**US Environmental Protection Agency**
**Office of Pesticide Programs**

# Risks of Atrazine Use to Federally Listed Endangered Pallid Sturgeon
(*Scaphirhynchus albus*)

**Pesticide Effects Determination**
**August 31, 2007**

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**Environmental Fate and Effects Division**
**Office of Pesticide Programs**
**Washington, D.C.  20460**

**August 31, 2007**

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## 1. Executive Summary

The purpose of this assessment is to make an "effects determination" for the pallid sturgeon (*Scaphirhynchus albus*) by evaluating the potential direct and indirect effects of the herbicide atrazine on the survival, growth, and reproduction of this Federally endangered species. This assessment was completed in accordance with the U.S. EPA's *Guidance for Ecological Risk Assessment* (U.S. EPA, 1998), and the Services' *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998), and is consistent with procedures and methodology outlined in the Overview Document (U.S. EPA, 2004) and reviewed by the U.S. Fish and Wildlife Service and National Marine Fisheries Service (USFWS/NMFS, 2004).

Atrazine is used throughout the United States on a number of agricultural commodities (primarily corn, sorghum, and sugarcane) and on non-agricultural sites (including residential uses, forestry, and turf). Although the action area is likely to encompass a large area of the United States, given atrazine's use, the scope of this assessment limits consideration of the overall action area to those portions that are applicable to the protection of the pallid sturgeon. Specifically, the pallid sturgeon is found in the Mississippi and Missouri Rivers and a few tributaries of these two major rivers (including the Atchafalaya River in Louisiana). The action area includes the entire watershed of rivers in the areas defined above. In general, the pallid sturgeon resides in large, turbid, free-flowing rivers of $8^{th}$ order or higher.

Environmental fate and transport models were used to estimate high-end exposure values as a result of agricultural and non-agricultural atrazine use in accordance with label directions. Modeling was initially performed using the Agency's standard ecological water body, which does not account for flow or dilution due to input from less contaminated sources. The non-flowing nature of the standard water body provides a reasonable estimation of peak exposures for many smaller headwater streams found in agricultural areas; however, it appears to overestimate exposures for longer time periods and for flowing water bodies. Exposure concentrations based on the standard ecological water body are likely to overestimate exposure for the pallid sturgeon because this species requires strong currents and turbid water in main channel habitats of large rivers, including the Missouri, Mississippi, and Atchafalaya Rivers, where the potential for dilution is expected to be high. Therefore, additional flow-adjusted modeling was used together with available monitoring data to refine atrazine exposures in flowing waters.

A robust set of surface water monitoring data exists for atrazine. Because of the species' habitat requirements (i.e., large turbid rivers with high volume and fast flow), the U.S. Geological Survey (USGS) National Stream Quality Accounting Network (NASQAN) monitoring data for selected big river basins in the United States were considered most directly relevant to the pallid sturgeon. Other sources of monitoring information, including data from the recently registrant-submitted Ecological Monitoring Program, USGS NAWQA program, and Louisiana Department of Environmental Quality (LDEQ) were also considered; however, they were not considered appropriate for the pallid sturgeon because the samples were collected from smaller order streams where the species does not occur. In general, the refined flow-adjusted modeling and the available monitoring data provide a reasonable estimate of exposures that is representative of the larger rivers where the pallid sturgeon resides.

The assessment endpoints for the pallid sturgeon include direct toxic effects on the survival, reproduction, and growth of the sturgeon itself, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. Direct effects to the pallid sturgeon are based on toxicity information for freshwater fish. Given that the sturgeon's prey items and habitat requirements are dependent on the availability of freshwater fish and aquatic invertebrates, aquatic plants, and terrestrial plants (i.e., riparian habitat), toxicity information for these taxonomic groups is also discussed. In addition to the registrant-submitted and open literature toxicity information, indirect effects to the pallid sturgeon, via impacts to aquatic plant community structure and function, are also evaluated based on time-weighted threshold concentrations that correspond to potential aquatic plant community-level effects.

Degradates of atrazine include hydroxyatrazine (HA), deethylatrazine (DEA), deisopropylatrazine (DIA), and diaminochloroatrazine (DACT). Comparison of available toxicity information for the degradates of atrazine indicates lesser aquatic toxicity than the parent for freshwater and estuarine/marine fish, aquatic invertebrates, and aquatic plants. Although degradate toxicity data are not available for terrestrial plants, lesser toxicity is assumed, given the available ecotoxicological information for other taxonomic groups including aquatic plants and the likelihood that the degradates of atrazine may lose efficacy as an herbicide. Because degradates are not of greater toxicological concern than atrazine, concentrations of the atrazine degradates are not assessed further, and the focus of this assessment is parent atrazine.

Risk quotients (RQs) are derived as quantitative estimates of potential high-end risk. Acute and chronic RQs are compared to the Agency's levels of concern (LOCs) to identify instances where atrazine use within the action area has the potential to adversely affect the pallid sturgeon via direct toxicity or indirectly based on direct effects to its food supply (i.e., freshwater fish and invertebrates) or habitat (i.e., aquatic plants and terrestrial riparian vegetation). When RQs for a particular type of effect are below LOCs, the pesticide is determined to have "no effect" on the subject species. Where RQs exceed LOCs, a potential to cause adverse effects is identified, leading to a conclusion of "may affect." If a determination is made that use of atrazine within the action area "may affect" the pallid sturgeon, additional information is considered to refine the potential for exposure and effects, and the best available information is used to distinguish those actions that "may affect, but are not likely to adversely affect" (NLAA) from those actions that are "likely to adversely affect" (LAA) the pallid sturgeon.

The best available data suggest that atrazine is not likely to adversely affect the pallid sturgeon by direct toxic effects or by indirect effects resulting from effects to aquatic plants and aquatic animals. An "LAA" determination was concluded for the pallid sturgeon based on indirect effects to habitat and water quality via direct effects to herbaceous/grassy riparian vegetation. However, atrazine is not likely to adversely affect the pallid sturgeon in watersheds with predominantly forested riparian areas because woody shrubs and trees are generally not sensitive to environmentally-relevant concentrations of atrazine. A summary of the risk conclusions and effects determination for the pallid sturgeon is presented in Table 1.1. Further information on the results of the effects determination is included as part of the Risk Description in Section 5.2.

**Table 1.1 Effects Determination Summary for the Pallid Sturgeon**

| Assessment Endpoint | Effects Determination | Basis for Determination |
|---|---|---|
| 1. Survival, growth, and reproduction of pallid sturgeon individuals via direct effects | May affect, but not likely to adversely affect (NLAA) | Acute and chronic LOCs are exceeded based on screening-level EECs from the non-flowing standard water body. However, flow-adjusted EECs and detected concentrations of atrazine in available monitoring data are less than those shown to cause adverse acute and chronic effects in freshwater fish. This finding is based on discountable effects (i.e., acute and chronic effects to atrazine at refined levels of exposure are not likely to result in a "take" of a single listed pallid sturgeon). |
| 2. Indirect effects to the pallid sturgeon via reduction of prey (i.e., freshwater fish and invertebrates) | May affect, but not likely to adversely affect (NLAA) | Fish: Although acute and chronic LOCs are exceeded for freshwater fish for some uses (based on screening-level EECs), consideration of flow-adjusted EECs and available monitoring data indicate that refined exposure concentrations are not of concern for freshwater fish (see effects determination for assessment endpoint #1).<br><br>Invertebrates:<br><br>**Acute effects:** Atrazine may affect sensitive food items, such as the midge; however, the low probability (<0.05 percent) of an individual effect to the midge is not likely to indirectly affect the pallid sturgeon, given the wide range of other types of freshwater invertebrates that the species consumes. Based on the non-selective feeding behavior in the pallid sturgeon, the low magnitude of anticipated acute individual effects to aquatic invertebrate prey species, and available monitoring data, atrazine is not likely to indirectly affect the pallid sturgeon via reduction in freshwater invertebrate food items. This finding is based on discountable (i.e., refined exposures are not likely to cause acute effects to the majority of freshwater invertebrate food items and the corresponding probability of an individual effect level is low) and insignificant effects (i.e., there is a low level of effect (< 0.05 percent at predicted levels of exposure and the use of the most sensitive species of freshwater invertebrate is likely to overestimate the sensitivity of the majority of freshwater invertebrate food items) in the context of a "take" of a single pallid sturgeon.<br><br>**Chronic effects:** Although chronic LOCs are exceeded based on screening-level EECs, refined measures of exposure (i.e., 21-day flow adjusted EECs and available monitoring data) are well below levels that result in chronic effects for the most |

| | | |
|---|---|---|
| | | sensitive freshwater invertebrate species. This finding is based on discountable effects (i.e., chronic effects to atrazine at the refined levels of exposure are not likely to occur and/or result in a "take" of a single listed pallid sturgeon via a reduction in freshwater invertebrates as food items). |
| 3. Indirect effects to the pallid sturgeon via reduction of habitat and/or primary productivity (i.e., aquatic plants) | May affect, but not likely to adversely affect (NLAA) | Individual aquatic plant species within the Missouri, Mississippi, and Atchafalaya Rivers may be affected. However, 14-, 30-, 60-, and 90-day EECs, which consider the impact of flow, are well below the threshold concentrations representing community-level effects. In addition, the available monitoring data for large rivers where the sturgeon occurs indicate that peak detected concentrations are less than the 14-day threshold concentration representing aquatic community-level impacts. This finding is based on insignificance of effects (i.e., community-level effects to aquatic plants cannot be meaningfully measured, detected, or evaluated in the context of a "take" of a single pallid sturgeon). |
| 4. Indirect effects to the pallid sturgeon via reduction of terrestrial vegetation (i.e., riparian habitat) required to maintain acceptable water quality | <u>Direct effects to forested riparian vegetation:</u> May affect, but not likely to adversely affect (NLAA)<br><br><u>Direct effects to grassy/herbaceous riparian vegetation:</u> Likely to adversely affect (LAA) | Riparian vegetation may be affected because terrestrial plant RQs are above LOCs. However, woody plants are generally not sensitive to environmentally-relevant concentrations of atrazine; therefore, effects on shading, streambank stabilization, and structural diversity of riparian areas in the action area are not expected. With respect to sedimentation, the potential for atrazine to affect the spawning habitat of the pallid sturgeon via impacts on riparian vegetation depends primarily on the extent of potentially sensitive (herbaceous and grassy) riparian areas and their impact on water quality in the rivers where the sturgeon is known to occur. Because woody plants are generally not sensitive to atrazine at expected exposure concentrations, riparian areas which have predominantly forested vegetation containing woody shrubs and trees are not likely to be impacted by atrazine use. This finding is based on insignificance of effects (i.e., although effects to individual plants may occur, effects to forested riparian vegetation cannot be meaningfully measured, detected, or evaluated in the context of a "take" of a single pallid sturgeon). For habitats of the pallid sturgeon that are in close proximity to potential atrazine use sites and where the riparian vegetation is comprised of grasses and non-woody plants, the effects determination is "may affect and likely to adversely affect or LAA". Until further analysis on specific land management practices and sensitivity of riparian vegetation adjacent to pallid sturgeon habitat is completed, potential effects to grassy herbaceous riparian vegetation are presumed to adversely affect the pallid sturgeon. |

## 2. Problem Formulation

Problem formulation provides a strategic framework for the risk assessment. By identifying the important components of the problem, it focuses the assessment on the most relevant life history stages, habitat components, chemical properties, exposure routes, and endpoints. The structure of this risk assessment is based on guidance contained in U.S. EPA's *Guidance for Ecological Risk Assessment* (U.S. EPA, 1998), the Services' *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998), and is consistent with procedures and methodology outlined in the Overview Document (U.S. EPA, 2004).

### 2.1 Purpose

This ecological risk assessment is a component of the settlement for the *Natural Resources Defense Council, Civ. No: 03-CV-02444 RDB (filed March 28, 2006)*. The purpose of this ecological risk assessment is to make an "effects determination," as directed in Section 7(a)(2) of the ESA, for the pallid sturgeon (*Scaphirhynchus albus*) by evaluating the potential direct and indirect effects resulting from use of the herbicide atrazine (6-chloro-N-ethyl-N-isopropyl-1,3,5-triazine-2,4-diamine) on the survival, growth, and/or reproduction of this Federally endangered species. The pallid sturgeon was federally listed as an endangered species on September 6, 1990 by the U.S. Fish and Wildlife Service (USFWS or the Service; 55 FR 36641; USFWS, 1990). USFWS is the branch of the Department of Interior responsible for listing endangered fish, such as the pallid sturgeon. No critical habitat has been designated for this species.

In this endangered species assessment, direct and indirect effects to the pallid sturgeon are evaluated in accordance with the screening-level methodology described in the Agency's Overview Document (U.S. EPA, 2004). It should be noted, however, that the indirect effects analysis in this assessment utilizes more refined data than are generally available to the Agency. Specifically, a robust set of microcosm and mesocosm data and aquatic ecosystem models are available for atrazine that allowed the Agency to refine the assessment of indirect effects associated with potential aquatic community-level effects (via aquatic plant community structural change and subsequent habitat modification) to the pallid sturgeon. Use of such information is consistent with the guidance provided in the Overview Document, which specifies that "the assessment process may, on a case-by-case basis, incorporate additional methods, models, and lines of evidence that the Agency finds technically appropriate for risk management objectives" (Section V, page 31 of U.S. EPA, 2004).

As part of the "effects determination," the Agency will reach one of the following three conclusions regarding the potential for atrazine to adversely affect the pallid sturgeon:

- "No effect;"
- "May affect, but not likely to adversely affect" (NLAA); or
- "Likely to adversely affect" (LAA).

If the results of the screening-level assessment show no indirect effects and levels of concern (LOCs) for the pallid sturgeon are not exceeded for direct effects, a "no effect" determination is made based on atrazine's use within the action area. If, however, indirect effects are anticipated and/or exposure exceeds the LOCs for direct effects, the Agency concludes a preliminary "may affect" determination for the pallid sturgeon.

If a determination is made that use of atrazine within the action area "may affect" the pallid sturgeon, additional information is considered to refine the potential for exposure at the predicted levels and for effects to the pallid sturgeon and other taxonomic groups upon which this species depends (i.e., freshwater fish and invertebrates, aquatic plants, riparian vegetation). Based on the refined information, the Agency uses the best available information to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that are "likely to adversely affect" the pallid sturgeon. This information is presented as part of the Risk Characterization in Section 5.

## 2.2 Scope

Atrazine is currently registered as an herbicide in the U.S. to control annual broadleaf and grass weeds in corn, sorghum, sugarcane, and other crops. In addition to food crops, atrazine is also used on a variety of non-food crops, forests, residential/industrial uses, golf course turf, recreational areas, and rights-of-way.

The end result of the EPA pesticide registration process is an approved product label. The label is a legal document that stipulates how and where a given pesticide may be used. Product labels (also known as end-use labels) describe the formulation type, acceptable methods of application, approved use sites, and any restrictions on how applications may be conducted. Thus, the use or potential use of atrazine in accordance with the approved product labels is "the action" being assessed.

This ecological risk assessment is for currently registered uses of atrazine in the action area associated with the pallid sturgeon. Further discussion of the action area for the pallid sturgeon is provided in Section 2.6.

Degradates of atrazine include hydroxyatrazine (HA), deethylatrazine (DEA), deisopropylatrazine (DIA), and diaminochloroatrazine (DACT). Comparison of available toxicity information for the degradates of atrazine indicates lesser aquatic toxicity than the parent for freshwater fish, aquatic invertebrates, and aquatic plants. Specifically, the available degradate toxicity data for HA indicate that it is not toxic to freshwater fish and invertebrates at the limit of its solubility in water. In addition, no adverse effects were observed in fish or daphnids at DACT concentrations up to 100 mg/L. Acute toxicity values for DIA are 8.5- and 36-fold less sensitive than acute toxicity values for atrazine in fish and daphnids, respectively. In addition, available aquatic plant toxicity data for HA, DEA, DIA, and DACT report non-definitive $EC_{50}$ values (i.e., 50% effect was not observed at the highest test concentrations) at concentrations that are at least 700 times higher than the lowest reported aquatic plant $EC_{50}$ value for parent atrazine. Although degradate toxicity data are not available for terrestrial plants, lesser toxicity is assumed, given the available ecotoxicological information for other taxonomic groups including aquatic plants and the likelihood that the degradates of atrazine may lose efficacy as an herbicide. Therefore, given the lesser toxicity of the degradates compared to the parent, and the relatively small proportion of the degradates expected to be in the environment and available for exposure relative to atrazine, the focus of this assessment is parent atrazine. A detailed summary of the available ecotoxicity information for all of the atrazine degradates is presented in Appendix A.

The Agency does not routinely include, in its risk assessments, an evaluation of mixtures of active ingredients (either those mixtures of multiple active ingredients in product formulations or those in the applicator's tank). In the case of product formulations of active ingredients (that is, a registered product containing more than one active ingredient), each active ingredient is subject to an individual risk assessment for regulatory decision regarding the active ingredient on a particular use site. If effects data are available for a formulated product containing more than one active ingredient, they may be used qualitatively or quantitatively in accordance with the Agency's Overview Document and the Services' Evaluation Memorandum (U.S. EPA, 2004; USFWS/NMFS, 2004).

Atrazine has registered products that contain multiple active ingredients. Analysis of the available open literature and acute oral mammalian $LD_{50}$ data for multiple active ingredient products relative to the single active ingredient is provided in Appendix B. The results of this analysis show that an assessment based on the toxicity of the single active ingredient of atrazine is appropriate.

The results of available toxicity data for environmental mixtures of atrazine with other pesticides are presented in Section A.7 of Appendix A. According to the available data, other pesticides may combine with atrazine to produce synergistic or additive toxic effects. Based on the results of the available data, study authors claim that synergistic effects with atrazine may occur for a number of organophosphate insecticides including diazinon, chlorpyrifos, and methyl parathion, as well as herbicides including alachlor. If chemicals that show synergistic effects with atrazine are present in the environment in combination with atrazine, the toxicity of atrazine may be increased, offset by other environmental factors, or even reduced by the presence of antagonistic contaminants if they are also present in the mixture. The variety of chemical interactions presented in the available data set suggests that the toxic effect of atrazine, in combination with other pesticides used in the environment, can be a function of many factors including but not necessarily limited to: (1) the exposed species, (2) the co-contaminants in the mixture, (3) the ratio of atrazine and co-contaminant concentrations, (4) differences in the pattern and duration of exposure among contaminants, and (5) the differential effects of other physical/chemical characteristics of the receiving waters (e.g., organic matter present in sediment and suspended water). Quantitatively predicting the combined effects of all these variables on mixture toxicity to any given taxa with confidence is beyond the capabilities of the available data. However, a qualitative discussion of implications of the available pesticide mixture effects data involving atrazine on the confidence of risk assessment conclusions for the pallid sturgeon is addressed as part of the uncertainty analysis for this effects determination.

## 2.3 Previous Assessments

A summary of the Agency's ecological risk assessments for atrazine is provided in the Interim Reregistration (IRED) decision for atrazine (U.S. EPA, 2003b) and previously submitted effects determinations for 16 listed species (U.S. EPA, 2006c, 2007a, 2007b, and 2007c).

