47.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**18.0**	**24.0**	**33.0**

Source: U.S. EPA analysis for this report.

Table I-15: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 2 in the South Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Flounders	587.0	$4.05	$5.87	$8.66	2.0	3.0	5.0
Total (Flatfish)	**587.0**	**$4.05**	**$5.87**	**$8.66**	**2.0**	**3.0**	**5.0**
Spotted seatrout	1,501.0	$2.84	$5.99	$12.59	4.1	8.9	18.7
Weakfish	347.0	$2.84	$5.99	$12.59	0.9	2.1	4.3
Total (Small Game)	**1,848.0**	**$2.84**	**$5.99**	**$12.59**	**5.0**	**11.0**	**23.0**
Croakers	76,510.0	$2.24	$2.98	$3.95	171.9	228.0	302.2
Pinfish	1,200.0	$2.24	$2.98	$3.95	2.7	3.6	4.7
Silver perch	58.0	$2.24	$2.98	$3.95	0.1	0.2	0.2
Spot	23,237.0	$2.24	$2.98	$3.95	52.2	69.2	91.8
Total (Other Saltwater)	**101,006.0**	**$2.24**	**$2.98**	**$3.95**	**227.0**	**301.0**	**399.0**
Total (Unidentified)	**1,502.0**	**$2.25**	**$2.99**	**$3.99**	**3.0**	**4.0**	**6.0**
Total (Undiscounted)	**104,943.0**	**.**	**.**	**.**	**238.0**	**320.0**	**433.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**129.0**	**173.0**	**234.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**86.0**	**115.0**	**156.0**

Source: U.S. EPA analysis for this report.

Table I-16: Recreational Fishing Benefits from Eliminating Baseline IM&E at Regulated Facilities in the South Atlantic Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Flounders	593.0	$4.05	$5.87	$8.66	2.0	3.0	5.0
Total (Flatfish)	**593.0**	**$4.05**	**$5.87**	**$8.66**	**2.0**	**3.0**	**5.0**
Spotted seatrout	1,604.0	$2.84	$5.99	$12.59	4.9	9.8	20.5
Weakfish	355.0	$2.84	$5.99	$12.59	1.1	2.2	4.5
Total (Small Game)	**1,960.0**	**$2.84**	**$5.99**	**$12.59**	**6.0**	**12.0**	**25.0**
Croakers	81,677.0	$2.24	$2.98	$3.95	183.3	243.6	323.0
Pinfish	1,283.0	$2.24	$2.98	$3.95	2.9	3.8	5.1
Silver perch	58.0	$2.24	$2.98	$3.95	0.1	0.2	0.2
Spot	23,943.0	$2.24	$2.98	$3.95	53.7	71.4	94.7
Total (Other Saltwater)	**106,961.0**	**$2.24**	**$2.98**	**$3.95**	**240.0**	**319.0**	**423.0**
Total (Unidentified)	**1,562.0**	**$2.25**	**$2.99**	**$3.99**	**4.0**	**5.0**	**6.0**
Total (Undiscounted)	**111,075.0**	**.**	**.**	**.**	**251.0**	**338.0**	**459.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**211.0**	**284.0**	**385.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**189.0**	**254.0**	**344.0**

Source: U.S. EPA analysis for this report.

I.5 Gulf of Mexico Region

Table I-17: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 4 in the Gulf of Mexico Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Mackerels	994.0	$3.00	$5.89	$11.55	3.0	5.9	11.5
Red drum	19,500.0	$3.00	$5.89	$11.55	58.6	114.9	225.2
Spotted seatrout	394,780.0	$3.00	$5.89	$11.55	1,185.5	2,325.3	4,558.4
Total (Small Game)	**415,274.0**	**$3.00**	**$5.89**	**$11.55**	**1,247.0**	**2,446.0**	**4,795.0**
Atlantic croaker	153,811.0	$2.23	$2.91	$3.78	343.5	446.7	581.4
Black drum	4,185.0	$2.23	$2.91	$3.78	9.3	12.2	15.8
Pinfish	6,006.0	$2.23	$2.91	$3.78	13.4	17.4	22.7
Sea bass	103.0	$2.23	$2.91	$3.78	0.2	0.3	0.4
Searobin	73,120.0	$2.23	$2.91	$3.78	163.3	212.4	276.4
Sheepshead	1.0	$2.23	$2.91	$3.78	0.0	0.0	0.0
Silver perch	67.0	$2.23	$2.91	$3.78	0.1	0.2	0.3
Spot	21,098.0	$2.23	$2.91	$3.78	47.1	61.3	79.8
Striped mullet	5,350.0	$2.23	$2.91	$3.78	11.9	15.5	20.2
Total (Other Saltwater)	**263,742.0**	**$2.23**	**$2.91**	**$3.78**	**589.0**	**766.0**	**997.0**
Total (Unidentified)	**70,129.0**	**$2.47**	**$3.83**	**$6.18**	**173.0**	**269.0**	**434.0**
Total (Undiscounted)	**749,144.0**	**.**	**.**	**.**	**2,009.0**	**3,481.0**	**6,225.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,260.0**	**2,183.0**	**3,904.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**914.0**	**1,583.0**	**2,831.0**

Source: U.S. EPA analysis for this report.

Table I-18: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under the Final Rule in the Gulf of Mexico Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Mackerels	1,032.0	$3.00	$5.89	$11.55	3.1	6.1	11.9
Red drum	20,239.0	$3.00	$5.89	$11.55	60.8	119.2	233.7
Spotted seatrout	409,748.0	$3.00	$5.89	$11.55	1,230.1	2,413.7	4,731.4
Total (Small Game)	**431,019.0**	**$3.00**	**$5.89**	**$11.55**	**1,294.0**	**2,539.0**	**4,977.0**
Atlantic croaker	159,643.0	$2.23	$2.91	$3.78	356.4	463.7	603.1
Black drum	4,295.0	$2.23	$2.91	$3.78	9.6	12.5	16.2
Pinfish	6,226.0	$2.23	$2.91	$3.78	13.9	18.1	23.5
Sea bass	107.0	$2.23	$2.91	$3.78	0.2	0.3	0.4
Searobin	75,892.0	$2.23	$2.91	$3.78	169.4	220.5	286.7
Sheepshead	1.0	$2.23	$2.91	$3.78	0.0	0.0	0.0
Silver perch	70.0	$2.23	$2.91	$3.78	0.2	0.2	0.3
Spot	21,898.0	$2.23	$2.91	$3.78	48.9	63.6	82.7
Striped mullet	5,552.0	$2.23	$2.91	$3.78	12.4	16.1	21.0
Total (Other Saltwater)	**273,683.0**	**$2.23**	**$2.91**	**$3.78**	**611.0**	**795.0**	**1,034.0**
Total (Unidentified)	**72,787.0**	**$2.47**	**$3.83**	**$6.18**	**180.0**	**279.0**	**450.0**
Total (Undiscounted)	**777,488.0**	**.**	**.**	**.**	**2,085.0**	**3,613.0**	**6,461.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**1,308.0**	**2,265.0**	**4,051.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**948.0**	**1,643.0**	**2,938.0**

Source: U.S. EPA analysis for this report.

Table I-19: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 2 in the Gulf of Mexico Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Mackerels	1,237.0	$3.00	$5.89	$11.55	3.7	7.3	14.3
Red drum	26,734.0	$3.00	$5.89	$11.55	80.3	157.5	308.7
Spotted seatrout	524,007.0	$3.00	$5.89	$11.55	1,573.0	3,086.3	6,050.1
Total (Small Game)	**551,978.0**	**$3.00**	**$5.89**	**$11.55**	**1,657.0**	**3,251.0**	**6,373.0**
Atlantic croaker	191,598.0	$2.23	$2.91	$3.78	428.1	556.8	723.9
Black drum	941,083.0	$2.23	$2.91	$3.78	2,102.6	2,734.6	3,555.8
Pinfish	160,133.0	$2.23	$2.91	$3.78	357.8	465.3	605.0
Sea bass	128.0	$2.23	$2.91	$3.78	0.3	0.4	0.5
Searobin	111,200.0	$2.23	$2.91	$3.78	248.4	323.1	420.2
Sheepshead	28.0	$2.23	$2.91	$3.78	0.1	0.1	0.1
Silver perch	933.0	$2.23	$2.91	$3.78	2.1	2.7	3.5
Spot	29,782.0	$2.23	$2.91	$3.78	66.5	86.5	112.5
Striped mullet	33,192.0	$2.23	$2.91	$3.78	74.2	96.5	125.4
Total (Other Saltwater)	**1,468,076.0**	**$2.23**	**$2.91**	**$3.78**	**3,280.0**	**4,266.0**	**5,547.0**
Total (Unidentified)	**117,807.0**	**$2.47**	**$3.83**	**$6.18**	**291.0**	**451.0**	**729.0**
Total (Undiscounted)	**2,137,861.0**	**.**	**.**	**.**	**5,228.0**	**7,968.0**	**12,649.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**3,357.0**	**5,116.0**	**8,122.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**2,476.0**	**3,774.0**	**5,991.0**

Source: U.S. EPA analysis for this report.