The Agency also conducted an evaluation of the submitted studies regarding the potential effects of atrazine on amphibian gonadal development and presented its assessment in the form of a white paper for external peer review to a FIFRA Scientific Advisory Panel (SAP) in June 2003[1]. In the white paper dated May 29, 2003, the Agency summarized seventeen studies consisting of both open literature and registrant-submitted laboratory and field studies involving both native and non-native species of frogs (U.S. EPA, 2003d). The Agency concluded that none of the studies fully accounted for environmental and animal husbandry factors capable of influencing endpoints that the studies were attempting to measure. The Agency also concluded that the current lines-of-evidence did not show that atrazine produced consistent effects across a range of exposure concentrations and amphibian species tested.

Based on this assessment, the Agency concluded and the SAP concurred that there was sufficient evidence to formulate a hypothesis that atrazine exposure may impact gonadal development in amphibians, but there were insufficient data to confirm or refute the hypothesis (http://www.epa.gov/oscpmont/sap/2003/June/junemeetingreport.pdf). Because of the inconsistency and lack of reproducibility across studies and an absence of a dose-response relationship in the currently available data, the Agency determined that the data did not alter the conclusions reached in the January 2003 IRED regarding uncertainties related to atrazine's potential effects on amphibians. The SAP supported EPA in seeking additional data to reduce uncertainties regarding potential risk to amphibians. Subsequent data collection has followed the multi-tiered process outlined in the Agency's white paper to the SAP (U.S. EPA, 2003d). In addition to addressing uncertainty regarding the potential use of atrazine to cause these effects, these studies are expected to characterize the nature of any potential dose-response relationship. A data call-in for the first tier of amphibian studies was issued in 2005. The results of these studies, as well as other recent open literature data which focus on the potential effects of atrazine on amphibian gonadal development, are being reviewed. This information will be presented and discussed as part of a second SAP to be held in October 2007.

The Agency has completed four separate effects determinations for atrazine as it relates to 16 of the listed species included in the Natural Resources Defense Council settlement

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[1] The Agency's May 2003 White Paper on Potential Developmental Effects of Atrazine on Amphibians is available at http://www.epa.gov/oscpmont/sap/2003/june/finaljune2002telconfreport.pdf.

agreement and one listed species included in a second settlement agreement with the Center for Biological Diversity and Save Our Springs Alliance. These effects determinations, which are available on the web at www.epa.gov/espp, review atrazine's potential direct and indirect effects to the following listed species: 1) Barton Springs salamander (*Eurycea sosorum*) (U.S. EPA, 2006c); 2) shortnose sturgeon (*Acipenser brevirostrum*), dwarf wedgemussel (*Alasmidonta heterodon*), loggerhead turtle (*Caretta caretta*), Kemp's ridley turtle (*Lepidochelys kempii*), leatherback turtle *(Dermochelys coriacea*), and green turtle (*Chelonia mydas*) in the Chesapeake Bay (U.S. EPA, 2007a); 3) Alabama sturgeon (*Scaphirhynchus suttkusi*) (U.S. EPA, 2007b); and 4) eight listed freshwater mussels including the pink mucket pearly mussel (*Lampsilis abrupta*), rough pigtoe mussel (*Pleurobema plenum*), shiny pigtoe pearly mussel (*Fusconaia edgariana*), fine-rayed pigtoe mussel (*F. cuneolus*), heavy pigtoe mussel (*P. taitianum*), ovate clubshell mussel (*P. perovatum*), southern clubshell mussel (*P. decisum*), and stirrup shell mussel (*Quadrula stapes*) (U.S. EPA, 2007c). The freshwater mussel effects determination also evaluates the potential for atrazine use to result in the destruction or adverse modification of designated critical habitat for the ovate clubshell and southern clubshell mussels. Based on the results of the Barton Springs salamander, Chesapeake Bay, and Alabama sturgeon endangered species risk assessments, atrazine effects determinations for the eight aforementioned listed species are either "no effect" or "may affect, but not likely to adversely affect (NLAA)." In the freshwater mussel assessment, an "LAA" determination was concluded for aquatic plant community-level effects to the pink pearly mucket, rough pigtoe, and fine-rayed pigtoe mussels that occur in highly vulnerable watersheds of the action area. In addition, an "LAA" determination was concluded for the critical habitat impact and indirect effects analysis for all mussels, with the exception of the stirrup shell, based on indirect effects to habitat and water quality via direct effects to herbaceous/grassy riparian vegetation.

Finally, On August 1, 2003, EPA released an assessment of the potential effects of atrazine to 26 listed Environmentally Significant Units (ESUs) of Pacific salmon and steelhead. That assessment concluded that registered uses of atrazine would have "no effect", directly or indirectly to the 26 ESUs nor to designated crtician habitat. While potential effects to riparian vegetation were noted, the extent of atrazine use in the large geographic areas comprising the relevant watersheds, lead to a conclusion that use would have no effect on the species from any potential effects to riparian areas.

## 2.4 Stressor Source and Distribution

### 2.4.1 Environmental Fate and Transport Assessment

The following fate and transport description for atrazine is based on information contained in the 2003 IRED (U.S. EPA, 2003a). In general, atrazine is expected to be mobile and persistent in the environment. The main route of dissipation is microbial degradation under aerobic conditions. Because of its persistence and mobility, atrazine is expected to reach surface and ground water. This is confirmed by the widespread detections of atrazine in surface water and ground water. Atrazine is persistent in soil, with a half-life (time until 50% of the parent atrazine remains) exceeding 1 year under some conditions (Armstrong et al., 1967). Atrazine can contaminate nearby non-target plants, soil, and surface water via spray drift during application. Atrazine is applied directly to target plants during foliar application, but pre-plant and pre-emergent applications are generally far more prevalent.

The resistance of atrazine to abiotic hydrolysis (stable at pH 5, 7, and 9) and to direct aqueous photolysis (stable under sunlight at pH 7), and its only moderate susceptibility to degradation in soil (aerobic laboratory half-lives of 3-4 months) indicate that atrazine is unlikely to undergo rapid degradation on foliage. Likewise, a relatively low Henry's Law constant ($2.6 \times 10^{-9}$ atm-$m^3$/mol) indicates that atrazine is not likely to undergo rapid volatilization from foliage. However, its relatively low octanol/water partition coefficient (log $K_{ow}$ = 2 .7) and soil/water partitioning (Freundlich $K_{ads}$ values < 3 and often < 1) may somewhat offset the low Henry's Law constant value, thereby possibly resulting in some volatilization from foliage. In addition, its relatively low adsorption characteristics indicate that atrazine may undergo substantial washoff from foliage. It should also be noted that foliar dissipation rates for numerous pesticides have generally been somewhat greater than otherwise indicated by their physical chemical and other fate properties.

In terrestrial field dissipation studies performed in Georgia, California, and Minnesota, atrazine dissipated with half-lives of 13, 58, and 261 days, respectively. The inconsistency in these reported half-lives could be attributed to the temperature variation between the studies in which atrazine was seen to be more persistent in colder climate. Long-term field dissipation studies also indicated that atrazine could persist over a year in such climatic conditions. A forestry field dissipation study in Oregon (aerial application of 4 lbs ai/A) estimated an 87-day half-life for atrazine on exposed soil, a 13-day half-life in foliage, and a 66-day half-life on leaf litter.

Atrazine is applied directly to soil during pre-planting and/or pre-emergence applications. Atrazine is transported indirectly to soil due to incomplete interception during foliar application, and due to washoff subsequent to foliar application. The available laboratory and field data are reported below. For aquatic environments, reported half-lives were much longer. In an anaerobic aquatic study, atrazine overall (total system), water, and sediment half-lives were given as 608, 578, and 330 days, respectively.

A number of degradates of atrazine were detected in laboratory and field environmental fate studies. Deethyl-atrazine (DEA) and deisopropyl-atrazine (DIA) were detected in all studies, and hydroxy-atrazine (HA) and diaminochloro-atrazine (DACT) were detected in all but one of the listed studies. Deethylhydroxy-atrazine (DEHA) and deisopropylhydroxy-atrazine (DIHA) were also detected in one of the aerobic studies.

All of the chloro-triazine and hydroxy-triazine degradates detected in the laboratory metabolism studies were present at less than the 10% of applied that the Agency uses to classify degradates as "major degradates" (U.S. EPA, 2004); however, several of these degradates were detected at percentages greater than 10% in soil and aqueous photolysis studies. Insufficient data are available to estimate half-lives for these degradates. The dealkylated degradates are more mobile than parent atrazine, while HA is less mobile than atrazine and the dealkylated degradates.

### 2.4.2 Mechanism of Action

Atrazine inhibits photosynthesis by stopping electron flow in Photosystem II. Triazine herbicides associate with a protein complex of the Photosystem II in chloroplast photosynthetic membranes (Schulz et al., 1990). The result is an inhibition in the transfer of electrons that in turn inhibits the formation and release of oxygen.

### 2.4.3 Use Characterization

Atrazine is widely used to control broadleaf and many other weeds, primarily in corn, sorghum, and sugarcane (U.S. EPA, 2003a). As a selective herbicide, atrazine is applied pre-emergence and post-emergence. Figure 2.1 presents the national distribution of use of atrazine (Kaul and Jones, 2006).

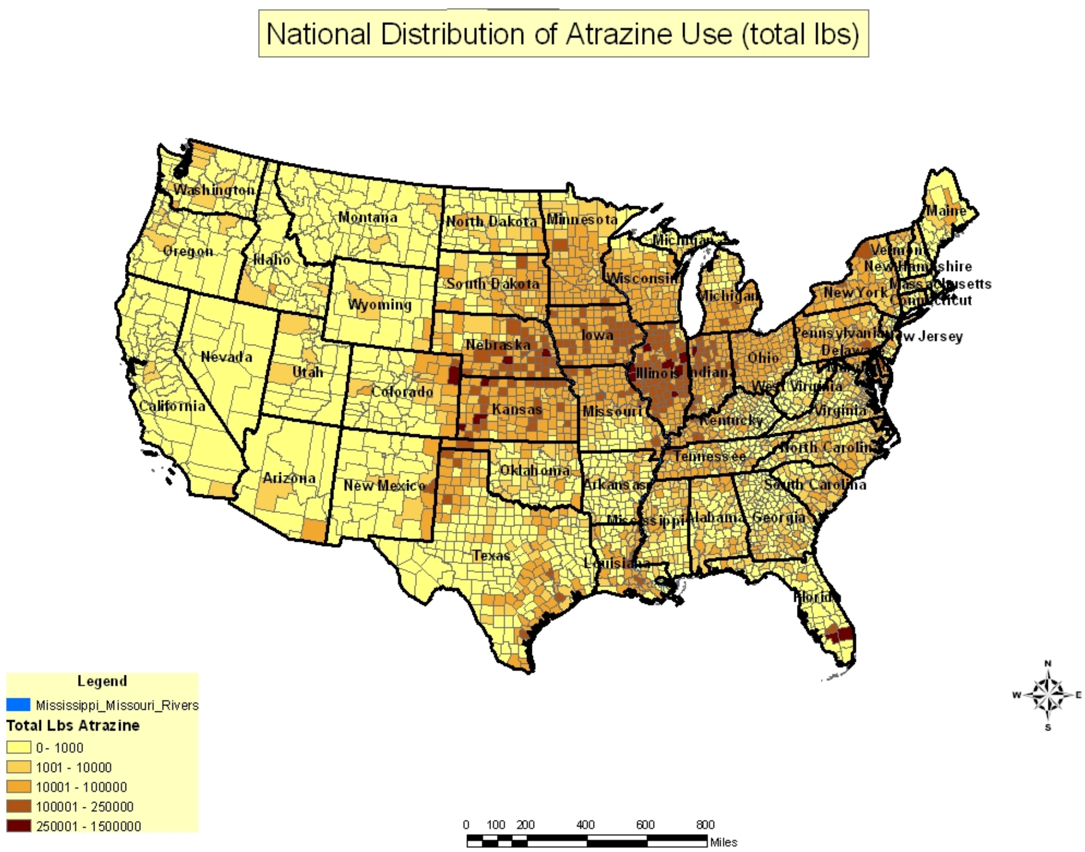


**Figure 2.1 National Extent of Atrazine Use (lbs)**

Atrazine is used on a variety of terrestrial food crops, non-food crops, forests, residential/industrial uses, golf course turf, recreational areas, and rights-of-way. Atrazine yields season-long weed control in corn, sorghum, and certain other crops. The major atrazine uses include: corn (83 percent of total ai produced per year - primarily applied pre-emergence), sorghum (11 percent of total ai produced), sugarcane (4 percent of total ai produced), and others (2 percent ai produced). Atrazine formulations include dry flowable, flowable liquid, liquid, water dispersible granule, wettable powder, and coated fertilizer granule. The maximum registered use rate for atrazine is 4 lbs ai/acre, and 4 lbs ai/acre is the maximum, single application rate for the following uses: sugarcane, forest trees (softwoods, conifers), forest plantings, guava, macadamia nuts, ornamental sod (turf farms), and ornamental and/or shade trees.

Assessment of the use information is critical to the development of appropriate modeling scenarios and evaluation of the appropriate model inputs (Kaul and Jones, 2006). Information on the agricultural uses of atrazine in the states comprising the regionalized exposure assessment approach (see Section 3.2.2 for more details) for the pallid sturgeon (Alabama, Georgia, Mississippi, Louisiana, Arkansas, Kansas, Missouri, Nebraska, Illinois, Indiana, Ohio, Kentucky, Tennessee, Iowa, North Dakota, South Dakota, and Montana), as defined in Section 2.6 of this assessment, was gathered (Kaul and Jones, 2006). In addition, typical atrazine crop use information was considered (Kaul et al., 2005). Use information within the action area is utilized to determine which uses should be modeled, while the application methods, intervals, and timing are critical model inputs. While the modeling described in Section 3.2 relies initially on maximum label application rates and numbers of applications, information on typical ranges of application rates and numbers of applications is also presented to characterize the modeling results. No state- or county-level usage information is available on non-agricultural uses (residential, rights-of-way, forestry, or turf) of atrazine.

Agricultural cropland (presented as cultivated cropland and hay/pasture) and atrazine use relative to the pallid sturgeon's action area are depicted in Figures 2.2 and 2.3, respectively. The landuse mapping presented in Figure 2.2 provides a breakout of aggregated turf uses (residential, recreational, and golf course). No consistent coverage is available for rights-of-way uses. Given the potential use pattern shown in Figure 2.2, atrazine could be used in close proximity to the species range.

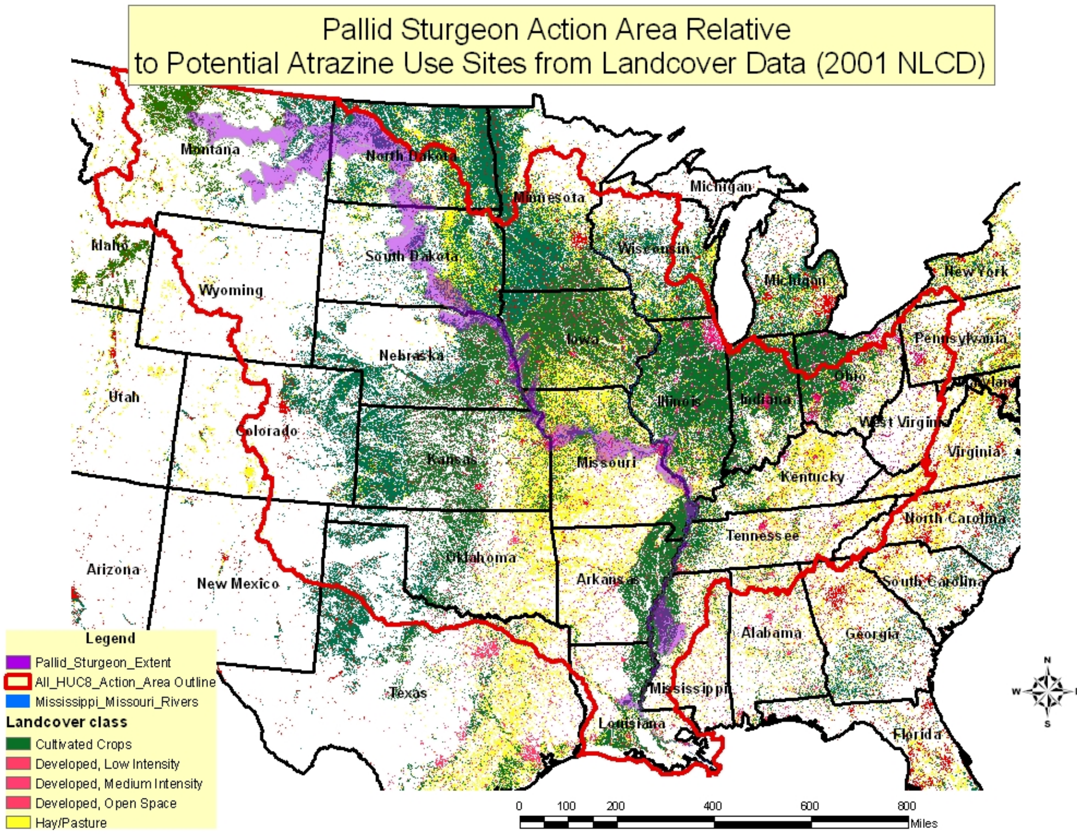


**Figure 2.2 Agricultural Cropland Relative to Pallid Sturgeon Action Area**

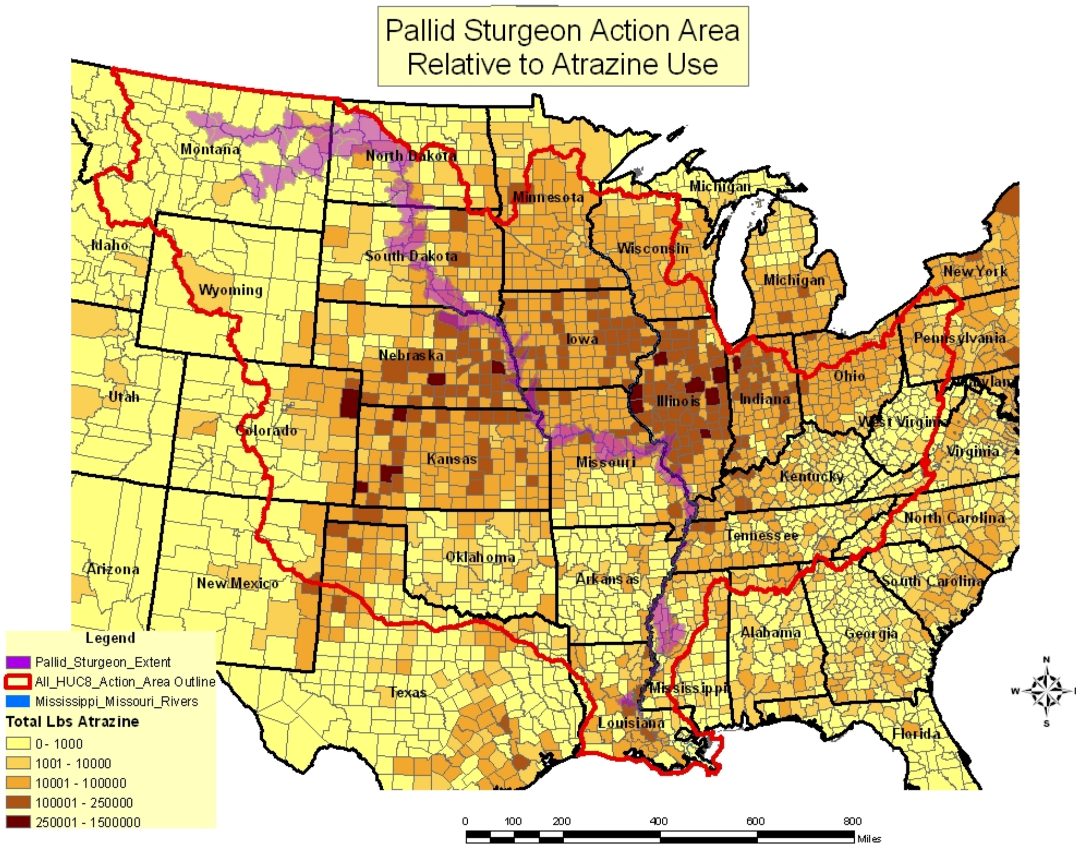


**Figure 2.3 Atrazine Use Relative to Action Area**

All agricultural use information for atrazine was considered in order to determine which uses occur within the action area for the pallid sturgeon (discussed further in Section 2.6). As noted above, information is not available for non-agricultural uses; therefore, they are presumed to occur within the action area and are included in this assessment. Agricultural uses of atrazine within the action area include corn, sweet corn, sorghum, sugarcane, and fallow/pasture. Specifically, county-level data for the areas within and immediately surrounding the action area were used (Kaul and Jones, 2006). County-level estimates of atrazine use were derived using state-level estimates from USDA-NASS and data obtained from Doane (www.doane.com; the full dataset is not provided due to its proprietary nature). State-level data from 1998 to 2004 were averaged together and extrapolated down to the county level based on apportioned county-level crop acreage data from the 2002 USDA Agriculture Census (AgCensus).

Of the seventeen principal states comprising the regionalized exposure approach (use information was not evaluated for several states far removed from the species' range, even though these areas are considered in the exposure assessment, because it is assumed that use within states in close proximity has the greatest impact on the species), approximately 56,000,000 total pounds of atrazine were used between 1998 and 2004 on average across all use sites. The state with the highest use was Illinois with approximately 12,000,000 lbs used, and the least use was reported in Montana. Atrazine was used on barley, corn, pecans, sorghum, sugarcane, sweet corn, and wheat. The crop with the greatest use was corn with approximately 50,000,000 lbs. All other crops averaged less use than corn.

In general, this information suggests that the central portion of the action area, including Illinois, Iowa, and Nebraska, is located within the highest atrazine use area. In general, atrazine use decreases further south and north of this area, with the lowest use in the far northern Great Plains (Montana) and in Arkansas. The atrazine use pattern within the action area is graphically presented in Figure 2.3. It should be noted, however, that information on non-agricultural use of atrazine is not available and, therefore, was not included in Figure 2.3.

Typical use information for atrazine is summarized in Table 2.1. The total average atrazine use per year from 1998 to 2004 was roughly 56,500,000 lbs within these states. Of this, roughly 50,000,000 lbs were used on corn or approximately 90% of total atrazine use. Of the remainder, only atrazine use on sorghum was at amounts at or above 1,000,000 lbs. For all uses, the typical application rate and numbers of applications are fairly consistent across all states and all uses. For all uses, the average application rate ranges from 0.6 to 1.5 lbs per acre, while the average number of applications ranges from 1.2 to 1.4. For corn, the average application rate is 1.2 lbs per acre, and the average number of applications is 1.1.

| Table 2.1 Summary of Typical Atrazine Use Information Collected Between 1998 and 2004 for All States in the Pallid Sturgeon Action Area | | | |
|---|---|---|---|
| **Crop** | **Total Pounds by Crop** | **Average Number of Applications by Crop** | **Average Application Rate (lbs/acre) by Crop** |
| corn | 50,207,000 | 1.2 | 1.1 |
| fallow/hay/pasture | 332,000 | 1.0 | 1.0 |
| sorghum | 5,190,000 | 1.1 | 1.3 |
| sugarcane | 600,000 | 1.4 | 1.5 |
| sweet corn | 55,000 | 1.2 | 1.1 |
| Wheat[1] | 111,000 | 1.1 | 0.6 |

1 – Atrazine is not labeled for use directly to wheat, but to control weeds during fallow conditions.

## 2.5 Assessed Species

A brief introduction to the pallid sturgeon, including a summary of habitat, diet, and reproduction data relevant to this endangered species risk assessment, is provided below. Further information on the status and life history of the pallid sturgeon is provided in Appendix C.

The pallid sturgeon (*Scaphirynchus albus*) is a freshwater fish (Figure C.1 of Appendix C) that is found in the Missouri and Mississippi Rivers from Montana to Louisiana (Kallemeyn, 1983) and the Atchafalaya River (Reed and Ewing, 1993). Within this range, pallid sturgeon tend to select main channel habitats (Sheehan et al., 1998) in the Mississippi River and main channel areas with islands or sand bars in the upper Missouri River (Bramblett, 1996) The pallid sturgeon resides in large rivers of 8$^{th}$ order or higher. The states within its range include Arkansas, Kansas, Kentucky, Illinois, Iowa, Louisiana, Mississippi, Missouri, Montana, Nebraska, North Dakota, South Dakota, and Tennessee. A map of the current range of the pallid sturgeon is shown in Figure 2.4.

The USFWS Recovery Plan for the pallid sturgeon (USFWS, 1993) divides its range into six recovery-priority management areas, which are depicted and further described in Figure C-3 and Section C.3, respectively, of Appendix C. These management areas were selected based upon the most recent pallid sturgeon records of occurrence and the probability that these areas still provide suitable habitat for restoration and recovery of the species.

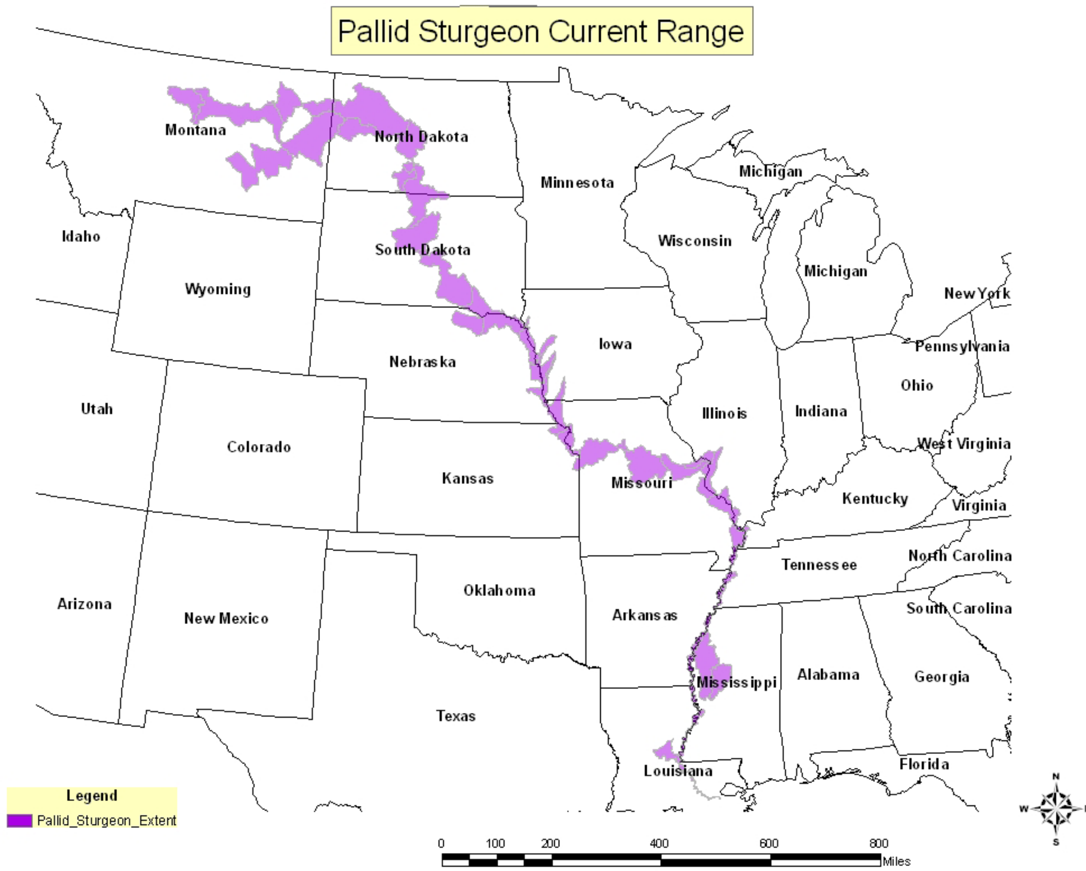


**Figure 2.4 Current Range of the Pallid Sturgeon**

According to the USFWS Recovery Plan (USFWS, 1993), destruction and alteration of habitat by human modification of the river system is believed to be the primary cause of pallid sturgeon decline. In addition, lack of natural reproduction, commercial harvest, and hybridization have also been identified as causes in the species' decline. The most obvious habitat-related changes have been the creation of a series of impoundments on the main stem of the upper Missouri River and Mississippi River tributaries, and channelization of the lower Missouri River for navigation. These types of modifications restrict the life cycle requirements of pallid sturgeon by blocking movements to spawning and feeding areas, destroying spawning areas, altering conditions and flows of potential remaining spawning areas, and reducing food sources by lowering productivity (USFWS, 2007 draft).

Pallid sturgeon require large, turbid, free-flowing riverine habitat with rocky or sandy substrate (Gilbraith et al., 1988). They occupy river bottoms where the velocity ranges from 10 to 90 centimeters per second (cps) (0.33 to 2.9 feet/sec) (USFWS, 1993). Food items of the pallid sturgeon include both aquatic insects and freshwater fish (Gerrity et al., 2005 and 2006; Wanner, 2006). Recent data on the stomach contents of released hatchery-reared juvenile pallid sturgeon indicate that the majority of their diet (90%) by wet weight is comprised of fish (Gerrity et al., 2006). However, other studies (Wanner, 2006) indicate that the composition of the juvenile pallid sturgeon diet is more evenly distributed between fish and aquatic insects. With regard to fish, it appears that sturgeon chub and sicklefin chub are common food items for juveniles; therefore, pallid sturgeon habitat may be influenced by the presence of cyprinid prey. In addition to fish, juvenile pallid sturgeon also consume aquatic invertebrates (mayflies, caddisflies, midges, dragonflies/damselflies, and aquatic sowbugs) as well as detritus (Gerrity et al., 2006; Wanner, 2006). Data on the relative percentages of aquatic insect and fish food items in the adult pallid sturgeon diet are not available. Although reproduction and spawning requirements of pallid sturgeon are not well understood, they are thought to spawn in swift water over gravel, cobble, or other hard surfaces (USFWS, 1993). Pallid sturgeon are slow to reach sexual maturity, with males reproducing at approximately five to seven years of age, and females spawning for the first time at 15 to 20 years (Erickson, 1992; Keenlyne and Jenkins, 1989). Spawning appears to occur between June and August, and females may not spawn each year (Kallemeyn, 1983). Larval fish produced from the spawning event drift downstream from the hatching site (Kynard et al., 2002), and begin to settle in the lower portion of the water column 11 to 17 days post-hatch (Braaten et al., in review). Drift distance is likely to vary with ambient water velocity, but may be more than 124 miles (200 km) in the first 11 days (Braaten and Fuller, 2005).

## 2.6 Action Area

For listed species assessment purposes, the action area is considered to be the area affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). It is recognized that the overall action area for the national registration of atrazine uses is likely to encompass considerable portions of the United States based on the large array of both agricultural and non-agricultural uses. Based on the available atrazine monitoring data (discussed further in Section 3.2.6) and the toxicity data for the most sensitive non-vascular aquatic plant, the Agency's LOCs are likely to be exceeded in many watersheds that are in proximity to or downstream of atrazine use sites. Therefore, the overall action area for atrazine is likely to include many watersheds of the United States that co-occur with and/or are in proximity to agricultural and non-agricultural atrazine use sites. However, in order to focus this assessment, the scope limits consideration of the overall action area to those geographic portions that may be applicable to the protection of the pallid sturgeon included in this assessment. Based on the available information on potential atrazine use sites, none of the streams and rivers that are within the range of the pallid sturgeon could be excluded from the action area. Therefore, the portion of the atrazine action area that is assessed as part of this endangered species risk assessment includes the area within the boundary of the watersheds that drain to known current locations of the pallid sturgeon.

The pallid sturgeon is known to currently exist in a wide geographic range from Louisiana north along the Mississippi River valley to the Missouri River valley north into Montana. In general, the species is found in the main stems of the Mississippi and Missouri Rivers with a few reported occurrences in nearby tributaries (e.g., Atchafalaya River in Louisiana). Historically, the pallid sturgeon is presumed to have ranged over a much broader area; however, this assessment focuses on the current range of the species. Information on the current range of the pallid sturgeon was obtained from the NatureServe website (http://www.natureserve.org/explorer/; accessed on May 3, 2007). Additional information on the species' current range was also obtained from the USFWS (G. Jordan, personal communication, 2007). The "action area" is the overall geographic scope where effects may occur. However, because this assessment is limited to the evaluation of potential effects of atrazine use to the pallid sturgeon, the action area is defined as the geographic scope where effects may occur, either directly or indirectly, to the pallid sturgeon. Therefore, the initial definition of the action area for this species is defined by the watersheds that drain to the known current range of the pallid sturgeon.

As shown in Figure 2.5, the action area for the pallid sturgeon stretches from a point near the mouth of the Mississippi River up into, and including, the Missouri River watershed. Deriving the geographical extent of this portion of the action area is the product of consideration of the types of effects atrazine may be expected to have on the environment, the exposure levels to atrazine that are associated with those effects, and the best available information concerning the use of atrazine and its fate and transport within the area identified in Figure 2.5.

Specifically, a map was created using ArcMap GIS, based on dialog with USFWS (G. Jordan, pers. comm., 2007) regarding current locations of the pallid sturgeon. Each of the streams, rivers, and watersheds where the pallid sturgeon is reportedly located were added to the map using the geographical locational information from the NatureServe website (http://www.natureserve.org/explorer/). Additional point locations not included in the NatureServe data were provided by the USFWS (G. Jordan, pers. comm., 2007). These point locations were assigned to a watershed (HUC8, or USGS hydrologic unit code) and added to the map. The next step in defining the action area was to assume that all waters, within or draining to the identified watersheds, are part of the action area. Areas draining to the specified watersheds were defined by identifying all watersheds located upstream of the known species' locations using the USGS' hydrologic unit code (HUC) watersheds.

The USGS has defined watersheds within the entire United States into increasingly smaller HUCs, from coarse scales (Regions, or HUC2 watersheds) to subregions (HUC4 watersheds) to accounting units (HUC6 watersheds) to cataloging units (HUC8 watersheds). The action area definition analysis started at the coarsest scale with regional HUCs (or HUC2 watersheds). For this analysis, the full extent of the area draining to the identified streams extends from the Rocky Mountains to the Gulf of Mexico. Once a drainage area was defined, the next level of refinement within the HUC classification (HUC4, HUC6, and HUC8) watershed was added to the analysis. Those HUCs not draining to the streams where the pallid sturgeon occurs were eliminated from the final map. Ultimately, the action area is defined by those HUC8 watersheds draining to the species' habitat range. Because of the vast extent of the range of the pallid sturgeon, the action area stretches from Montana to the Gulf of Mexico and includes all streams within this area including the main stems of the major rivers (e.g. Mississippi River) where the species reside.

More detail on the Agency's enhanced reach file (ERF) stream data and the USGS' HUC classification scheme may be found at the following websites:

http://www.epa.gov/waters/doc/refs.html

http://water.usgs.gov/GIS/huc.html

The results of the screening-level assessment suggest that effects on aquatic plants are possible anywhere within the defined area. In general, available monitoring data for the action area show that peak concentrations are less than those predicted by modeling, but greater than the Agency's screening levels of concern for indirect effects (see Section 3.2.7). Longer-term exposures from monitoring data are difficult to assess relative to the Agency's LOCs. For monitoring data that are not specifically targeted to highly vulnerable areas (described further in Section 3.2.6), the limited sampling frequency precludes a direct comparison to longer-term exposures (e.g., 30-day average concentrations) with modeling. Comparison of annual average concentrations from non-targeted monitoring data (e.g., data in which the study was not specifically designed to capture atrazine concentrations in high use areas) suggests that long-term exposure in monitoring data are generally below modeled concentrations of atrazine and the Agency's LOCs.

Preliminary analysis of the Ecological Monitoring Program data (Section 3.2.6.3), which are targeted for watersheds most vulnerable to atrazine runoff, suggests that longer-term exposures (e.g., 30-day average concentrations) in selected watersheds exceed the Agency's LOCs. However, these samples were collected from $2^{nd}$ and $3^{rd}$ order streams and are not considered representative of the flow regimes (e.g., large rivers with high flow rates and volumes) in which the pallid sturgeon reside. The action area for the pallid sturgeon is defined as shown in Figure 2.5. Further information on the definition of the action area follows.

An evaluation of use information was conducted to determine whether any or all of the area described above should be included in the action area. As part of this effort, current labels were reviewed and local use information was evaluated to determine which atrazine uses could potentially be present within the defined area. These data suggest that extensive agricultural uses are present within the defined area and that the existence of non-agricultural uses cannot be precluded. Finally, local land cover data were considered to refine the characterization of potential atrazine use in the areas defined above. The overall conclusion of this analysis was that while certain agricultural uses could likely be excluded (i.e., guava and macadamia nuts) and some non-agricultural uses of atrazine were unlikely, none of the full extent depicted in Figure 2.5 could be excluded from the final action area based on usage and land cover data.

The environmental fate properties of atrazine were also evaluated to determine which routes of transport are likely to have an impact on the pallid sturgeon. Review of the environmental fate data, as well as physico-chemical properties of atrazine, suggests that transport via runoff and spray drift are likely to be the dominant routes of exposure. In addition, long-range atmospheric transport of pesticides could potentially contribute to atrazine concentrations in the aquatic habitat used by the pallid sturgeon. Given the physico-chemical profile for atrazine and data showing that atrazine has been detected in both air and rainfall samples, the potential for long-range transport from outside the area defined above cannot be precluded. However, the contribution of atrazine via long-range atmospheric transport is not expected to approach the concentrations predicted by modeling (see Section 3.2).

Atrazine transport away from the site of application by both spray drift and volatilization has been documented. Spray drift is addressed as a localized route of transport from the application site in the exposure assessment. However, quantitative models are currently unavailable to address the longer-range transport of pesticides from application sites. The environmental fate profile of atrazine, coupled with the available monitoring data, suggest that long-range transport of volatilized atrazine is a possible route of exposure to non-target organisms; therefore, the full extent of the action area could be influenced by this route of exposure. However, given the amount of direct use of atrazine within the immediate area surrounding the species, the magnitude of documented exposures in rainfall at or below available surface water and groundwater monitoring data concentrations (as well as modeled estimates for surface water), and the lack of modeling tools to predict the impact of long-range transport of atrazine, the extent of the action area is defined by the transport processes of runoff and spray drift only for the purposes of this assessment.

Based on this analysis, the action area for atrazine as it relates to the pallid sturgeon is defined by the entire watersheds depicted in Figure 2.5.