Table I-20: Recreational Fishing Benefits from Eliminating Baseline IM&E at Regulated Facilities in the Gulf of Mexico Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Mackerels	1,374.0	$3.00	$5.89	$11.55	4.1	8.1	15.9
Red drum	31,114.0	$3.00	$5.89	$11.55	93.4	183.2	359.3
Spotted seatrout	600,729.0	$3.00	$5.89	$11.55	1,803.5	3,537.7	6,936.8
Total (Small Game)	**633,217.0**	**$3.00**	**$5.89**	**$11.55**	**1,901.0**	**3,729.0**	**7,312.0**
Atlantic croaker	212,766.0	$2.23	$2.91	$3.78	475.3	618.2	804.0
Black drum	1,591,629.0	$2.23	$2.91	$3.78	3,555.8	4,624.9	6,014.2
Pinfish	266,978.0	$2.23	$2.91	$3.78	596.5	775.8	1,008.8
Sea bass	142.0	$2.23	$2.91	$3.78	0.3	0.4	0.5
Searobin	135,234.0	$2.23	$2.91	$3.78	302.1	393.0	511.0
Sheepshead	47.0	$2.23	$2.91	$3.78	0.1	0.1	0.2
Silver perch	1,532.0	$2.23	$2.91	$3.78	3.4	4.5	5.8
Spot	35,116.0	$2.23	$2.91	$3.78	78.5	102.0	132.7
Striped mullet	52,351.0	$2.23	$2.91	$3.78	117.0	152.1	197.8
Total (Other Saltwater)	**2,295,795.0**	**$2.23**	**$2.91**	**$3.78**	**5,129.0**	**6,671.0**	**8,675.0**
Total (Unidentified)	**148,605.0**	**$2.47**	**$3.83**	**$6.18**	**367.0**	**569.0**	**919.0**
Total (Undiscounted)	**3,077,617.0**	**.**	**.**	**.**	**7,397.0**	**10,969.0**	**16,905.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**6,457.0**	**9,575.0**	**14,756.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**5,955.0**	**8,831.0**	**13,610.0**

Source: U.S. EPA analysis for this report.

I.6 Great Lakes Region

Table I-21: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 4 in the Great Lakes Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	2,314.0	$4.63	$8.95	$17.38	16.7	8,870.0	17,216.0
White bass	632,325.0	$4.63	$8.95	$17.38	4,567.3	8,870.0	17,216.0
Total (Bass)	**634,639.0**	**$4.63**	**$8.95**	**$17.38**	**4,584.0**	**8,870.0**	**17,216.0**
Whitefish	40,464.0	$6.39	$9.87	$15.34	332.0	514.0	799.0
Total (Other Trout)	**40,464.0**	**$6.39**	**$9.87**	**$15.34**	**332.0**	**514.0**	**799.0**
Black crappie	107.0	$0.73	$1.39	$2.61	0.3	0.5	1.0
Bluegill	1,010.0	$0.73	$1.39	$2.61	2.6	4.9	9.2
Channel catfish	12,995.0	$0.73	$1.39	$2.61	32.9	62.7	117.9
Crappie	321.0	$0.73	$1.39	$2.61	0.8	1.5	2.9
Rainbow smelt	4,722.0	$0.73	$1.39	$2.61	12.0	22.8	42.8
Sculpin	197.0	$0.73	$1.39	$2.61	0.5	1.0	1.8
Smelts	8,453.0	$0.73	$1.39	$2.61	21.4	40.8	76.7
Sunfish	676.0	$0.73	$1.39	$2.61	1.7	3.3	6.1
Yellow perch	29,926.0	$0.73	$1.39	$2.61	75.8	144.5	271.6
Total (Panfish)	**58,408.0**	**$0.73**	**$1.39**	**$2.61**	**148.0**	**282.0**	**530.0**
Salmon	609.0	$8.53	$13.88	$22.61	8.0	14.0	22.0
Total (Salmon)	**609.0**	**$8.53**	**$13.88**	**$22.61**	**8.0**	**14.0**	**22.0**
Northern Pike	3.0	$2.28	$4.30	$8.16	0.0	0.0	0.0
Walleye	18,082.0	$2.28	$4.30	$8.16	264.0	497.9	945.8
Total (Walleye/Pike)	**18,085.0**	**$2.28**	**$4.30**	**$8.16**	**264.0**	**498.0**	**946.0**
Total (Unidentified)	**579,751.0**	**$3.49**	**$6.51**	**$12.25**	**3,032.0**	**5,661.0**	**10,661.0**
Total (Undiscounted)	**1,331,956.0**	**.**	**.**	**.**	**8,370.0**	**15,838.0**	**30,174.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**7,306.0**	**13,825.0**	**26,338.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**6,738.0**	**12,751.0**	**24,292.0**

Source: U.S. EPA analysis for this report.

Table I-22: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under the Final Rule in the Great Lakes Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	2,546.0	$4.63	$8.95	$17.38	11.8	6,257.0	12,144.0
White bass	696,159.0	$4.63	$8.95	$17.38	3,222.2	6,257.0	12,144.0
Total (Bass)	**698,705.0**	**$4.63**	**$8.95**	**$17.38**	**3,234.0**	**6,257.0**	**12,144.0**
Whitefish	44,532.0	$6.39	$9.87	$15.34	284.0	440.0	683.0
Total (Other Trout)	**44,532.0**	**$6.39**	**$9.87**	**$15.34**	**284.0**	**440.0**	**683.0**
Black crappie	118.0	$0.73	$1.39	$2.61	0.1	0.2	0.3
Bluegill	1,112.0	$0.73	$1.39	$2.61	0.8	1.6	2.9
Channel catfish	14,302.0	$0.73	$1.39	$2.61	10.4	20.0	37.3
Crappie	362.0	$0.73	$1.39	$2.61	0.3	0.5	0.9
Rainbow smelt	5,347.0	$0.73	$1.39	$2.61	3.9	7.5	13.9
Sculpin	224.0	$0.73	$1.39	$2.61	0.2	0.3	0.6
Smelts	9,303.0	$0.73	$1.39	$2.61	6.8	13.0	24.2
Sunfish	766.0	$0.73	$1.39	$2.61	0.6	1.1	2.0
Yellow perch	32,942.0	$0.73	$1.39	$2.61	24.0	46.0	85.8
Total (Panfish)	**64,475.0**	**$0.73**	**$1.39**	**$2.61**	**47.0**	**90.0**	**168.0**
Salmon	671.0	$8.53	$13.88	$22.61	6.0	9.0	15.0
Total (Salmon)	**671.0**	**$8.53**	**$13.88**	**$22.61**	**6.0**	**9.0**	**15.0**
Northern Pike	3.0	$2.28	$4.30	$8.16	0.0	0.0	0.0
Walleye	20,041.0	$2.28	$4.30	$8.16	46.0	86.0	164.0
Total (Walleye/Pike)	**20,044.0**	**$2.28**	**$4.30**	**$8.16**	**46.0**	**86.0**	**164.0**
Total (Unidentified)	**638,223.0**	**$3.49**	**$6.51**	**$12.25**	**2,224.0**	**4,153.0**	**7,821.0**
Total (Undiscounted)	**1,466,650.0**	**.**	**.**	**.**	**5,841.0**	**11,034.0**	**20,995.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**3,793.0**	**7,166.0**	**13,636.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**2,820.0**	**5,328.0**	**10,138.0**

Source: U.S. EPA analysis for this report.

Table I-23: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 2 in the Great Lakes Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	2,902.0	$4.63	$8.95	$17.38	13.4	8,250.0	16,013.0
White bass	918,361.0	$4.63	$8.95	$17.38	4,250.6	8,250.0	16,013.0
Total (Bass)	**921,263.0**	**$4.63**	**$8.95**	**$17.38**	**4,264.0**	**8,250.0**	**16,013.0**
Whitefish	50,757.0	$6.39	$9.87	$15.34	324.0	501.0	779.0
Total (Other Trout)	**50,757.0**	**$6.39**	**$9.87**	**$15.34**	**324.0**	**501.0**	**779.0**
Black crappie	135.0	$0.73	$1.39	$2.61	0.1	0.2	0.4
Bluegill	1,334.0	$0.73	$1.39	$2.61	1.0	1.8	3.5
Channel catfish	16,552.0	$0.73	$1.39	$2.61	12.1	22.9	43.3
Crappie	4,373.0	$0.73	$1.39	$2.61	3.2	6.1	11.4
Rainbow smelt	76,779.0	$0.73	$1.39	$2.61	56.2	106.4	200.7
Sculpin	3,489.0	$0.73	$1.39	$2.61	2.6	4.8	9.1
Smelts	10,636.0	$0.73	$1.39	$2.61	7.8	14.7	27.8
Sunfish	10,788.0	$0.73	$1.39	$2.61	7.9	15.0	28.2
Yellow perch	41,148.0	$0.73	$1.39	$2.61	30.1	57.0	107.6
Total (Panfish)	**165,234.0**	**$0.73**	**$1.39**	**$2.61**	**121.0**	**229.0**	**432.0**
Salmon	910.0	$8.53	$13.88	$22.61	8.0	13.0	21.0
Total (Salmon)	**910.0**	**$8.53**	**$13.88**	**$22.61**	**8.0**	**13.0**	**21.0**
Northern Pike	5.0	$2.28	$4.30	$8.16	0.0	0.0	0.0
Walleye	89,320.0	$2.28	$4.30	$8.16	204.0	384.0	729.0
Total (Walleye/Pike)	**89,325.0**	**$2.28**	**$4.30**	**$8.16**	**204.0**	**384.0**	**729.0**
Total (Unidentified)	**816,530.0**	**$3.49**	**$6.51**	**$12.25**	**2,846.0**	**5,313.0**	**10,006.0**
Total (Undiscounted)	**2,044,018.0**	**.**	**.**	**.**	**7,766.0**	**14,690.0**	**27,978.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**4,717.0**	**8,922.0**	**16,993.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**3,359.0**	**6,354.0**	**12,102.0**