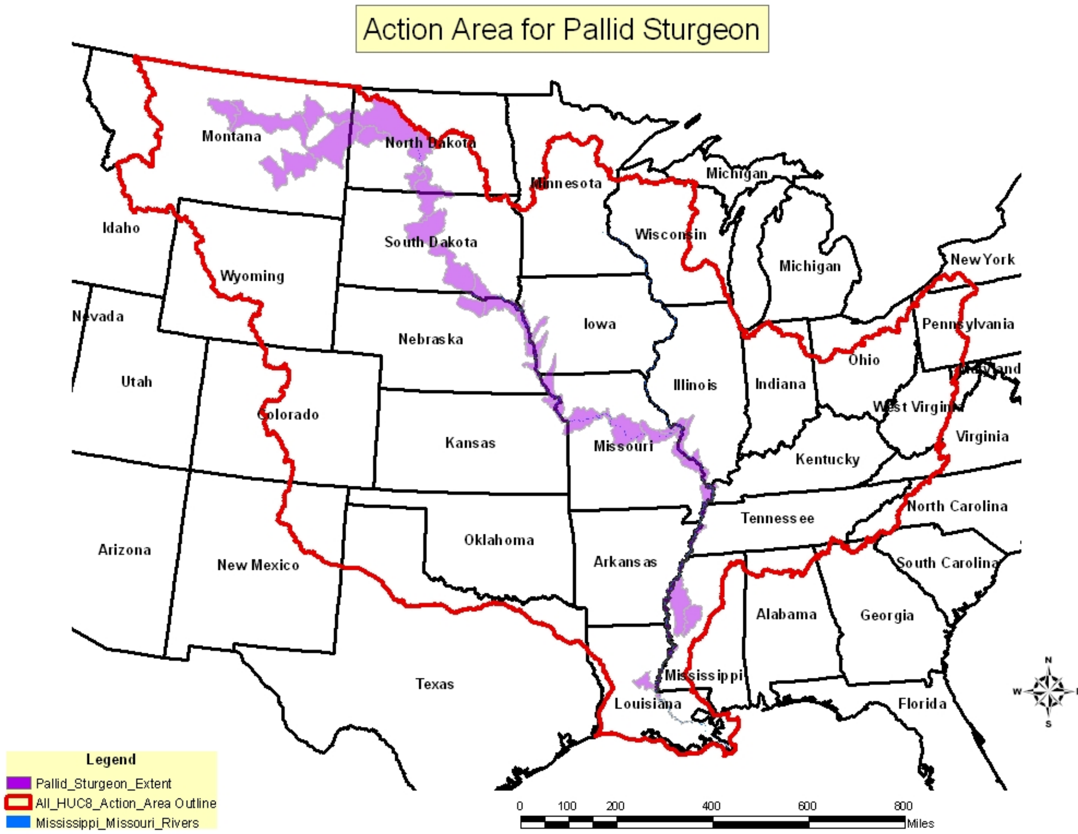


**Figure 2.5 Pallid Sturgeon Action Area Defined by Hydrologic Unit Code (HUC8) Watersheds**

## 2.7 Assessment Endpoints and Measures of Ecological Effect

Assessment endpoints are defined as "explicit expressions of the actual environmental value that is to be protected."[2] Selection of the assessment endpoints is based on valued entities (i.e., pallid sturgeon), the ecosystems potentially at risk (i.e., Missouri, Mississippi, and Atchafalaya Rivers and tributaries), the migration pathways of atrazine (i.e., runoff and spray drift), and the routes by which ecological receptors are exposed to atrazine-related contamination (i.e., direct contact).

Assessment endpoints for the pallid sturgeon include direct toxic effects on the survival, reproduction, and growth of the sturgeon, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. Each assessment endpoint requires one or more "measures of ecological effect," which are defined as changes in the attributes of an assessment endpoint or changes in a surrogate entity or attribute in response to exposure to a pesticide. Specific measures of ecological effect are evaluated based on acute and chronic toxicity information from registrant-submitted guideline tests that are

[2] From U.S. EPA (1992). *Framework for Ecological Risk Assessment.* EPA/630/R-92/001.

performed on a limited number of organisms. Additional ecological effects data from the open literature, including effects data on aquatic freshwater microcosm and mesocosm data, were also considered.

Measures of effect from microcosm and mesocosm data provide an expanded view of potential indirect effects of atrazine on aquatic organisms, their populations, and communities in the laboratory, in simulated field situations, and in actual field situations. With respect to the microcosm and mesocosm data, threshold concentrations were determined from realistic and complex time-variable atrazine exposure profiles (chemographs) for modeled aquatic community structure changes. Methods were developed to estimate ecological community responses for monitoring data sets of interest based on their relationship to micro- and mesocosm study results, and thus to determine whether a certain exposure profile within a particular use site and/or action area may have exceeded community-level threshold concentrations. Ecological modeling with the Comprehensive Aquatic Systems Model (CASM) (Bartell et al., 2000; Bartell et al., 1999; and DeAngelis et al., 1989) was used to integrate direct and indirect effects of atrazine to indicate changes to aquatic community structure and function.

A complete discussion of all the toxicity data available for this risk assessment, including use of CASM and associated aquatic community-level threshold concentrations, and the resulting measures of ecological effect selected for each taxonomic group of concern, is included in Section 4 of this document. A summary of the assessment endpoints and measures of ecological effect selected to characterize potential pallid sturgeon risks associated with exposure to atrazine is provided in Table 2.2.

**Table 2.2 Summary of Assessment Endpoints and Measures of Ecological Effect**

| Assessment Endpoint | Measures of Ecological Effect |
|---|---|
| 1. Survival, growth, and reproduction of pallid sturgeon individuals via direct effects | 1a. Rainbow trout acute $LC_{50}$<br>1b. Brook trout chronic NOAEC |
| 2. Survival, growth, and reproduction of pallid sturgeon individuals via indirect effects on prey (i.e., freshwater invertebrates and fish) | 2a. Midge acute $EC_{50}$ and 1a<br>2b. Scud chronic NOAEC and 1b<br>2c Sensitivity distribution of acute $EC/LC_{50}$ data for freshwater invertebrates that are potential food items for the pallid sturgeon |
| 3. Survival, growth, and reproduction of pallid sturgeon individuals via indirect effects on habitat and/or primary productivity (i.e., aquatic plant community) | 3a. Vascular plant (duckweed) acute $EC_{50}$<br>3b. Non-vascular plant (freshwater algae) acute $EC_{50}$<br>3c. Microcosm/mesocosm threshold concentrations showing aquatic primary productivity community-level effects |
| 4. Survival, growth, and reproduction of pallid sturgeon individuals via indirect effects on terrestrial vegetation (riparian habitat) required to maintain acceptable water quality and spawning habitat | 4a. Monocot and dicot seedling emergence $EC_{25}$<br>4b. Monocot and dicot vegetative vigor $EC_{25}$ |

## 2.8 Conceptual Model

### 2.8.1 Risk Hypotheses

Risk hypotheses are specific assumptions about potential adverse effects (i.e., changes in assessment endpoints) and may be based on theory and logic, empirical data, mathematical models, or probability models (U.S. EPA, 1998). For this assessment, the risk is stressor-linked, where the stressor is the release of atrazine to the environment. The following risk hypotheses are presumed for this endangered species assessment:

- Atrazine in surface water and/or runoff/drift from treated areas may directly affect the pallid sturgeon by causing mortality or adversely affecting growth or fecundity;
- Atrazine in surface water and/or runoff/drift from treated areas may indirectly affect the pallid sturgeon by reducing or changing the composition of prey populations;
- Atrazine in surface water and/or runoff/drift from treated areas may indirectly affect the pallid sturgeon by reducing or changing the composition of the aquatic plant community in the Missouri, Mississippi, and Atchafalaya Rivers and tributaries, thus affecting primary productivity and/or cover; and
- Atrazine in surface water and/or runoff/drift from treated areas may indirectly affect the pallid sturgeon by reducing or changing the composition of the terrestrial plant community (i.e., riparian habitat) required to maintain acceptable water quality and spawning habitat for the pallid sturgeon.

### 2.8.2 Diagram

The conceptual model is a graphic representation of the structure of the risk assessment. It specifies the stressor (atrazine), release mechanisms, abiotic receiving media, biological receptor types, and effects endpoints of potential concern. The conceptual model for the atrazine endangered species assessment for the pallid sturgeon is shown in Figure 2.6. Exposure routes shown in dashed lines are not quantitatively considered because the contribution of those potential exposure routes to potential risks to the pallid sturgeon is expected to be negligible.

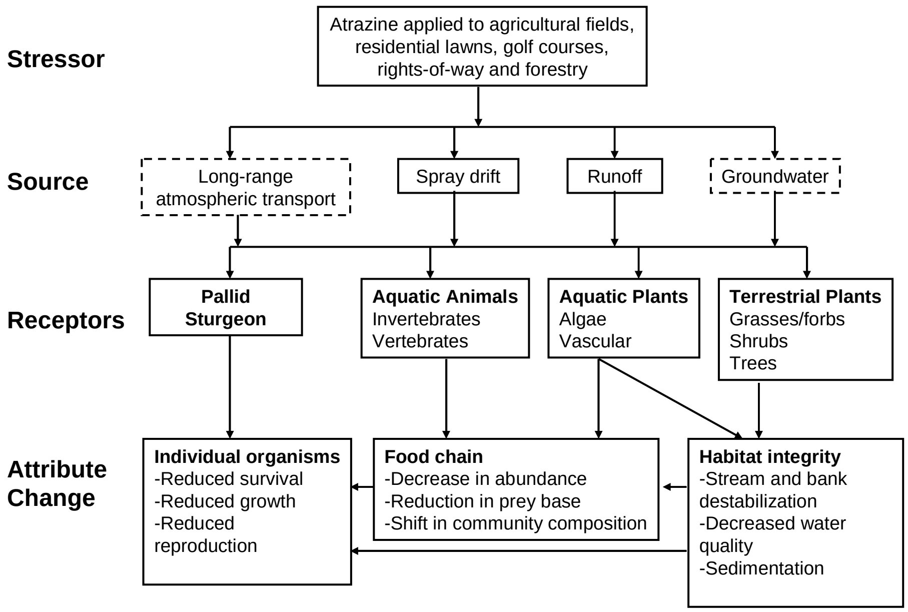


**Figure 2.6 Conceptual Model for Pallid Sturgeon**

The conceptual model provides an overview of the expected exposure routes for pallid sturgeon within the atrazine action area previously described in Section 2.6. In addition to freshwater aquatic vertebrates including the pallid sturgeon and fish food items, other aquatic receptors on which the sturgeon depends for survival, growth or reproduction that may be potentially exposed to atrazine include freshwater invertebrates and aquatic plants. For freshwater vertebrate and invertebrate species, the major routes of exposure are considered to be via the respiratory surface (gills) or the integument. Direct uptake and adsorption are the major routes of exposure for aquatic plants. Direct effects to freshwater invertebrates and aquatic plants resulting from exposure to atrazine may indirectly affect the pallid sturgeon via reduction in food and habitat availability. The available data indicate that atrazine is not likely to bioconcentrate in aquatic food items, with fish bioconcentration factors (BCFs) ranging from 2 to 8.5 (U.S. EPA, 2003c). Therefore, bioconcentration of atrazine in sturgeon via the diet was not considered as a route of exposure.

In addition to aquatic receptors, terrestrial plants may also be exposed to spray drift and runoff from atrazine use in the vicinity of the pallid sturgeon's range. Impacts to riparian vegetation adjacent to or upstream from spawning areas of the pallid sturgeon may adversely affect sturgeon egg development and reduce the amount of suitable spawning habitat via increased sedimentation.

The source and mechanism of release of atrazine into surface water are ground and aerial application via foliar spray and coated fertilizer granules to agricultural (i.e., corn, sorghum, and fallow/idle land) and non-agricultural crops (i.e., golf courses, residential lawns, rights-of-way, and forestry). Surface water runoff from the areas of atrazine application is assumed to follow topography, resulting in direct runoff to aquatic habitat within the range of the pallid sturgeon. Spray drift and runoff of atrazine may also affect the foliage and seedlings of terrestrial plants that comprise the riparian habitat surrounding rivers where pallid sturgeon reside. Additional release mechanisms include spray drift and atmospheric transport via volatilization, which may potentially transport site-related contaminants to the surrounding air. Atmospheric transport is not considered as a major route of exposure for this assessment because the magnitude of documented exposures in rainfall are at or below available surface water monitoring data concentrations, as well as modeled estimates of exposure.

## 2.9 Analysis Plan

The purpose of this assessment is to make an "effects determination" for the pallid sturgeon (*Scaphirhynchus albus*) by evaluating the potential direct and indirect effects of the herbicide atrazine on the survival, growth, and reproduction of this Federally endangered species. This assessment was completed in accordance with the procedures outlined in the Agency's Overview Document (U.S. EPA, 2004) and the Services' Evaluation Memorandum (USFWS/NMFS, 2004b).

Atrazine is used throughout the United States on a number of agricultural crops (primarily corn, sorghum, and sugarcane) and on non-agricultural sites (including residential uses, forestry, and turf). Although the action area is likely to encompass a large area of the United States, given atrazine's use, the scope of this assessment limits consideration of the overall action area to those portions that are applicable to the protection of the pallid sturgeon. Specifically, the action area for the pallid sturgeon includes the Missouri, Mississippi, and Atchafalaya Rivers, their tributaries, and all watersheds that drain to these major river basins. In general, the pallid sturgeon resides in large, turbid, free-flowing rivers.

Screening-level estimates of aquatic exposure are based on PRZM/EXAMS modeling, which assumes a static non-flowing water body. Terrestrial plant exposure concentrations were estimated using OPP's TerrPlant model (U.S. EPA, 2007d; Version 1.2.2), considering use conditions likely to occur in the watersheds where the sturgeon occurs. Screening-level EECs were modeled for agricultural (corn, sorghum, sugarcane, fallow/idle land) and non-agricultural (forestry, turf, residential) uses in accordance with the label. The non-flowing nature of the standard water body provides a reasonable estimation of peak exposures for many smaller headwater streams found in agricultural areas; however, it appears to overestimate exposures for longer time periods and for flowing water bodies. Given that exposure concentrations based on the standard ecological water body are likely to overestimate exposure for the pallid sturgeon (because this species requires strong currents and turbid water in main channel habitats of large rivers), additional flow-adjusted modeling was used together with available monitoring data to refine atrazine exposures in flowing waters. It is expected that atrazine exposure concentrations, particularly longer term exposures, will decrease with distance downstream from the site of application due to increased discharge rates (hence less residence time for the compound) and greater dilution from runoff water from non-treated areas.

A robust set of surface water monitoring data, which is described in further detail in Section 3.2.6, is available for atrazine. Although targeted atrazine monitoring data are available from the Ecological Monitoring Program, this data set was not considered as appropriate for the pallid sturgeon because the samples were collected from smaller order streams where pallid sturgeon do not occur (typically $2^{nd}$ or $3^{rd}$ order streams while the sturgeon resides in rivers of $8^{th}$ order or higher). The USGS NASQAN monitoring data for big river basins in the United States was considered as the most directly relevant to the pallid sturgeon, given the species' habitat requirements (large turbid rivers with high volume and fast flow) as these sites typically represent high order waters.

The assessment endpoints for the pallid sturgeon include direct toxic effects on the survival, reproduction, and growth of the sturgeon itself, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. Direct effects to the pallid sturgeon are based on toxicity information for freshwater fish. Given that the sturgeon's prey items and habitat requirements are dependent on the availability of freshwater fish and aquatic invertebrates, aquatic plants, and terrestrial plants (i.e., riparian habitat), toxicity information for these taxonomic groups is also discussed. In addition to the registrant-submitted and open literature toxicity information, indirect effects to the pallid sturgeon via impacts to aquatic plant community structure and function are also evaluated based on time-weighted threshold concentrations that correspond to potential aquatic plant community-level effects.

Degradates of atrazine include hydroxyatrazine (HA), deethylatrazine (DEA), deisopropylatrazine (DIA), and diaminochloroatrazine (DACT). Comparison of available toxicity information for the degradates of atrazine indicates lesser aquatic toxicity than the parent for freshwater and estuarine/marine fish, aquatic invertebrates, and aquatic plants. Although degradate toxicity data are not available for terrestrial plants, lesser toxicity is assumed, given the available ecotoxicological information for other taxonomic groups including aquatic plants and the likelihood that the degradates of atrazine may lose efficacy as an herbicide. Because degradates are not of greater toxicological concern than atrazine, concentrations of the atrazine degradates are not assessed further, and the focus of this assessment is parent atrazine.

Risk quotients (RQs) are derived as quantitative estimates of potential high-end risk. Acute and chronic RQs are compared to the Agency's levels of concern (LOCs) to identify instances where atrazine use within the action area has the potential to adversely affect the pallid sturgeon via direct toxicity or indirectly based on direct effects to their food supply (i.e., freshwater fish and invertebrates) or habitat (i.e., aquatic plants and terrestrial riparian vegetation). When RQs for a particular type of effect are below LOCs, the pesticide is considered to have "no effect" on the species. Where RQs exceed LOCs, a potential to cause adverse effects is identified, leading to a conclusion of "may affect." If a determination is made that use of atrazine within the action area "may affect" the pallid sturgeon, additional information is considered to refine the potential for exposure and effects, and the best available information is used to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that are "likely to adversely affect" the pallid sturgeon.

## 3. Exposure Assessment

### 3.1 Label Application Rates and Intervals

Atrazine labels may be categorized into two types: labels for manufacturing uses (including technical grade atrazine and its formulated products) and end-use products. Technical products, which contain atrazine of high purity, are not used directly in the environment, but instead are used to make formulated products, which can be applied in specific areas to control weeds. The formulated product labels legally limit atrazine's potential use to only those sites that are specified on the labels and under the conditions of use (rate, timing, etc.) specified on the label..

In the January and October 2003 IREDs (U.S. EPA, 2003a and b), EPA stipulated numerous changes to the use of atrazine including label restrictions and other mitigation measures designed to reduce risk to human health and the environment. Specifically pertinent to this assessment are provisions of a Memorandum of Agreement (MOA) between the Agency and atrazine registrants. In the MOA, the Agency stipulated that certain label changes must be implemented on all manufacturing-use product labels for atrazine and on all end-use product labels for atrazine prior to the 2005 growing season. These label changes included cancellation of certain uses, reduction in application rates, and requirements for harmonization across labels including setbacks from waterways. Specifically, the label changes prohibit atrazine use within 50 feet of sinkholes, 66 feet of intermittent and perennial streams, and 200 feet of lakes and reservoirs.

While these setbacks were required to reduce atrazine deposition to water bodies as a result of spray drift, it is expected that they will also result in a reduction in loading due to runoff across the setback zone; however, current models do not address this reduction quantitatively. Therefore, these restrictions are not quantitatively evaluated in this assessment. A qualitative discussion of the potential impact of these setbacks on estimated environmental concentrations of atrazine for the pallid sturgeon is discussed further in Section 3.2.3. Table 3.1 provides a summary of label application rates for atrazine uses evaluated in this assessment.

Currently registered non-agricultural uses of atrazine within the action area include residential areas such as playgrounds and home lawns, turf (golf courses and recreational fields), rights-of-way, and forestry. Agricultural uses within the action area include corn, sorghum, fallow/idle land[3], and sugarcane. Other agricultural uses (macadamia nut and guava) are not present in the action area.