Source: U.S. EPA analysis for this report.

Table I-24: Recreational Fishing Benefits from Eliminating Baseline IM&E at Regulated Facilities in the Great Lakes Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	2,976.0	$4.63	$8.95	$17.38	13.8	8,870.0	17,216.0
White bass	987,522.0	$4.63	$8.95	$17.38	4,570.2	8,870.0	17,216.0
Total (Bass)	**990,498.0**	**$4.63**	**$8.95**	**$17.38**	**4,584.0**	**8,870.0**	**17,216.0**
Whitefish	52,059.0	$6.39	$9.87	$15.34	332.0	514.0	799.0
Total (Other Trout)	**52,059.0**	**$6.39**	**$9.87**	**$15.34**	**332.0**	**514.0**	**799.0**
Black crappie	138.0	$0.73	$1.39	$2.61	0.1	0.2	0.4
Bluegill	1,393.0	$0.73	$1.39	$2.61	1.0	1.9	3.6
Channel catfish	17,068.0	$0.73	$1.39	$2.61	12.4	23.7	44.6
Crappie	5,932.0	$0.73	$1.39	$2.61	4.3	8.2	15.5
Rainbow smelt	104,556.0	$0.73	$1.39	$2.61	76.2	145.3	273.0
Sculpin	4,759.0	$0.73	$1.39	$2.61	3.5	6.6	12.4
Smelts	10,921.0	$0.73	$1.39	$2.61	8.0	15.2	28.5
Sunfish	14,686.0	$0.73	$1.39	$2.61	10.7	20.4	38.3
Yellow perch	43,518.0	$0.73	$1.39	$2.61	31.7	60.5	113.6
Total (Panfish)	**202,970.0**	**$0.73**	**$1.39**	**$2.61**	**148.0**	**282.0**	**530.0**
Salmon	986.0	$8.53	$13.88	$22.61	8.0	14.0	22.0
Total (Salmon)	**986.0**	**$8.53**	**$13.88**	**$22.61**	**8.0**	**14.0**	**22.0**
Northern Pike	5.0	$2.28	$4.30	$8.16	0.0	0.0	0.0
Walleye	115,883.0	$2.28	$4.30	$8.16	264.0	498.0	946.0
Total (Walleye/Pike)	**115,889.0**	**$2.28**	**$4.30**	**$8.16**	**264.0**	**498.0**	**946.0**
Total (Unidentified)	**870,008.0**	**$3.49**	**$6.51**	**$12.25**	**3,032.0**	**5,661.0**	**10,661.0**
Total (Undiscounted)	**2,232,409.0**	**.**	**.**	**.**	**8,370.0**	**15,838.0**	**30,174.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**7,306.0**	**13,825.0**	**26,338.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**6,738.0**	**12,751.0**	**24,292.0**

Source: U.S. EPA analysis for this report.

I.7 Inland Region

Table I-25: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 4 in the Inland Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	8,142.0	$4.48	$9.43	$19.96	36.5	76.8	162.5
White bass	537,712.0	$4.48	$9.43	$19.96	2,410.5	5,070.2	10,731.5
Total (Bass)	**545,853.0**	**$4.48**	**$9.43**	**$19.96**	**2,447.0**	**5,147.0**	**10,894.0**
Whitefish	1,355.0	$1.59	$2.96	$5.53	2.0	4.0	7.0
Total (Other Trout)	**1,355.0**	**$1.59**	**$2.96**	**$5.53**	**2.0**	**4.0**	**7.0**
Black bullhead	20,797.0	$0.55	$1.11	$2.20	11.5	23.0	45.8
Black crappie	11,790.0	$0.55	$1.11	$2.20	6.5	13.0	25.9
Bluegill	276,051.0	$0.55	$1.11	$2.20	152.5	305.3	607.4
Brown bullhead	3,953.0	$0.55	$1.11	$2.20	2.2	4.4	8.7
Bullhead	2,682.0	$0.55	$1.11	$2.20	1.5	3.0	5.9
Channel catfish	188,768.0	$0.55	$1.11	$2.20	104.3	208.8	415.4
Crappie	20,410.0	$0.55	$1.11	$2.20	11.3	22.6	44.9
Menhaden	213.0	$0.55	$1.11	$2.20	0.1	0.2	0.5
Rainbow smelt	2,565.0	$0.55	$1.11	$2.20	1.4	2.8	5.6
Smelts	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Sunfish	161,748.0	$0.55	$1.11	$2.20	89.4	178.9	355.9
White Perch	3,360.0	$0.55	$1.11	$2.20	1.9	3.7	7.4
Yellow perch	247,054.0	$0.55	$1.11	$2.20	136.5	273.3	543.6
Total (Panfish)	**939,390.0**	**$0.55**	**$1.11**	**$2.20**	**519.0**	**1,039.0**	**2,067.0**
Salmon	4.0	$8.53	$13.88	$22.61	0.0	0.0	0.0
Total (Salmon)	**4.0**	**$8.53**	**$13.88**	**$22.61**	**0.0**	**0.0**	**0.0**
American shad	2,122.0	$1.68	$5.61	$18.90	3.6	11.8	40.2
Striped bass	13,681.0	$1.68	$5.61	$18.90	23.1	76.3	258.9
Sturgeon	154.0	$1.68	$5.61	$18.90	0.3	0.9	2.9
Total (Small Game)	**15,957.0**	**$1.68**	**$5.61**	**$18.90**	**27.0**	**89.0**	**302.0**
Northern pike	25.0	$2.07	$4.29	$8.92	0.1	0.1	0.2
Sauger	6,672.0	$2.07	$4.29	$8.92	13.9	28.5	59.6
Walleye	11,116.0	$2.07	$4.29	$8.92	23.1	47.4	99.2
Total (Walleye/Pike)	**17,812.0**	**$2.07**	**$4.29**	**$8.92**	**37.0**	**76.0**	**159.0**
Total (Unidentified)	**2,049,682.0**	**$1.13**	**$2.33**	**$4.81**	**2,325.0**	**4,784.0**	**9,865.0**
Total (Undiscounted)	**3,570,053.0**	**.**	**.**	**.**	**5,357.0**	**11,140.0**	**23,295.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**3,503.0**	**7,284.0**	**15,231.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**2,616.0**	**5,440.0**	**11,375.0**

Source: U.S. EPA analysis for this report.

Table I-26: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under the Final Rule in the Inland Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	9,392.0	$4.48	$9.43	$19.96	42.1	88.6	187.4
White bass	560,751.0	$4.48	$9.43	$19.96	2,513.9	5,287.5	11,191.6
Total (Bass)	**570,143.0**	**$4.48**	**$9.43**	**$19.96**	**2,556.0**	**5,376.0**	**11,379.0**
Whitefish	1,401.0	$1.59	$2.96	$5.53	2.0	4.0	8.0
Total (Other Trout)	**1,401.0**	**$1.59**	**$2.96**	**$5.53**	**2.0**	**4.0**	**8.0**
Black bullhead	21,509.0	$0.55	$1.11	$2.20	11.9	23.8	47.3
Black crappie	12,888.0	$0.55	$1.11	$2.20	7.1	14.2	28.4
Bluegill	285,614.0	$0.55	$1.11	$2.20	158.0	315.7	628.4
Brown bullhead	4,136.0	$0.55	$1.11	$2.20	2.3	4.6	9.1
Bullhead	2,781.0	$0.55	$1.11	$2.20	1.5	3.1	6.1
Channel catfish	196,096.0	$0.55	$1.11	$2.20	108.5	216.7	431.5
Crappie	23,044.0	$0.55	$1.11	$2.20	12.7	25.5	50.7
Menhaden	220.0	$0.55	$1.11	$2.20	0.1	0.2	0.5
Rainbow smelt	2,683.0	$0.55	$1.11	$2.20	1.5	3.0	5.9
Smelts	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Sunfish	174,183.0	$0.55	$1.11	$2.20	96.3	192.5	383.2
White Perch	3,477.0	$0.55	$1.11	$2.20	1.9	3.8	7.7
Yellow perch	256,905.0	$0.55	$1.11	$2.20	142.1	283.9	565.2
Total (Panfish)	**983,538.0**	**$0.55**	**$1.11**	**$2.20**	**544.0**	**1,087.0**	**2,164.0**
Salmon	4.0	$8.53	$13.88	$22.61	0.0	0.0	0.0
Total (Salmon)	**4.0**	**$8.53**	**$13.88**	**$22.61**	**0.0**	**0.0**	**0.0**
American shad	2,194.0	$1.68	$5.61	$18.90	3.7	12.4	41.5
Striped bass	14,146.0	$1.68	$5.61	$18.90	24.0	79.7	267.4
Sturgeon	167.0	$1.68	$5.61	$18.90	0.3	0.9	3.2
Total (Small Game)	**16,507.0**	**$1.68**	**$5.61**	**$18.90**	**28.0**	**93.0**	**312.0**
Northern pike	26.0	$2.07	$4.29	$8.92	0.1	0.1	0.2
Sauger	7,825.0	$2.07	$4.29	$8.92	16.1	33.8	69.8
Walleye	12,546.0	$2.07	$4.29	$8.92	25.8	54.1	112.0
Total (Walleye/Pike)	**20,396.0**	**$2.07**	**$4.29**	**$8.92**	**42.0**	**88.0**	**182.0**
Total (Unidentified)	**2,139,619.0**	**$1.13**	**$2.33**	**$4.81**	**2,427.0**	**4,994.0**	**10,298.0**
Total (Undiscounted)	**3,731,608.0**	**.**	**.**	**.**	**5,599.0**	**11,642.0**	**24,343.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**3,661.0**	**7,613.0**	**15,918.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**2,735.0**	**5,686.0**	**11,889.0**