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[3] Fallow or idle land is defined by the Agency as arable land not under rotation that is set at rest for a period of time ranging from one to five years before it is cultivated again, or land usually under permanent crops, meadows or pastures, which is not being used for that purpose for a period of at least one year. Arable land,

Atrazine is formulated as liquid, wettable powder, dry flowable, and granular formulations. Application methods for the agricultural uses include ground application (the most common application method), aerial application, band treatment, and incorporated treatment; and application using various sprayers (low-volume, hand held, directed) for liquids, and spreaders for granulars. Risks from ground boom and aerial applications are considered in this assessment because they are expected to result in the highest off-target levels of atrazine due to generally higher spray drift levels. Ground boom and aerial modes of application tend to use lower volumes applied in finer sprays than applications coincident with sprayers and spreaders, and thus have a higher potential for off-target movement via spray drift.

**Table 3.1 Atrazine Label Application Information for the Pallid Sturgeon Assessment[a]**

| Scenario | Maximum Application Rate (lbs/acre) | Maximum Number of Applications | Formulation | Method of Application | Interval Between Applications |
|---|---|---|---|---|---|
| Forestry | 4.0 | 1 | Liquid | Aerial and Ground | NA |
| Residential | 2.0 | 2 | Granular | Ground | 30 days |
| Residential | 1.0 | 2 | Liquid | Ground | 30 days |
| Rights-of-Way | 1.0 | 1 | Liquid | Ground | NA |
| Fallow/ Idle land | 2.25 | 1 | Liquid | Ground and Aerial | NA |
| Corn | 2.5 | 2 | Liquid | Ground and Aerial | 30 days |
| Sorghum | 2.0 | 1 | Liquid | Ground and Aerial | NA |
| Turf | 2.0 | 2 | Granular | Ground | 30 days |
| Turf | 1.0 | 2 | Liquid | Ground | 30 days |

which is normally used for the cultivation of temporary crops, but which is temporarily used for grazing, is also included.

| Table 3.1 Atrazine Label Application Information for the Pallid Sturgeon Assessment[a] | | | | | |
|---|---|---|---|---|---|
| **Scenario** | **Maximum Application Rate (lbs/acre)** | **Maximum Number of Applications** | **Formulation** | **Method of Application** | **Interval Between Applications** |
| Sugarcane | 4.0 | 3 (not to exceed 10 lb/year) | Liquid | Aerial | 60 days |
| [a] Based on 2003 IRED and Label Change Summary Table memorandum dated June 12, 2006 (U.S. EPA, 2006b). | | | | | |

## 3.2 Aquatic Exposure Assessment

As discussed in Section 2.5 and Appendix C, the pallid sturgeon resides principally in major rivers and their principal tributaries in the mid-continent of the United States. Specifically, the pallid sturgeon is found in the Mississippi and Missouri Rivers and a few tributaries of these two major rivers (including the Atchafalaya River in Louisiana). The action area includes the entire watershed of rivers in the areas defined above and is presented graphically in Figure 2.5. In general, the pallid sturgeon resides in major rivers that are typically classified as greater than stream order 8 using the Strahler system. Further discussion of the species' required flow regimes may be found in Section 2.5 and Appendix C, which details the life history information for the pallid sturgeon.

### 3.2.1 Introduction

The assessment of exposure within the action area is dependent upon a combination of modeling and monitoring data. In accordance with the Overview Document (U.S. EPA, 2004), screening-level exposures were based on modeling which assumes a static water body. Available monitoring data for atrazine, as well as refined flow-adjusted modeling (adjusted based on flow data from rivers where the pallid sturgeon has been observed), were used to refine the screening-level modeled exposures.

For this assessment, screening-level modeling using a static water body indicates long-term (e.g., 30-day average) exposure concentrations that are higher than concentrations seen in most monitoring data. Refined modeling based on flowing water suggests that concentrations in flowing water are lower than screening-level EECs particularly for longer durations of exposure (e.g., 30-day rolling average). This is not unexpected given that monitored concentrations, particularly for longer durations of exposure, will decrease with distance downstream. Although monitoring targeted to the upper 20$^{th}$ percentile vulnerable watersheds (based on WARP modeling[4]) indicates that, under certain conditions, long-term atrazine concentrations can be higher than those estimated by flow-adjusted modeling, these monitoring data represent low-order streams (generally 2$^{nd}$ and 3$^{rd}$ order), while the rivers where the pallid sturgeon occur are 8$^{th}$ order and greater.

[4] Watershed Regression of Pesticides model (USGS, 2005) at http://pubs.usgs.gov/circ/2005/1291/

With the exception of USGS NASQAN data for large rivers, the bulk of the available targeted monitoring data is collected from areas where the pallid sturgeon does not reside (i.e. low order streams). Given the nature of the targeted data (typically 2nd and 3rd order streams highly vulnerable to runoff) and the habitat where the species resides (typically 8th order and higher streams with high flow rates, drainage areas, and volume), the targeted data are not considered to be representative of exposures where the pallid sturgeon occurs. Available non-targeted monitoring data (i.e., monitoring data in which the study design was not specifically targeted to detect atrazine in high-use areas) suggest a similar pattern of exposure as the targeted data; however, many of these sites are located in the most vulnerable areas represented by the targeted data and are also not representative of large rivers where the pallid sturgeon occurs.

Screening-level EECs based on the PRZM/EXAMS static water body are used in the risk estimation to derive initial RQs and distinguish between “no effect” and may affect” determinations. Refined EECs are used to characterize exposure in the risk description for pallid sturgeon based on a combination of flow-adjusted EECs and available monitoring data. These refined exposure estimates are used to distinguish whether the pallid sturgeon is likely or not likely to be adversely affected by the action.
Further detail on the standard modeling, refined modeling, monitoring data evaluation, and characterization of exposure is presented in the following sections.

### 3.2.2 Modeling Approach

Screening-level risk quotients (RQs) were initially based on EECs derived using the Pesticide Root Zone Model/Exposure Analysis Modeling System (PRZM/EXAMS) standard ecological pond scenario, according to the methodology specified in the Overview Document (U.S. EPA, 2004). While peak concentrations predicted with the static water body are generally consistent with monitored values for lower-order streams, longer-term EECs likely overestimate exposure based on modeling with the static water body. Further, the pallid sturgeon resides in major rivers with high flow rates and corresponding dilution potential. Therefore, additional flow-adjusted modeling (Section 3.2.5) and available monitoring data (Section 3.2.6) are used to characterize and refine potential exposures for the pallid sturgeon. Where LOCs for direct/indirect effects are exceeded based on the modeled screening-level EECs using the static water body (i.e., “may affect”), the refined modeling and available monitoring data were used to differentiate “may affect, but not likely to adversely affect” from “may affect and likely to adversely affect” determinations for the assessed species.

The general conceptual model of exposure for this assessment is that the highest exposures are expected to occur in the headwater streams adjacent to agricultural fields and other non-agricultural use sites (residential, right-of-way, turf, and forestry). Many of the streams and rivers within the action area defined for this assessment are in close proximity to both agricultural and non-agricultural use sites (Figures 2.2 and 2.3). The action area was divided into four representative regions, and modeling scenarios were selected to represent each area. These four areas represent the western (Arkansas, Missouri, and northeastern Kansas), southern (Mississippi, Alabama, Georgia, western Tennessee, and Louisiana), northern (Kentucky, Ohio, Illinois, and Indiana), and the upper Great Plains (Iowa, Nebraska, South Dakota, North Dakota, and Montana) regions of the action area (Figure 3.1).


**Figure 3.1 Regionalization of Pallid Sturgeon Action Area**

Available usage data (Kaul et al., 2005) suggest that the heaviest usage of atrazine relative to the action area is likely to be in a band stretching from western Illinois across Iowa to central Nebraska with decreasing intensity south and north of this area. As noted above, the action area was segmented into regions to allow for modeling that covers the expected range of runoff vulnerability, as predicted by the WARP model. All existing PRZM scenarios were evaluated, and a subset was selected for use in this assessment. The scenarios were selected to provide a spatial context to predicted exposures.

Currently a suite of 63 PRZM standard scenarios and 7 Barton Springs scenarios (recently developed for use in the Barton Springs salamander endangered species risk assessment (U.S. EPA, 2006c)) are available for use in ecological risk assessments representing predominantly agricultural uses. Each scenario is intended to represent a high-end exposure setting for a particular crop. Scenario locations are selected based on various factors including crop acreage, runoff and erosion potential, climate, and agronomic practices. Once a location is selected, a scenario is developed using locally specific soil, climatic, and agronomic data. Each PRZM scenario is assigned a specific climatic weather station providing 30 years of daily weather values.

Specific scenarios were selected for use in this assessment using two criteria. First, an evaluation of all available PRZM scenarios was conducted, and those scenarios that represent atrazine uses (e.g., Ohio corn) were selected for modeling. Weather information was assigned to these scenarios at development. Second, an additional suite of scenarios was identified to represent both agricultural and non-agricultural uses for which scenarios within the action area are not available (e.g., Barton Springs residential). These scenarios were used in the assessment as surrogates for atrazine uses without current scenarios (e.g., Oregon Christmas tree as surrogate for forestry) and to provide geographic coverage where no current scenario exists (e.g., Ohio corn scenario modeled using Springfield, Missouri weather data).

Scenarios selected as surrogates for this assessment (e.g., Oregon Christmas tree and Kansas sorghum) are considered to be conservative representations of exposure in the action area because they were developed using a hydrologic group C soil with relatively high curve numbers and moderate slopes. These are the most important PRZM scenario parameters for generating runoff coupled with rainfall, which is higher within the action area than the areas where the scenarios were originally developed. In addition, the curve numbers and slopes are expected to be higher than those present in the action area, which generally have lower slopes and less runoff-prone soils.

Further description (metadata) and copies of the existing PRZM scenarios may be found at the following websites.

http://www.epa.gov/oppefed1/models/water/index.htm#przmexamsshell

http://www.epa.gov/oppefed1/models/water/przmenvironmentdisclaim.htm

For this assessment, available PRZM weather stations were associated with watersheds highly vulnerable to atrazine runoff based on WARP predictions. As shown in Figure 3.2, weather stations associated with Sioux City, Iowa; Springfield, Missouri; Evansville/Indianapolis, Indiana; and Mobile, Alabama were selected to represent highly vulnerable locations for modeling surrogate scenarios (both agricultural and non-agricultural). As such, surrogate scenarios used to model this region were run using weather data from these locations to represent exposures within the entire region. There is uncertainty associated with using a modeling scenario developed for a given geographic area with climatic data from another area. However, runoff is driven primarily by hydrologic soil type (defining the curve number) and the rainfall. Thus, a scenario that represents a similar hydrologic soil type to the area being assessed and representative weather data for that region are expected to yield high end exposures.

For this assessment, the following corn scenarios were modeled to represent the following four regions of the action area: 1) North Dakota scenario using weather data from Fargo for the upper Great Plains states; 2) Illinois and Ohio scenarios using weather data from Peoria and Dayton, respectively for the northern tier states; 3) Mississippi scenario using the weather data from Mobile, Alabama for the southern tier states; and 4) the Ohio scenario using the Springfield, Missouri weather data for the western tier states. The Kansas sorghum scenario (the only existing sorghum scenario) was modeled with local weather stations including Topeka, Kansas (western states), Sioux City, Iowa (upper Great Plains states), and Mobile, Alabama (southern states). Finally, the Louisiana sugarcane scenario was modeled (using the standard Baton Rouge weather data) to represent atrazine use on sugarcane in southern Louisiana (for the southern region only).

Currently, the only non-agricultural scenarios available for use in aquatic exposure assessment are those developed specifically for the Barton Springs Salamander Endangered Species Risk Assessment (U.S. EPA, 2006c). For the Barton Springs salamander assessment, a suite of non-agricultural scenarios was developed including a residential, impervious (to be used in tandem with the residential scenario), and rights-of-way scenarios. These scenarios were used in this assessment in a manner similar to the agricultural scenarios described above. Each scenario was modeled using a representative weather station for each region. For example, the residential scenario was modeled using the Mobile, Alabama weather data to represent exposures in the southern states, while the same scenario was modeled with the Sioux City, Iowa weather data to represent the upper Great Plains states, the Indianapolis weather data to represent the northern tier states, and the Springfield, Missouri weather data to represent the western states. Figure 3.2 shows the locations of these weather stations relative to the action area. A summary of all the modeled scenarios along with associated weather information is included in Table 3.2.

Both the agricultural and non-agricultural scenarios were used within the standard framework of PRZM/EXAMS modeling using the standard graphical user interface (GUI) shell, PE4v01.pl. The models and GUI used in this assessment may be found at the following website:

http://www.epa.gov/oppefed1/models/water/index.htm

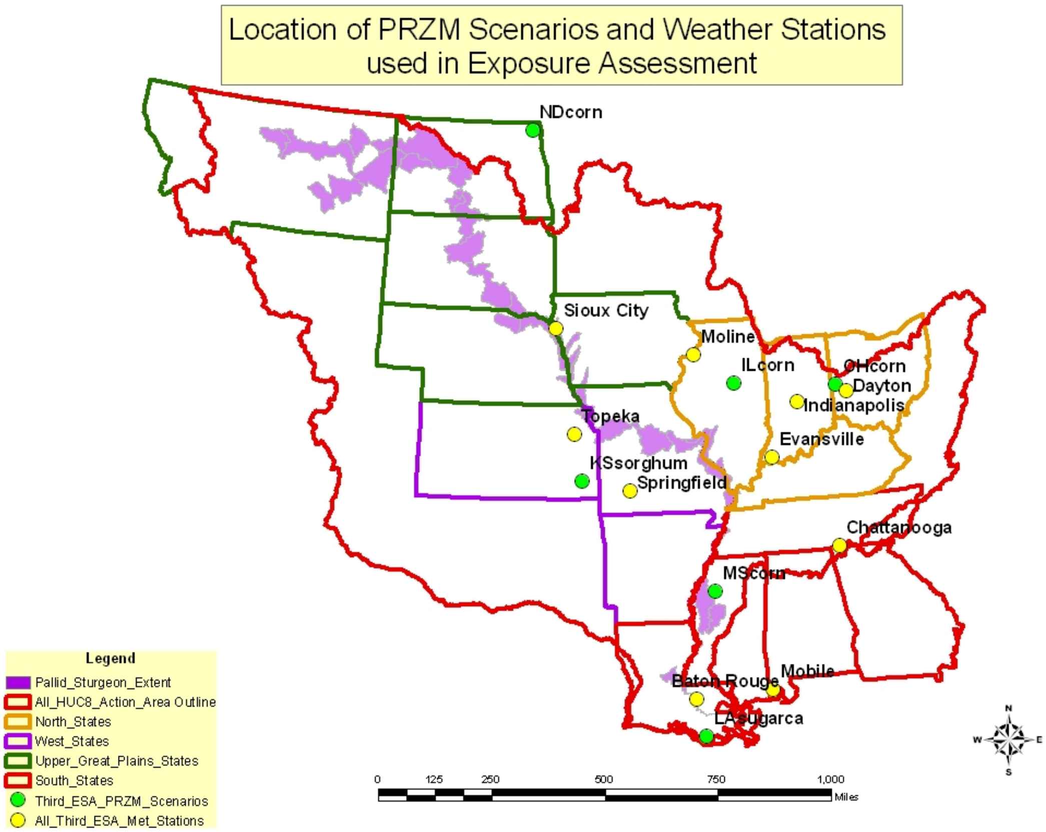


**Figure 3.2 Locations of Various Weather Stations Used to Model Non-Agricultural Uses (Residential, Right-of-Way, Turf, and Forestry)**

| Table 3.2 Summary of PRZM Scenarios | | | | |
|---|---|---|---|---|
| **Region** | **Use** | **Scenario** | **First Application** | **Weather Station (WBAN #)** |
| South | Corn | MS corn | April 1 | Mobile, AL (13894) |
| | Sorghum | KS sorghum | May 1 | Mobile, AL (13894) |
| | Fallow | BSS meadow[a] | November 15 | Mobile, AL (13894) |
| | Residential | BSS residential | April 1 | Mobile, AL (13894) |
| | Right-of-way | BSS row | June 1 | Mobile, AL (13894) |
| | Forestry | OR xmastree | June 1 | Mobile, AL (13894) |
| | Turf | BSS turf | April 1 | Mobile, AL (13894) |
| | Sugarcane | LA sugarcane | August 1 | Baton Rouge, LA (13970) |
| North | Corn | OH corn<br>IL corn | April 15 | Dayton, OH (93815)<br>Moline, IL (14923) |
| | Sorghum | KS sorghum | May 1 | Evansville, IN (93817) |
| | Fallow | BSS meadow | October 15 | Evansville, IN (93817) |
| | Residential | BSS residential | May 1 | Indianapolis, IN (93819) |
| | Right-of-way | BSS row | June 1 | Indianapolis, IN (93819) |
| | Forestry | OR xmastree | June 1 | Evansville, IN (93819) |
| | Turf | BSS turf | May 1 | Indianapolis, IN (93819) |
| West | Corn | IL corn | April 15 | Springfield, MO (13995) |
| | Sorghum | KS sorghum | May 1 | Topeka, KS (13996) |
| | Fallow | BSS meadow | November 1 | Springfield, MO (13995) |
| | Residential | BSS residential | April 15 | Springfield, MO (13995) |
| | Right-of-way | BSS row | June 1 | Springfield, MO (13995) |
| | Forestry | OR xmastree | June 1 | Springfield, MO (13995) |
| | Turf | BSS turf | April 15 | Springfield, MO (13995) |
| Upper Great Plains | Corn | ND corn | April 1 | Fargo, ND (14914) |
| | Sorghum | KS sorghum | May 1 | Sioux City, SD (14943) |

| Table 3.2 Summary of PRZM Scenarios | | | | |
|---|---|---|---|---|
| **Region** | **Use** | **Scenario** | **First Application** | **Weather Station (WBAN #)** |
| | Fallow | BSS meadow | November 1 | Sioux City, SD (14943) |
| | Residential | BSS residential | May 1 | Sioux City, SD (14943) |
| | Right-of-way | BSS row | June 1 | Sioux City, SD (14943) |
| | Forestry | OR xmastree | June 1 | Sioux City, SD (14943) |
| | Turf | BSS turf | May 1 | Sioux City, SD (14943) |

[a] BSS scenarios developed for Barton Springs Salamander (BSS) Endangered Species Risk Assessment (U.S. EPA, 2006c).

Peak concentrations, as well as rolling time-weighted averages of 14 days, 21 days, 30 days, 60 days, and 90 days, were derived for comparison with the appropriate ecotoxicity endpoints (including the community-level threshold concentrations) for atrazine.
The 30-year time series output file was used to recalculate the peak, 14-day, 21-day, 30-day, 60-day, and 90-day rolling averages at the 90$^{th}$ percentile. All model outputs were post-processed manually using Microsoft Excel to provide the equivalent of the standard one-in-ten-year return frequency exposures, as predicted by PRZM/EXAMS. A sample of how this post-processing was conducted may be found in the previous atrazine assessments for the Chesapeake Bay and Alabama Sturgeon (U.S. EPA, 2007b and c).

Additional information on the modeling approach for the non-agricultural residential, rights-of-way, and forestry use scenarios may also be found in the previous atrazine endangered species risk assessments (U.S. EPA, 2007b and c).

### 3.2.3 Model Inputs

The estimated concentrations from surface water sources were calculated using Tier II PRZM (Pesticide Root Zone Model) and EXAMS (Exposure Analysis Modeling System). PRZM is used to simulate pesticide transport as a result of runoff and erosion from a standardized watershed, and EXAMS estimates environmental fate and transport of pesticides in surface waters. The linkage program shell (PE4v01.pl) that incorporates the site-specific scenarios was used to run these models.

Scenarios used in this assessment consist of agricultural uses for corn, sorghum, and surgarcane developed previously. Other scenarios representing areas outside the action area were modeled using weather stations specific to the action area in order to represent atrazine uses where no scenario existed within the action area including one agricultural use (fallow/idle land) and several non-agricultural uses (residential, turf, forestry, and rights-of-way). All scenarios were modeled using local weather data as described above. Linked use site-specific scenarios and meteorological data were used to estimate exposure as a result of specific use for each modeling scenario. The PRZM/EXAMS model was used to calculate concentrations using the standard ecological water body scenario in EXAMS. Weather and agricultural practices were simulated over 30 years so that the 1–in-10-year exceedance probability at the site was estimated for the standard ecological water body.

One outcome of the 2003 IRED process was a modification to all existing atrazine labels that requires setback distances around intermittent/perennial streams and lakes/reservoirs. The label changes specify setback distances of 66 feet and 200 feet for atrazine applications surrounding intermittent/perennial streams and lakes/reservoirs, respectively. The Agency incorporated these distances into this assessment and has modified the standard spray drift assumptions accordingly using AgDRIFT model (Version 2.01) to estimate the impact of a setback distance of 66 feet on the fraction of drift reaching a surface water body. The revised spray drift percentages, which are incorporated into the PRZM/EXAMS modeling, are 0.6% for ground applications and 6.5% for aerial applications.

Models to estimate the effect of setbacks on load reduction for runoff are not currently available. It is well documented that vegetated setbacks can result in a substantial reduction in pesticide load to surface water (USDA, NRCS, 2000). Specifically for atrazine, data reported in the USDA study indicate that well vegetated setbacks have been documented to reduce atrazine loading to surface water by as little as 11% and as much as 100% of total runoff compared to the loading without a setback. It is expected that the presence of a well-vegetated setback between the site of atrazine application and receiving water bodies would result in reduction in loading. Therefore, the aquatic EECs presented in this assessment are likely to over-estimate exposure in areas with well-vegetated setbacks.

The date of first application was developed based on several sources of information including data provided by the Agency's Biological and Economic Analysis Division (BEAD) and Crop Profiles maintained by the USDA. More detail on the crop profiles may be found at:

http://pestdata.ncsu.edu/cropprofiles/cropprofiles.cfm

The appropriate PRZM input parameters were selected from the environmental fate data submitted by the registrant and in accordance with US EPA-OPP EFED water model parameter selection guidelines, Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides, Version 2.3, February 28, 2002. These parameters are consistent with those used in both the 2003 IRED (U.S. EPA, 2003a) and the cumulative triazine risk assessment (U.S. EPA, 2006a) and are summarized in Table 3.3. More detail on these assessments may be found at:

http://www.epa.gov/oppsrrd1/REDs/atrazine_ired.pdf

http://www.epa.gov/pesticides/cumulative/common_mech_groups.htm#chloro

| **Table 3.3 Summary of PRZM/EZAMS Environmental Fate Data Used for Aquatic Exposure Inputs for Atrazine Pallid Sturgeon Assessment** | | |
|---|---|---|
| **Fate Property** | **Value** | **MRID[a] (or source)** |
| Molecular Weight | 215.7 g | MRID 41379803 |
| Henry's Law Constant | $2.58 \times 10^{-9}$ | MRID 41379803 |
| Vapor Pressure | $3 \times 10^{-7}$ | MRID 41379803 |
| Solubility in Water | 33 mg/l | MRID 41379803 |
| Photolysis in Water | 335 days | MRID 42089904 |
| Aerobic Soil Metabolism Half-life | 152 days | MRID 40431301<br>MRID 40629303<br>MRID 42089906 |
| Hydrolysis | stable | MRID 40431319 |
| Aerobic Aquatic Metabolism (water column) | 304 days | 2x aerobic soil metabolism rate constant |
| Anaerobic Aquatic Metabolism (benthic) | 608 days | MRID 40431323 |
| Koc | 88.78 ml/g | MRID 40431324<br>MRID 41257901<br>MRID 41257902<br>MRID 41257904<br>MRID 41257905<br>MRID 41257906 |
| Application Efficiency | 95 % for aerial<br>99 % for ground | Default value[c] |
| Spray Drift Fraction[b] | 6.5 % for aerial<br>0.6 % for ground | AgDrift adjusted values based on label restrictions |

[a] Master Record Identification (MRID) is a record tracking system used within OPP to manage data submissions to the Agency. Each data submission is given a unique MRID number for tracking purposes.
[b] Spray drift not included in final EEC due to edge-of-field estimation approach.
[c] Inputs determined in accordance with EFED "*Guidance for Chemistry and Management Practice Input Parameters for Use in Modeling the Environmental Fate and Transport of Pesticides*" dated February 28, 2002.

### 3.2.4 Results

As noted above, a total of eight scenarios were evaluated in this assessment. Of these, four were developed as part of the Barton Springs salamander endangered species risk assessment (U.S. EPA, 2006c). Two of the Barton Springs scenarios (residential and rights-of-way) were used in tandem with an impervious scenario, while two (fallow/idle land and turf) are standard PRZM/EXAMS scenarios. The remaining four scenarios (corn, sorghum, sugarcane, and Christmas trees as surrogate for forestry) were taken from existing scenarios developed for other regions of the United States and modeled using local weather data. No new scenarios were developed specifically for this assessment. The results of the modeling are summarized in Table 3.4. An example of the modeling approach and the model input files may be found in Appendix D of the previous endangered species risk assessments for atrazine (U.S. EPA, 2006c, and 2007a, b, and c).

In general, these EECs show a pattern of exposure for all durations that is influenced by the persistence of the compound and the lack of flow through the static water body. Predicted atrazine concentrations, though high across durations of exposure for a single year, do not increase across the 30-year time series; therefore, accumulation is not a concern.

| Table 3.4 Summary of PRZM/EXAMS Output Screening-Level EECs for all Modeled Scenarios | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Region** | **Use Site (see Table 3.2 for Scenarios Used)** | **Application Rate (lbs/acre)** | **No. of Applications** | **90$^{th}$ Percentile of 30 Years of Output** | | | | | | |
| | | | | **Peak EEC (µg/L)** | **14-day EEC (µg/L)** | **21-day EEC (µg/L)** | **30-day EEC (µg/L)** | **60-day EEC (µg/L)** | **90-day EEC (µg/L)** | **Annual Average EEC (µg/L)** |
| South | Corn | 2.0 | 2 (not to exceed 2.5 lbs/year) | 109.1 | 107.8 | 107.0 | 106.3 | 103.9 | 101.4 | 79.7 |
| South | Sorghum | 2.0 | 1 | 63.6 | 62.9 | 62.4 | 61.7 | 59.6 | 57.4 | 47.4 |
| South | Fallow | 2.25 | 1 | 58.8 | 58.2 | 58.0 | 57.6 | 56.6 | 55.6 | 43.7 |
| South | Residential[a] Granular | 2.0 | 2 (not to exceed 4.0 lbs/year) | 19.9 | 19.6 | 19.4 | 19.2 | 18.6 | 17.9 | 14.5 |
| South | Residential[a] Liquid | 1.0 | 2 (not to exceed 2.0 lbs/year) | 14.6 | 14.4 | 14.2 | 14.1 | 13.7 | 13.4 | 9.9 |
| South | Rights-of-way[b] | 1.0 | 1 | 2.4 | 2.4 | 2.4 | 2.4 | 2.3 | 2.2 | 1.7 |
| South | Forestry | 4.0 | 1 | 46.1 | 45.2 | 44.7 | 44.1 | 42.2 | 40.8 | 32.5 |
| South | Turf Granular | 2.0 | 2 (not to exceed 4.0 lbs/year) | 17.9 | 17.7 | 17.7 | 17.7 | 17.6 | 17.1 | 12.5 |
| South | Turf Liquid | 1.0 | 2 (not to exceed 2.0 lbs/year) | 14.8 | 14.6 | 14.4 | 14.3 | 13.7 | 13.1 | 9.6 |
| South | Sugarcane | 4.0 | 3 (not to exceed 10 lbs/year) | 407.5 | 405.2 | 405.1 | 404.8 | 396.5 | 392.7 | 307.5 |

| Region | Use Site (see Table 3.2 for Scenarios Used) | Application Rate (lbs/acre) | No. of Applications | 90[th] Percentile of 30 Years of Output | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak EEC (µg/L) | 14-day EEC (µg/L) | 21-day EEC (µg/L) | 30-day EEC (µg/L) | 60-day EEC (µg/L) | 90-day EEC (µg/L) | Annual Average EEC (µg/L) |
| North | Corn | 2.0 | 2 (not to exceed 2.5 lbs/year) | 100.8 | 100.3 | 99.9 | 99.3 | 97.5 | 96.2 | 80.3 |
| North | Sorghum | 2.0 | 1 | 58.4 | 57.7 | 57.4 | 56.9 | 54.9 | 52.8 | 42.5 |
| North | Fallow | 2.25 | 1 | 51.6 | 51.5 | 51.5 | 51.5 | 51.0 | 50.4 | 32.5 |
| North | Residential[a] Granular | 2.0 | 2 (not to exceed 4.0 lbs/year) | 9.9 | 9.9 | 9.9 | 9.9 | 9.9 | 9.9 | 8.5 |
| North | Residential[a] Liquid | 1.0 | 2 (not to exceed 2.0 lbs/year) | 7.6 | 7.5 | 7.5 | 7.5 | 7.5 | 7.4 | 6.2 |
| North | Rights-of-way[b] | 1.0 | 1 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.5 | 2.1 |
| North | Forestry | 4.0 | 1 | 48.5 | 47.7 | 47.2 | 46.7 | 44.9 | 43.3 | 36.4 |
| North | Turf Granular | 2.0 | 2 (not to exceed 4.0 lbs/year) | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 5.8 |
| North | Turf Liquid | 1.0 | 2 (not to exceed 2.0 lbs/year) | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.5 | 5.7 |
| West | Corn | 2.0 | 2 (not to exceed 2.5 lbs/year) | 92.8 | 91.7 | 91.4 | 90.7 | 88.0 | 85.4 | 72.2 |
| West | Sorghum | 2.0 | 1 | 60.1 | 59.4 | 58.9 | 58.4 | 57.3 | 56.3 | 45.4 |
| West | Fallow | 2.25 | 1 | 103.4 | 103.1 | 103.1 | 103.1 | 103.0 | 103.0 | 67.2 |

| Region | Use Site (see Table 3.2 for Scenarios Used) | Application Rate (lbs/acre) | No. of Applications | 90th Percentile of 30 Years of Output | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak EEC (µg/L) | 14-day EEC (µg/L) | 21-day EEC (µg/L) | 30-day EEC (µg/L) | 60-day EEC (µg/L) | 90-day EEC (µg/L) | Annual Average EEC (µg/L) |
| West | Residential[a] Granular | 2.0 | 2 (not to exceed 4.0 lbs/year) | 11.9 | 11.8 | 11.7 | 11.6 | 11.3 | 11.0 | 7.9 |
| West | Residential[a] Liquid | 1.0 | 2 (not to exceed 2.0 lbs/year) | 9.9 | 9.7 | 9.7 | 9.6 | 9.3 | 9.1 | 6.7 |
| West | Rights-of-way[b] | 1.0 | 1 | 3.8 | 3.8 | 3.8 | 3.8 | 3.6 | 3.5 | 2.9 |
| West | Forestry | 4.0 | 1 | 27.4 | 26.9 | 26.8 | 26.5 | 25.6 | 24.8 | 21.0 |
| West | Turf Granular | 2.0 | 2 (not to exceed 4.0 lbs/year) | 7.2 | 7.1 | 7.0 | 7.0 | 6.7 | 6.5 | 4.1 |
| West | Turf Liquid | 1.0 | 2 (not to exceed 2.0 lbs/year) | 7.6 | 7.5 | 7.5 | 7.5 | 7.4 | 7.2 | 5.3 |
| Upper Great Plains | Corn | 2.0 | 2 (not to exceed 2.5 lbs/year) | 84.8 | 84.0 | 83.6 | 83.5 | 82.3 | 80.8 | 76.0 |
| Upper Great Plains | Sorghum | 2.0 | 1 | 57.2 | 56.6 | 56.3 | 55.8 | 54.4 | 52.8 | 45.5 |
| Upper Great Plains | Fallow | 2.25 | 1 | 49.2 | 49.1 | 49.1 | 49.1 | 49.1 | 48.8 | 41.7 |
| Upper Great Plains | Residential[a] Granular | 2.0 | 2 (not to exceed 4.0 lbs/year) | 10.9 | 10.9 | 10.9 | 10.8 | 10.8 | 10.8 | 8.9 |

| Region | Use Site (see Table 3.2 for Scenarios Used) | Application Rate (lbs/acre) | No. of Applications | 90th Percentile of 30 Years of Output | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak EEC (µg/L) | 14-day EEC (µg/L) | 21-day EEC (µg/L) | 30-day EEC (µg/L) | 60-day EEC (µg/L) | 90-day EEC (µg/L) | Annual Average EEC (µg/L) |
| Upper Great Plains | Residential[a] Liquid | 1.0 | 2 (not to exceed 2.0 lbs/year) | 8.2 | 8.1 | 8.1 | 8.0 | 7.8 | 7.6 | 6.5 |
| Upper Great Plains | Rights-of-way[b] | 1.0 | 1 | 3.3 | 3.2 | 3.2 | 3.2 | 3.1 | 3.0 | 2.6 |
| Upper Great Plains | Forestry | 4.0 | 1 | 64.5 | 61.0 | 60.7 | 60.2 | 58.3 | 56.5 | 50.9 |
| Upper Great Plains | Turf Granular | 2.0 | 2 (not to exceed 4.0 lbs/year) | 10.1 | 10.1 | 10.1 | 10.1 | 10.0 | 9.9 | 7.4 |
| Upper Great Plains | Turf Liquid | 1.0 | 2 (not to exceed 2.0 lbs/year) | 8.2 | 8.1 | 8.1 | 8.0 | 8.0 | 7.9 | 5.8 |

a Assumes 1% overspray of atrazine to the impervious surfaces.
b Assumes only 10% of any watershed is in right-of-way.

### 3.2.5 Additional Modeling Exercises Used to Characterize Potential Exposures

Additional characterization of the screening-level modeling results has been completed, including a characterization of the importance of flowing water, a detailed analysis of monitoring data, and alternative modeling assumptions. These analyses are described in the sections that follow.

#### *3.2.5.1 Impact of Flowing Water on Modeled EECs*

The Agency's standard ecological assessment for aquatic organisms relies on estimates of exposure derived from PRZM/EXAMS using the standard water body. The standard water body is a 1-hectare pond that is 2 meters deep with a total volume of 20,000,000 liters and is modeled without flow. The standard water body was developed in order to provide an approximation of high-end exposures expected in ponds, lakes, and perennial/intermittent streams adjacent to treated agricultural fields. Typically, this has been interpreted as a stream with little or low flow representing low order streams . For pesticides with low to moderate persistence, the standard water body provides a reasonable high-end estimate of exposure in headwater streams and other low flow water bodies for both acute and longer-term exposures. For more persistent compounds, the non-flowing nature of the standard water body provides a reasonable high-end estimate of peak exposure for many streams found in agricultural areas; however, it appears to over-estimate exposure for longer time periods in all but the most static water bodies.

The pallid sturgeon resides in major rivers typified by the Mississippi and Missouri Rivers with moderate to swift currents and classified as $8^{th}$ order or higher using the Strahler classification. Conversely, the monitoring data from the Ecological Monitoring Program represent predominantly $2^{nd}$ and $3^{rd}$ order streams, while the screening-level EEC from modeling with the static water body represent static water and $1^{st}$ order streams. The hydrologic landscape of the pallid sturgeon's action area is diverse and has been broken into four regions (upper Great Plains, north, west, and south), as shown in Figure 3.1. Screening-level EECs for three of these regions (north, west, and south) were previously derived for the Alabama sturgeon (U.S. EPA, 2007b) and eight listed mussels (U.S. EPA 2007c) atrazine endangered species risk assessments and are used again in this assessment because there has been no change in atrazine use rates since completion of these assessments. In addition, an analysis of the impact of flowing water on modeled screening-level EECs was previously completed to refine exposures that are representative of the habitat for the assessed species. This refinement entails using the Index Reservoir water body as a surrogate for a flowing water body. The Index Reservoir was developed to mimic a small reservoir used as a drinking water source and allows for incorporation of flow through the system. Typically, flow rates in drinking water assessments are derived by the model to accumulate all runoff from the contributing watershed and route that through the reservoir. In this assessment, the accumulation has been over-ridden and actual flow rates from occupied streams have been modeled as the flow rate through the reservoir. There is uncertainty with this approach in that the geometry of the reservoir does not match that of occupied streams and the flow rates of watersheds occupied by the pallid sturgeon are higher than would be found in watersheds the size of the Index Reservoir. However, until such time as a model to estimate exposure in stream-type receiving water bodies has been developed, this approach is used as a means to characterize the magnitude of exposures expected in flowing water bodies occupied by the pallid sturgeon. Further details on how this analysis was conducted may be found in the previous atrazine endangered species risk assessments (U.S. EPA, 2007b and 2007c).

In general, the analyses from previous assessments showed that long-term screening-level EECs (e.g., 30-day average) were reduced to concentrations below levels of concern by adjusting the EECs to account for low to moderate flow rates (between 22 and 105 $ft^3$/sec) for streams of 3$^{rd}$ to 5$^{th}$ order. Because the flow rates for the river systems (8$^{th}$ order or higher) where the pallid sturgeon reside are much higher than previously considered flow rates for other species (e.g., the lowest flow rate for the pallid sturgeon in the previously assessed regions (north, south and west) is approximately 24,000 $ft^3$/sec for the Red River in Louisiana), and higher flow rates will generally result in lower long-term average concentrations, this analysis is not repeated for these regions. However, flow-adjusted modeling was completed for new scenarios specific for this assessment including Louisiana sugarcane and atrazine use scenarios in the upper Great Plains.

The Louisiana sugarcane scenario, which yields higher screening-level EECs than those previously assessed, was considered in this assessment due to proximity of the pallid sturgeon to areas of sugarcane. In this case, flow-adjusted modeling was conducting using the screening-level PRZM EEC for the Louisiana sugarcane scenario and flow rates from occupied pallid sturgeon river locations in the vicinity of sugarcane in Louisiana. For the sugarcane-growing region in Louisiana, the lowest flowing water body with available information was the Red River (at Shreveport) with a mean seasonal flow rate of 24,818 $ft^3$/sec (by way of comparison, other occupied rivers with flow, such as the Mississippi River, had mean seasonal flows at least an order of magnitude higher).

Flow-adjusted modeling was also conducted for the upper Great Plains atrazine uses to account for flowing waters typical of the pallid sturgeon habitat in this region (i.e., Missouri River). In this case, the corn scenario was chosen because it yielded the highest EEC of all the upper Great Plains modeled uses. As with the Louisiana sugarcane scenario, flow rates from the Missouri River north of the confluence with the Mississippi River are higher than those previously modeled, with the lowest flow rate available at 9500 $ft^3$/sec near Fort Peck, Montana.