Source: U.S. EPA analysis for this report.

Table I-27: Recreational Fishing Benefits from Reducing IM&E at Regulated Facilities under Proposal Option 2 in the Inland Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	141,379.0	$4.48	$9.43	$19.96	633.7	633.7	633.7
White bass	1,286,644.0	$4.48	$9.43	$19.96	5,767.3	12,132.1	5,767.3
Total (Bass)	**1,428,023.0**	**$4.48**	**$9.43**	**$19.96**	**6,401.0**	**6,401.0**	**6,401.0**
Whitefish	1,688.0	$1.59	$2.96	$5.53	3.0	3.0	3.0
Total (Other Trout)	**1,688.0**	**$1.59**	**$2.96**	**$5.53**	**3.0**	**3.0**	**3.0**
Black bullhead	25,487.0	$0.55	$1.11	$2.20	14.1	14.1	14.1
Black crappie	108,409.0	$0.55	$1.11	$2.20	59.9	59.9	59.9
Bluegill	354,207.0	$0.55	$1.11	$2.20	195.8	195.8	195.8
Brown bullhead	11,390.0	$0.55	$1.11	$2.20	6.3	6.3	6.3
Bullhead	4,307.0	$0.55	$1.11	$2.20	2.4	2.4	2.4
Channel catfish	348,937.0	$0.55	$1.11	$2.20	192.9	192.9	192.9
Crappie	286,830.0	$0.55	$1.11	$2.20	158.6	158.6	158.6
Menhaden	254.0	$0.55	$1.11	$2.20	0.1	0.1	0.1
Rainbow smelt	7,121.0	$0.55	$1.11	$2.20	3.9	3.9	3.9
Smelts	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Sunfish	1,131,661.0	$0.55	$1.11	$2.20	625.6	625.6	625.6
White Perch	4,461.0	$0.55	$1.11	$2.20	2.5	2.5	2.5
Yellow perch	491,893.0	$0.55	$1.11	$2.20	271.9	271.9	271.9
Total (Panfish)	**2,774,958.0**	**$0.55**	**$1.11**	**$2.20**	**1,534.0**	**1,534.0**	**1,534.0**
Salmon	4.0	$8.53	$13.88	$22.61	0.0	0.0	0.0
Total (Salmon)	**4.0**	**$8.53**	**$13.88**	**$22.61**	**0.0**	**0.0**	**0.0**
American shad	2,531.0	$1.68	$5.61	$18.90	4.3	14.2	47.9
Striped bass	16,318.0	$1.68	$5.61	$18.90	27.5	91.5	308.7
Sturgeon	1,294.0	$1.68	$5.61	$18.90	2.2	7.3	24.5
Total (Small Game)	**20,143.0**	**$1.68**	**$5.61**	**$18.90**	**34.0**	**113.0**	**381.0**
Northern pike	29.0	$2.07	$4.29	$8.92	0.1	0.1	0.3
Sauger	133,280.0	$2.07	$4.29	$8.92	276.3	572.0	1,188.8
Walleye	155,606.0	$2.07	$4.29	$8.92	322.6	667.8	1,387.9
Total (Walleye/Pike)	**288,916.0**	**$2.07**	**$4.29**	**$8.92**	**599.0**	**1,240.0**	**2,577.0**
Total (Unidentified)	**5,190,603.0**	**$1.13**	**$2.33**	**$4.81**	**5,889.0**	**12,116.0**	**24,981.0**
Total (Undiscounted)	**9,704,334.0**	**.**	**.**	**.**	**14,459.0**	**30,007.0**	**62,557.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**8,290.0**	**17,204.0**	**35,865.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**5,726.0**	**11,883.0**	**24,773.0**

Source: U.S. EPA analysis for this report.