The results, along with the flow rates used in this evaluation, are presented in Table 3.5. As expected, the flow-adjusted EECs are lower than the screening-level EECs from the standard static ecological water body. Impact of flow on the EECs is greater as flow rate and exposure duration increase.

| Table 3.5 Comparison of Alternative PRZM Modeling (assuming flow) with EECs Generated Using the Static Water Body | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Scenario** | **Flow ($ft^3$/sec)** | **Peak EEC (µg/L)** | **14-day EEC (µg/L)** | **21-day EEC (µg/L)** | **30-day EEC (µg/L)** | **60-day EEC (µg/L)** | **90-day EEC (µg/L)** | **Annual Average EEC (µg/L)** |
| **South Region** | | | | | | | | |
| South corn with static water body[a] | 0 | 109.1 | 107.8 | 107.0 | 106.3 | 103.9 | 101.4 | 79.4 |
| South corn (IR) with mean seasonal flow from USGS stream data[b] | 105 | 113 | 14 | 10 | 7 | 3 | 2 | 0.6 |
| Percent decrease in EEC using USGS mean seasonal flow data | | na | 87 | 91 | 93 | 97 | 98 | 99 |
| **Louisiana Sugarcane** | | | | | | | | |
| South sugarcane with static water body[a] | 0 | 407.5 | 405.2 | 405.1 | 404.8 | 396.5 | 392.7 | 307.5 |
| South sugarcane (IR) with mean seasonal flow from USGS stream data[b] | 24,818 | 132.7 | 13.2 | 8.8 | 6.2 | 3.1 | 2.4 | 0.6 |
| Percent decrease in EEC using USGS mean seasonal flow data | | 67 | 97 | 98 | 99 | 99 | 99 | >99 |
| **North Region** | | | | | | | | |
| North corn with static water body[a] | 0 | 100.8 | 100.3 | 99.9 | 99.3 | 97.5 | 96.2 | 80.3 |

| Table 3.5 Comparison of Alternative PRZM Modeling (assuming flow) with EECs Generated Using the Static Water Body | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Scenario** | **Flow ($ft^3$/sec)** | **Peak EEC (µg/L)** | **14-day EEC (µg/L)** | **21-day EEC (µg/L)** | **30-day EEC (µg/L)** | **60-day EEC (µg/L)** | **90-day EEC (µg/L)** | **Annual Average EEC (µg/L)** |
| North corn (IR) with mean seasonal flow from USGS stream data[b] | 22 | 65 | 16 | 12 | 8 | 4 | 3 | 0.8 |
| Percent decrease in EEC using USGS mean seasonal flow data | | 36 | 84 | 88 | 92 | 96 | 97 | 99 |
| **West Region** | | | | | | | | |
| West fallow with static water body[a] | 0 | 103.4 | 103.1 | 103.1 | 103.1 | 103.0 | 103.0 | 67.2 |
| West fallow (IR) with mean seasonal flow from USGS stream data[b] | 90 | 74 | 7 | 5 | 4 | 2 | 1 | 0.3 |
| Percent decrease in EEC using USGS mean seasonal flow data | | 28 | 93 | 95 | 97 | 98 | 99 | >99 |
| **Upper Great Plains Region** | | | | | | | | |
| Upper Great Plains corn with static water body[a] | 0 | 84.8 | 84.0 | 83.6 | 83.5 | 82.3 | 80.8 | 76.0 |
| Upper Great Plains corn (IR) with mean seasonal flow from USGS stream data[b] | 9503 | 47 | 6 | 4 | 3 | 2 | 1 | 0.3 |

| Table 3.5 Comparison of Alternative PRZM Modeling (assuming flow) with EECs Generated Using the Static Water Body | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Scenario** | **Flow ($ft^3$/sec)** | **Peak EEC (µg/L)** | **14-day EEC (µg/L)** | **21-day EEC (µg/L)** | **30-day EEC (µg/L)** | **60-day EEC (µg/L)** | **90-day EEC (µg/L)** | **Annual Average EEC (µg/L)** |
| Percent decrease in EEC using USGS mean seasonal flow data | | 45 | 93 | 95 | 96 | 98 | 99 | >99 |

[a] EECs generated using PE4v01.pl in this table are slightly different from those presented in Table 3.4 due to different duration of exposure and slight differences in the manual estimation technique used in Table 3.4.
[b] Index Reservoir scenarios EECs are typically reported using percent cropped area (PCA) of 46% for corn and 87% for fallow. In this characterization, no PCA is applied to the modeled output.

### 3.2.6 Existing Monitoring Data

The second step in the process of characterizing EECs used for risk description was to compare the modeling results with available surface water monitoring data. A fairly robust set of surface water monitoring data exists for atrazine from a variety of targeted and non-targeted studies. Targeted studies are those studies whose design is specifically tailored to the use pattern for a specific compound. Sample location, number of samples, frequency of sampling, and sample collection timing are designed specifically to capture exposures for the target compound. Non-targeted monitoring is typically more general in nature and is not designed for a specific compound. The study design for non-targeted studies is typically broad with the intent of capturing as many compounds as possible, but not necessarily focused on the main exposure period for a single compound.

Atrazine data from the USGS NAWQA program (http://water.usgs.gov.nawqa), USGS NASQAN program (http://water.usgs.gov/nasqan/), Watershed Regression for Pesticides (WARP), Heidelberg College, Community Water System (CWS) data from drinking water sources, targeted atrazine sugarcane monitoring from the Louisiana Department of Environmental Quality (LDEQ), published USGS studies, and data recently submitted by the atrazine registrants (Ecological Stream Monitoring Program) are included in this assessment. These monitoring data are characterized in terms of general statistics including number of samples, frequency of detection, maximum concentration, and mean from all detections. In general, with the exception of the USGS NASQAN data and to a lesser extent the LDEQ data, none of these sources are directly relevant to the pallid sturgeon. The pallid sturgeon resides in major rivers with high flow rates and volumes, while the bulk of the data (including the targeted ecological stream monitoring) represents samples collected from lower-order streams. As such, while all data are summarized in this assessment, only the USGS NASQAN, LDEQ, and Ecological Monitoring data are used for direct comparison to modeled screening-level EECs; only NASQAN data are directly relevant for comparison with flow-adjusted EECs for the pallid sturgeon. A summary of the USGS NASQAN, LDEQ, and Ecological Monitoring data is provided below in Sections 3.2.6.1 through 3.2.6.3, respectively. Additional atrazine monitoring data are provided in Appendix D.

#### *3.2.6.1 USGS NASQAN Data*

The USGS initiated a water quality monitoring program designed to focus on major rivers in selected major river basins in the United States. The National Stream Quality Accounting Network, or NASQAN, is intended to provide ongoing characterization of exposure to a variety of contaminants in large rivers of the United States. When initially established, the major impetus of the program was to develop baseline water chemistry data for chemicals including atrazine. The program consists of three phases of data collection. The first phase ran from 1974 to 1995 with over 500 stations, although the number and frequency of samples decreased over the sampling period. Typically, these data are from rivers representing Strahler stream orders of 8 or higher.

In 1995, the program underwent a redesign with a new emphasis on monitoring water quality of the nation's largest rivers including the Mississippi, Missouri, Ohio, Columbia, Colorado, and the Rio Grande. During this phase of the program, NASQAN operated a network of approximately 41 stations that were chosen at major nodes within the river basin network to provide characterization of large sub basins of these rivers. The sampling strategy was changed to focus on characterizing the annual variations in chemical and sediment concentrations, particularly the variability that occurs between low and high flows and during different seasons. In this way, NASQAN data can be used to evaluate mass fluxes or loads of constituents to ultimately determine regional source areas for these materials. Subsequently, since 2001, the program has focused on decreased sampling in the Colorado and Columbia River basins with little change in the Mississippi basin.

NASQAN data from the 1995 to 2000 period (more recent data are provisional and have not been included) for atrazine were downloaded from the USGS website (http://water.usgs.gov/nasqan/) on May 14, 2007. For the entire U.S., a total of 2,477 samples were analyzed for atrazine from the four major river basins. Of these samples, a total of 1,952 had positive detections of atrazine (212 of the positive detections were estimated; six above the limit of quantitation [LOQ] and 206 below the LOQ) for a frequency of detection of 78.8%. The maximum concentration detected was an estimated value of 34 µg/L from station 6805500 on the Platte River at Louisville, Nebraska in 1996. Of the positive detections, 235 samples were detected at concentrations above 1 µg/L.

Only data from the Mississippi Basin were evaluated because data from the other three basins (Rio Grand, Colorado, and Columbia) are outside of the pallid sturgeon action area boundary. A total of 1,323 samples were analyzed for atrazine; of these, a total of 1,278 detected atrazine above the LOQ (27 of these were estimated). The frequency of detection in the Mississippi basin was 96.6%. The maximum value in this subset was also the 34 µg/L value from the Platte River. Of the positive detections, 212 samples were above 1 µg/L.

The frequency of sampling was such that comparison with CASM rolling average concentrations (e.g. 30-day average concentration) could not be completed. However, additional analysis of the NASQAN data was completed in order to provide context to atrazine exposure in major rivers by comparing annual average concentrations from the NASQAN data with modeling. Specifically, the data were separated into individual stations by year for a total of 90 site years of data. Each site year was characterized by determining the annual time-weighted mean (TWM) concentration and maximum concentration. The minimum criterion for calculating TWM means for each sampling station was at least 4 samples in a single year. The equation used for calculating the annual TWM is as follows:

$$[((T_{0+1}-T_0) + ((T_{0+2}-T_{0+1})/2))*C_{t0+1})] + (((T_{i+1}-T_{i-1})/2)*C_i) + [((T_{end}-T_{end-1}) + ((T_{end-1}-T_{end-2})/2)*C_{Tend-1})]/365$$

where: Ci = Concentration of pesticide at sampling time (Ti)
Ti = Julian time of sample with concentration Ci
$T_0$ = Julian time at start of year = 0
$T_{end}$ = Julian time at end of year = 365

In general, this analysis indicates that the maximum TWM concentration was 7.419 µg/L from the Platte River in Nebraska from 1996 (corresponding to the site with the maximum peak concentration of 34 µg/L). Of the 90 site years of data, 10 sites had TWM concentrations above 1 µg/L including sites in Nebraska, Indiana, and Illinois. The remaining site years had TWM concentrations ranging from 0.001 to 0.998 µg/L. Generally, the sites with the lowest TWM concentrations were in Montana, North Dakota, and South Dakota, while the highest concentrations were found in the Midwestern corn belt and Louisiana. The estimated TWM values for these sites should be evaluated with caution because the typical NASQAN site included in this analysis consists of only 10 to 15 samples per year, which limits the robustness of the data. It is expected, because of the interpolation required for limited data sets, that if more samples were included, the TWM concentration would be lower. Figure 3.3 shows the locations of the 20 NASQAN sample sites. The results of this analysis are summarized for the 20 sampling sites in Table 3.6; data for each individual station by year are provided in Table D.1 of Appendix D.

| Table 3.6 Summary of USGS NASQAN Atrazine Data | | | | | | |
|---|---|---|---|---|---|---|
| **Station** | **NAME** | **Latitude** | **Longitude** | **Dates** | **TWM (µg/L)** | **Max (µg/L)** |
| 3216600 | Ohio River at Greenup Dam near Greenup, KY | 38.646944 | -82.860000 | 3/4/97 - 4/17/00 | 0.057 - 0.221 | 0.311 - 1.480 |
| 3303280 | Ohio River at Cannelton Dam at Cannelton, IN | 37.900000 | -86.706111 | 4/24/96 - 4/19/00 | 0.156 - 0.618 | 0.690 – 3.000 |
| 3378500 | Wabash River at New Harmony, IN | 38.131944 | -87.940000 | 3/19/97 - 5/23/00 | 1.241 - 2.066 | 5.170 - 20.700 |
| 3609750 | Tennessee River at Highway 60 near Paducah, KY | 37.038056 | -88.528889 | 3/12/97 - 4/27/00 | 0.116 - 0.167 | 0.474 – 0.680 |
| 3612500 | Ohio River at Dam 53 near Grand Chain, IL | 37.203056 | -89.041944 | 4/9/96 - 4/5/00 | 0.235 - 1.138 | 2.560 – 8.190 |
| 5330000 | Minnesota River near Jordan, MN | 44.693056 | -93.641944 | 6/13/96 - 4/2/98 | 0.129 - 0.182 | 1.090 – 1.800 |
| 5331580 | Mississippi R. below Lock & Dam 2 at Hastings, MN | 44.746944 | -92.851944 | 5/15/96 - 5/26/99 | 0.063 - 0.127 | 0.190 - 0.765 |
| 5420500 | Mississippi River at Clinton, IA | 41.781111 | -90.251944 | 4/23/96 - 5/22/00 | 0.134 - 0.262 | 0.810 - 2.440 |
| 5587455 | Mississippi River below Grafton, IL | 38.951111 | -90.371111 | 4/3/97 - 4/3/00 | 0.530 - 0.957 | 2.510 - 5.960 |
| 6185500 | Missouri River near Culbertson, MT | 48.123056 | -104.475000 | 5/21/97 - 5/1/00 | 0.001 - 0.002 | 0.002 - 0.005 |
| 6329500 | Yellowstone River near Sidney, MT | 47.678056 | -104.156944 | 6/18/96 - 4/19/00 | 0.004 - 0.017 | 0.008 - 0.177 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6338490 | Missouri River at Garrison Dam, ND | 47.501944 | -101.431110 | 6/13/97 - 5/15/00 | 0.003 - 0.005 | 0.007 - 0.008 |
| 6440000 | Missouri River at Pierre, SD | 44.373056 | -100.368056 | 6/10/97 6/14/00- | 0.009 - 0.022 | 0.012 - 0.052 |
| 6610000 | Missouri River at Omaha, NE | 41.258889 | -95.923056 | 3/28/96 - 4/4/00 | 0.097 - 0.395 | 0.338 - 4.000 |
| 6805500 | Platte River at Louisville, NE | 41.015000 | -96.158056 | 5/25/96 - 3/21/00 | 0.380 - 7.419 | 3.140 - 34.000 |
| 6934500 | Missouri River at Hermann, MO | 38.710000 | -91.438889 | 3/29/96 - 5/5/00 | 0.471 - 0.959 | 2.630 – 7.400 |
| 7022000 | Mississippi River at Thebes, IL | 37.216944 | -89.463889 | 3/26/96 - 8/14/00 | 0.426 - 1.020 | 2.050 – 5.960 |
| 7263620 | Arkansas River at David D. Terry Lock & Dam | 34.668889 | -92.155000 | 3/12/96 - 5/5/00 | 0.263 - 0.464 | 0.420 - 0.866 |
| 7373420 | Mississippi River near St. Francisville, LA | 30.758889 | -91.396111 | 5/1/96 - 6/23/00 | 0.126 - 0.679 | 1.830 - 4.710 |
| 7381495 | Atchafalaya River at Melville, LA | 30.691111 | -91.736111 | 5/2/96 - 4/13/00 | 0.250 - 0.870 | 1.510 - 4.100 |

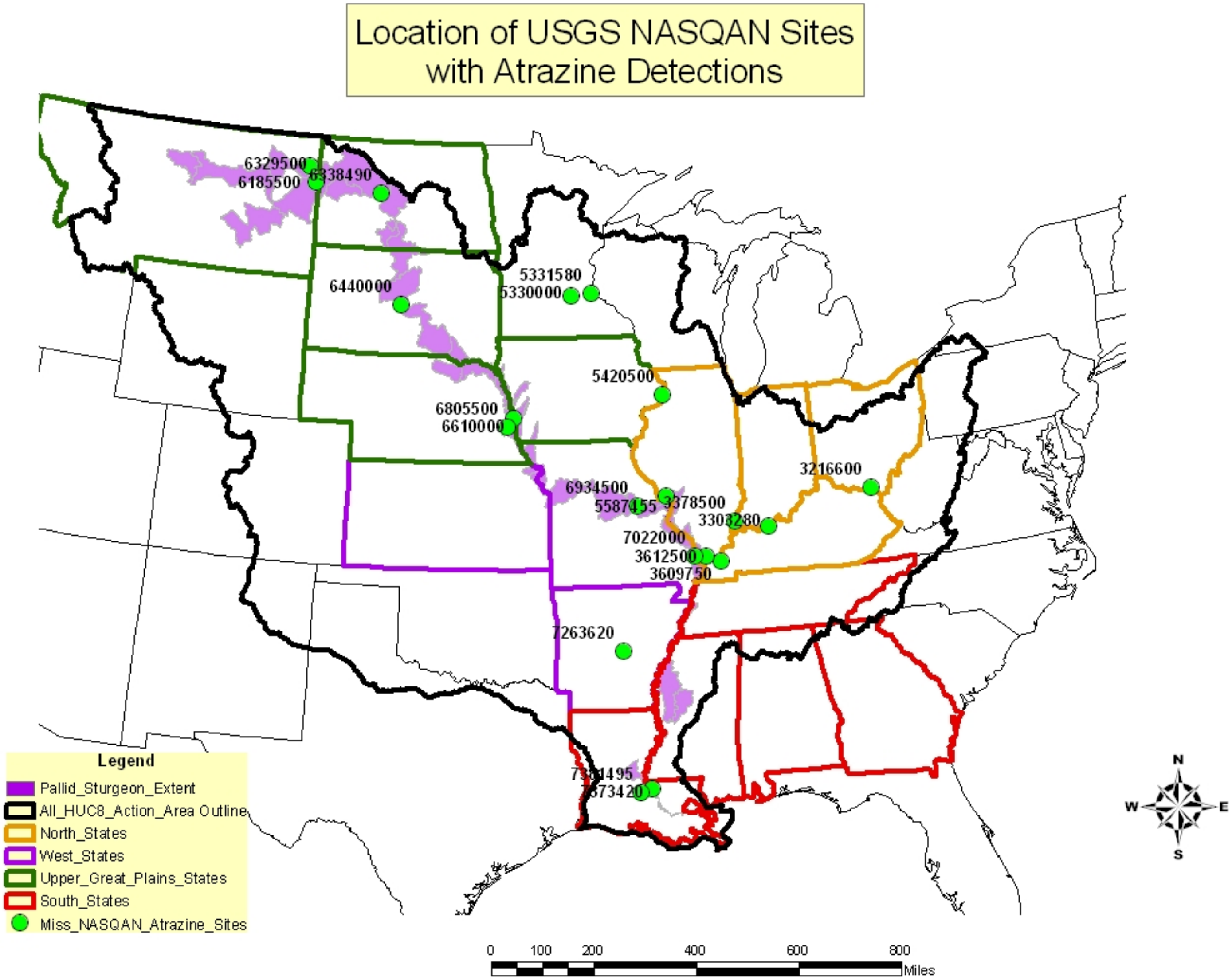


**Figure 3.3 Location of USGS NASQAN Sites**

### *3.2.6.2 Louisiana Atrazine Monitoring*

Since 1992, the Louisiana Department of Agriculture and Forestry (LDAF) has collected data on atrazine and other pesticides in surface and ground water. LDAF and the Louisiana Department of Environmental Quality (LDEQ) have been collecting surface water data on atrazine in the Upper Terrebonne watershed basin, which lies just west of the Mississippi River at Baton Rouge and east of the Atchafalaya River Basin. The basin covers an area extending approximately 120 miles from the Mississippi River on the north to the Gulf of Mexico to the south, and varies in width from 18 to 70 miles. It is primarily lowland and is subject to flooding, except for the natural levees along major waterways. The coastal portion of the basin is prone to tidal flooding and consists of marshes ranging from fresh to saline. Much of the recent Upper Terrebonne data are available on the state internet site at

http://www.deq.state.la.us/surveillance/atrazine/index.htm

Data from 1998 are summarized below in Table 3.7 with the maximum and mean concentrations by site (29 sites) against the percentage of sites with equal or greater concentrations.