Table I-28: Recreational Fishing Benefits from Eliminating Baseline IM&E at Regulated Facilities in the Inland Region, by Species (2011$)

Species	Annual Increase in Recreational Harvest (harvestable adult fish)	Value per Fish			Annual Benefits from Increase in Recreational Harvest (2011$, thousands)		
		5th	Mean	95th	5th	Mean	95th
Smallmouth bass	180,693.0	$4.48	$9.43	$19.96	810.0	1,703.8	3,606.4
White bass	1,567,058.0	$4.48	$9.43	$19.96	7,025.0	14,776.2	31,276.6
Total (Bass)	**1,747,751.0**	**$4.48**	**$9.43**	**$19.96**	**7,835.0**	**16,480.0**	**34,883.0**
Whitefish	1,947.0	$1.59	$2.96	$5.53	3.0	6.0	11.0
Total (Other Trout)	**1,947.0**	**$1.59**	**$2.96**	**$5.53**	**3.0**	**6.0**	**11.0**
Black bullhead	29,349.0	$0.55	$1.11	$2.20	16.2	32.4	64.6
Black crappie	137,629.0	$0.55	$1.11	$2.20	76.1	152.2	302.9
Bluegill	410,040.0	$0.55	$1.11	$2.20	226.7	453.3	902.4
Brown bullhead	14,007.0	$0.55	$1.11	$2.20	7.7	15.5	30.8
Bullhead	5,099.0	$0.55	$1.11	$2.20	2.8	5.6	11.2
Channel catfish	417,819.0	$0.55	$1.11	$2.20	231.0	461.9	919.5
Crappie	365,941.0	$0.55	$1.11	$2.20	202.3	404.6	805.4
Menhaden	291.0	$0.55	$1.11	$2.20	0.2	0.3	0.6
Rainbow smelt	8,741.0	$0.55	$1.11	$2.20	4.8	9.7	19.2
Smelts	1.0	$0.55	$1.11	$2.20	0.0	0.0	0.0
Sunfish	1,430,230.0	$0.55	$1.11	$2.20	790.8	1,581.1	3,147.6
White Perch	5,183.0	$0.55	$1.11	$2.20	2.9	5.7	11.4
Yellow perch	592,175.0	$0.55	$1.11	$2.20	327.4	654.7	1,303.3
Total (Panfish)	**3,416,505.0**	**$0.55**	**$1.11**	**$2.20**	**1,889.0**	**3,777.0**	**7,519.0**
Salmon	5.0	$8.53	$13.88	$22.61	0.0	0.0	0.0
Total (Salmon)	**5.0**	**$8.53**	**$13.88**	**$22.61**	**0.0**	**0.0**	**0.0**
American shad	2,905.0	$1.68	$5.61	$18.90	4.9	16.2	54.9
Striped bass	18,729.0	$1.68	$5.61	$18.90	31.4	104.6	354.1
Sturgeon	1,640.0	$1.68	$5.61	$18.90	2.7	9.2	31.0
Total (Small Game)	**23,274.0**	**$1.68**	**$5.61**	**$18.90**	**39.0**	**130.0**	**440.0**
Northern pike	34.0	$2.07	$4.29	$8.92	0.1	0.1	0.3
Sauger	170,509.0	$2.07	$4.29	$8.92	353.4	731.8	1,520.9
Walleye	198,517.0	$2.07	$4.29	$8.92	411.5	852.0	1,770.8
Total (Walleye/Pike)	**369,060.0**	**$2.07**	**$4.29**	**$8.92**	**765.0**	**1,584.0**	**3,292.0**
Total (Unidentified)	**6,341,808.0**	**$1.13**	**$2.33**	**$4.81**	**7,195.0**	**14,803.0**	**30,522.0**
Total (Undiscounted)	**11,900,351.0**	**.**	**.**	**.**	**17,725.0**	**36,781.0**	**76,666.0**
Total (3% discount rate)	**.**	**.**	**.**	**.**	**15,471.0**	**32,105.0**	**66,919.0**
Total (7% discount rate)	**.**	**.**	**.**	**.**	**14,270.0**	**29,611.0**	**61,722.0**

Source: U.S. EPA analysis for this report.