**Table 3.7 Summary of LDEQ Atrazine Data**

| % Probability | Peak | 95% | 90% | 75% | 50% |
|---|---|---|---|---|---|
| **Maximum Concentration (µg/L)** | 216.2 | 210.0 | 125.8 | 34.7 | 13.3 |
| **Mean Concentration (µg/L)** | 56.7 | 54.7 | 24.5 | 8.0 | 4.5 |

Twenty-nine stations were sampled either weekly or in conjunction with atrazine "events," (i.e., pre-emergent, post emergent, lay-by, or fall applications) in areas near bayous, canals, and ditches in the Terrebonne watershed. The majority of stations were located downstream on streams that receive runoff from predominantly sugarcane and corn production areas. The data show peak levels over 200 µg/L for more than one station, and over 100 µg/L for at least two more. Data from these sample sites appear to represent lower-order waters than those occupied by the pallid sturgeon; however, they provide relevant context to the modeled screening-level EECs using the static water body.

Similar to the USGS NASQAN data, additional analysis of the LDEQ data was completed. In this case, the data were separated by station and summarized by year for annual average concentration, TWM concentration, and maximum concentration. The data indicate that TWM concentrations range from a high of 37.6 µg/L to a low of 0.00 µg/L (where all samples were reported as below the detection limit with no numeric value reported). The site with the maximum TWM concentration (#16; Bayou

Maringouin) was also the site with the highest peak concentration at 216.2 µg/L. Unlike the NASQAN sites, most of the LDEQ sites (22 out of 29) had TWM concentrations above 1 µg/L. This is likely influenced by the fact that these data were collected from streams, bayous, and ditches that are much smaller than those characterized by NASQAN. Generally, where applicable, the LDEQ sites are from canals and ditches draining agricultural fields into 1st and 2nd order streams, while the NASQAN sites are generally 6th to 8th order streams. The locations of the LDEQ sample sites are shown in Figure 3.4. The results of this analysis are presented in Table 3.8.

**Table 3.8 Summary of Louisiana Department of Environmental Quality (LDEQ) Atrazine Monitoring Including Location, Stream Name, and Time Weighted Mean (TWM) Concentration**

| Station # | Latitude | Longitude | Stream | Date | Annual Average (µg/L) | TWM (µg/L) | Maximum (µg/L) |
|---|---|---|---|---|---|---|---|
| 1 | 30.55915 | -91.5564 | Bayou Grosse Tete | 1998 | 9.455 | 3.733 | 129.6 |
| 2 | 30.56785 | -91.5564 | Bayou Fordoche | 1998 | 6.76 | 3.683 | 15.3 |
| 3 | 30.55332 | -91.5027 | Bayou Tommy | 1998 | 0 | 0 | 0 |
| 4 | 30.55114 | -91.461 | Bayou Sterling | 1998 | 1.225 | 0.799 | 4.9 |
| 5 | 30.54916 | -91.4552 | Bayou Cholpe | 1998 | 7.76 | 7.218 | 16.2 |
| 6 | 30.5421 | -91.4338 | Drainage Ditch | 1998 | 7.89 | 6.182 | 11.6 |
| 7 | 30.53405 | -91.4078 | Bayou Poydras | 1998 | 4.1955 | 6.416 | 33.7 |
| 8 | 30.52141 | -91.3729 | Drainage Ditch | 1998 | 3.1525 | 2.339 | 8.61 |
| 9 | 30.51709 | -91.3602 | Bayou Stumpy | 1998 | 0.91 | 0.657 | 1.94 |
| 10 | 30.51454 | -91.3525 | Unnamed Ditch | 1998 | 5.005 | 3.83 | 17.22 |
| 11 | 30.5079 | -91.3328 | Unnamed Canal | 1998 | 13.83 | 10.765 | 46.82 |
| 12 | 30.47697 | -91.3878 | Bayou Tommy | 1998 | 53.2 | 35.153 | 205.9 |
| 13 | 30.44991 | -91.4394 | Unnamed Canal | 1998 | 5.7525 | 4.372 | 15.8 |
| 14 | 30.44175 | -91.4523 | Bayou Grosse Tete | 1998 | 10.7155 | 4.88 | 55.4 |
| 15 | 30.41576 | -91.503 | Bayou Maringouin | 1998 | 26.886 | 15.207 | 106.1 |
| 16 | 30.48906 | -91.5227 | Bayou Maringouin | 1998 | 56.5 | 37.593 | 216.2 |
| 17 | 30.44332 | -91.347 | Bayou Choctaw | 1998 | 10.728 | 6.184 | 49 |
| 19 | 30.40985 | -91.3276 | Johnson Canal | 1998 | 0.5175 | 0.405 | 2.07 |
| 20 | 30.40395 | -91.3215 | Unnamed Canal | 1998 | 0 | 0 | 0 |

| **Table 3.8 Summary of Louisiana Department of Environmental Quality (LDEQ) Atrazine Monitoring Including Location, Stream Name, and Time Weighted Mean (TWM) Concentration** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Station #** | **Latitude** | **Longitude** | **Stream** | **Date** | **Annual Average (µg/L)** | **TWM (µg/L)** | **Maximum (µg/L)** |
| 22 | 30.32229 | -91.3111 | Bayou Bourbeaux | 1998 | 4.2225 | 3.393 | 11.1 |
| 23 | 30.29602 | -91.3021 | Wilbert Canal | 1998 | 4.316 | 2.742 | 15 |
| 24 | 30.26832 | -91.321 | ICWW | 1998 | 5.837 | 3.261 | 32.6 |
| 25 | 30.25759 | -91.3125 | Bayou Plaquemine | 1998 | 3.7345 | 2.906 | 11.5 |
| 26 | 30.43271 | -91.2118 | ICWW | 1998 | 0 | 0 | 0 |
| 27 | 30.69432 | -91.4721 | Portage Canal No. 1 | 1998 | 6.445 | 9.179 | 20.88 |
| 28 | 30.22199 | -91.3179 | ICWW | 1998 | 3.0825 | 2.415 | 12.33 |
| 29 | 30.34347 | -91.5243 | Bar Ditch | 1998 | 2.5325 | 2.131 | 4.7 |
| 31 | 30.62019 | -91.4765 | Lighthouse Canal | 1998 | 0.25 | 0.24 | 1 |
| B-1 | 30.22595 | -91.4191 | Upper Grand River | 1998 | 1.6 | 1.181 | 4.6 |

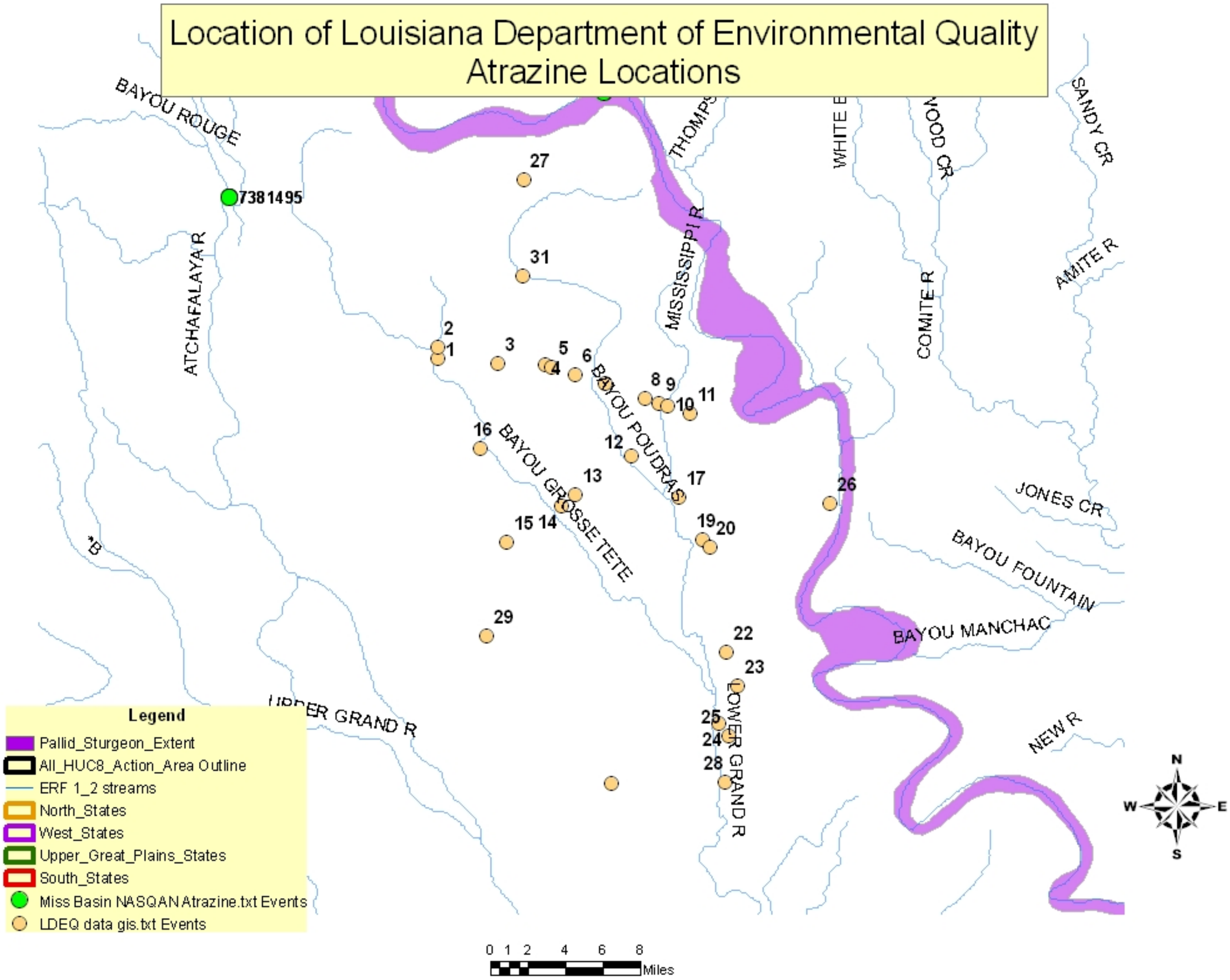


**Figure 3.4 Locations of LDEQ Sample Sites**

Additional data analysis was completed to provide context to the locations relative to pallid sturgeon habitat. In general, the pallid sturgeon resides in major rivers with high volume and fast flow rates. The LDEQ sample sites, while in close proximity to known occurrences of the pallid sturgeon, are located in streams, canals, ditches, and bayous draining directly from treated sugarcane fields that ultimately drain to the Mississippi and Atchafalaya Rivers. The LDEQ peak concentrations are lower than screening-level modeled values for sugarcane by a factor of two and the TWM concentrations from the LDEQ data range from well below 1 μg/L to as high as 38 μg/L. These TWM concentrations are lower than those predicted by static water modeling, but higher than those predicted by flow-adjusted modeling. However, a more detailed analysis suggests that these high TWM sites are being influenced by the limited sample frequency (i.e., 23 of 29 sites had only 4 samples), which can bias the TWM concentration based on a single detection. For the sites with 20 samples, the TWM concentrations ranged from 3 to 6.5 μg/L. While these sites are somewhat more robust with 20 samples versus 4 samples, it is still expected that a higher frequency of sampling would yield lower TWM concentrations.

Additional sources of data from the vicinity of these sites are provided for comparative purposes. Data from two NASQAN sites and four CWS intake locations from the major rivers in the vicinity of the LDEQ sites were considered. The two NASQAN sites (#7381495 & #7373420) are in the vicinity of the LDEQ sites on the Mississippi and Atchafalaya Rivers within the range of pallid sturgeon occurrence. The maximum TWM concentrations for both of these sites are 0.679 μg/L and 0.870 μg/L, which is consistent with those predicted by the flow-adjusted modeling. The four CWS sites are located south and east of the LDEQ sites and yielded average concentrations ranging from 0.8 to 2.8 μg/L. Figure 3.5 presents the location of LDEQ, NASQAN, and CWS sites relative to species locations (defined by HUC8 watersheds) and sugarcane acreage in Louisiana.

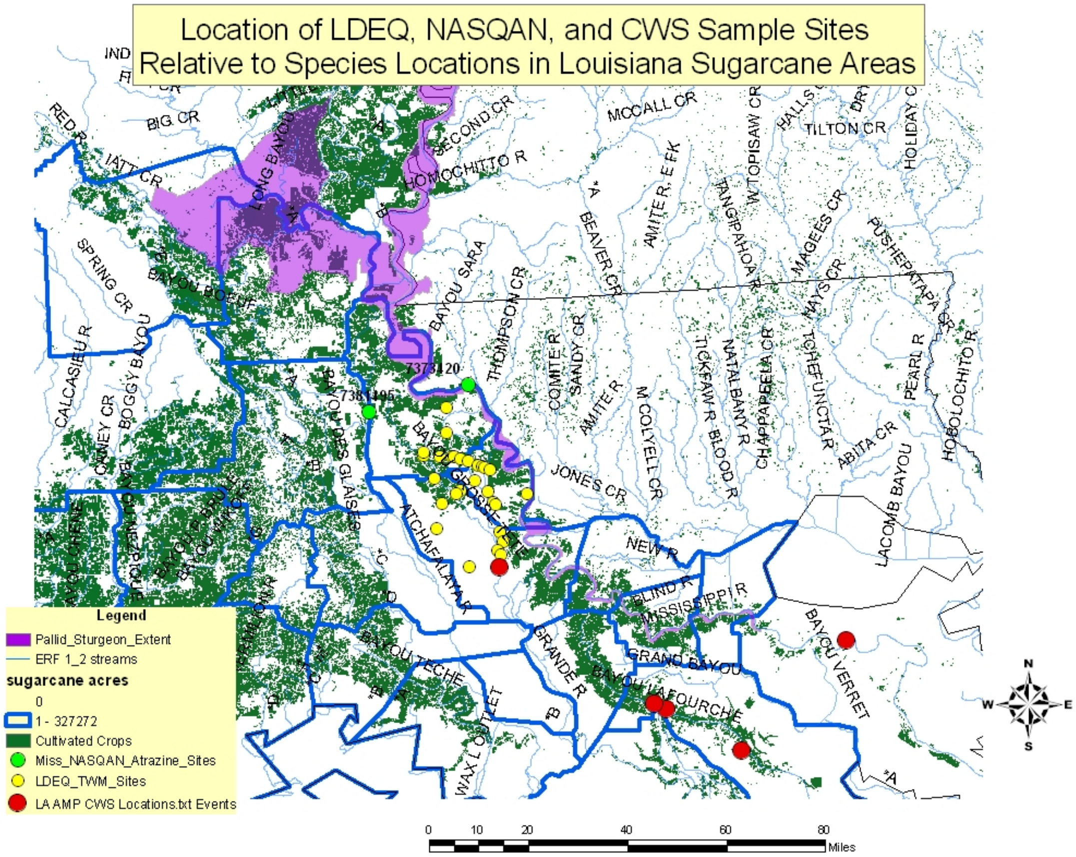


**Figure 3.5 All LDEQ, NASQAN, and CWS Sites Relative to the Pallid Sturgeon Action Area in Louisiana**

*3.2.6.3 Ecological Stream Monitoring Program Data*

The 2003 IRED required the atrazine registrants to conduct watershed monitoring for atrazine as a condition of re-registration. One component of the monitoring program is focused on flowing water bodies, and provides two to three years of monitoring data, accrued over a three-year period (2004-2006), in the most vulnerable watersheds associated with corn and sorghum production. These data are targeted specifically to atrazine use and are designed to represent exposure in the watersheds most prone to atrazine runoff. In this case, vulnerability was defined using the USGS WARP model. The principal factors influencing WARP predictions of exposure and hence the vulnerability ranking are:

- Atrazine use,
- Rainfall intensity,
- Soil erodibility,
- Watershed area, and
- Dunne overland flow

Surface water data included in this study were collected using a targeted methodology that relied on WARP to identify the upper 20th percentile of vulnerable watersheds and a statistical design to select a subset of 40 watersheds that may be representative of 1,172 vulnerable watersheds. The atrazine use input was derived by calculating the mean annual atrazine concentration (at the 95th percent confidence limit) across all watersheds in the United States where atrazine is used. Given the statistical nature of the sampling design of this study, it is not possible to extrapolate the monitoring data from the 40 watersheds beyond the upper 20th percentile of watersheds (i.e., the 1,172 vulnerable watersheds).

Samples were collected from 20 locations within the designated watersheds every four days during the peak use period for atrazine (April to August) during the 2004-2005 growing season, and a second set of 20 watersheds were sampled during the 2005-2006 growing season (several watersheds from the 2004-2005 sample period were carried over for a third year of monitoring). The strength of this data set is the targeted nature of site selection to areas of high atrazine use, the frequency of the sampling (every four days during peak use season), and the collection of multiple samples on selected days from a number of sites that allows for a statistical description of the variability surrounding the time series data. More detail on the approach, methodology, and objectives of the surface water Ecological Monitoring Program for atrazine may be found at:

http://www.epa.gov/oppsrrd1/reregistration/atrazine/

A preliminary analysis of this Ecological Monitoring Program data from 2004 to 2006 has been completed. The data have been statistically evaluated for each site/year combination, including number of non-detections, frequency of detection, maximum concentration, mean concentration, median concentration, and number of scheduled samples that ultimately did not occur or samples that were not subsequently analyzed. These statistics provide a general picture of the level of exposures seen in these data relative to the other data sets described in this assessment.

Overall, the data suggest a similar pattern of atrazine exposure in surface water as in the other data sets evaluated as part of this assessment. Atrazine was detected in a total of 2,979 out of 3,601 samples for an overall frequency of detection of 79%. The frequency of detection ranged across all watersheds and years from a maximum of 100% to a minimum of 11%. The maximum concentration detected from all watersheds was 208.8 μg/L from the Indiana 11 site in 2005. The mean annual concentrations ranged from a maximum of 9.5 μg/L from the Missouri 01 site in 2004 to a low of 0.1 μg/L for the Nebraska 06 site in 2006, while the median values ranged from 4.2 μg/L for the Missouri 02 site in 2004 to 0.1 μg/L for the Ohio 03 site in 2004. It should be noted that a number of watersheds, particularly in Nebraska, experienced dry periods where scheduled sampling did not take place; therefore, the statistics for those watersheds may not represent actual conditions expected in normal or wetter years.

This data set is currently releasable only upon completion and submission of an Affirmation of Non-multinational Status form under section 10(g) of FIFRA.

Information on how to submit a request to obtain a copy of the data may be obtained from the following website:

http://www.epa.gov/espp/atrazine_ewm_data.htm

More detail on the watershed analysis is presented in Appendix D.

Although the ecological monitoring data set was targeted specifically to high atrazine use areas, very few of the watersheds are co-located with the HUC8 watersheds used to identify pallid sturgeon locations (Figure 3.6), and none are representative of the species' habitat. The pallid sturgeon resides in major rivers such as the Mississippi and Missouri Rivers, which are generally classified as 8th order streams or greater, while the Ecological monitoring watersheds are generally 2nd and 3rd order streams. Because the pallid sturgeon resides in major rivers, targeted monitoring data collected from 2nd and 3rd order streams likely over-estimate exposures in these larger rivers, and are therefore not considered as representative of atrazine exposures for the pallid sturgeon.

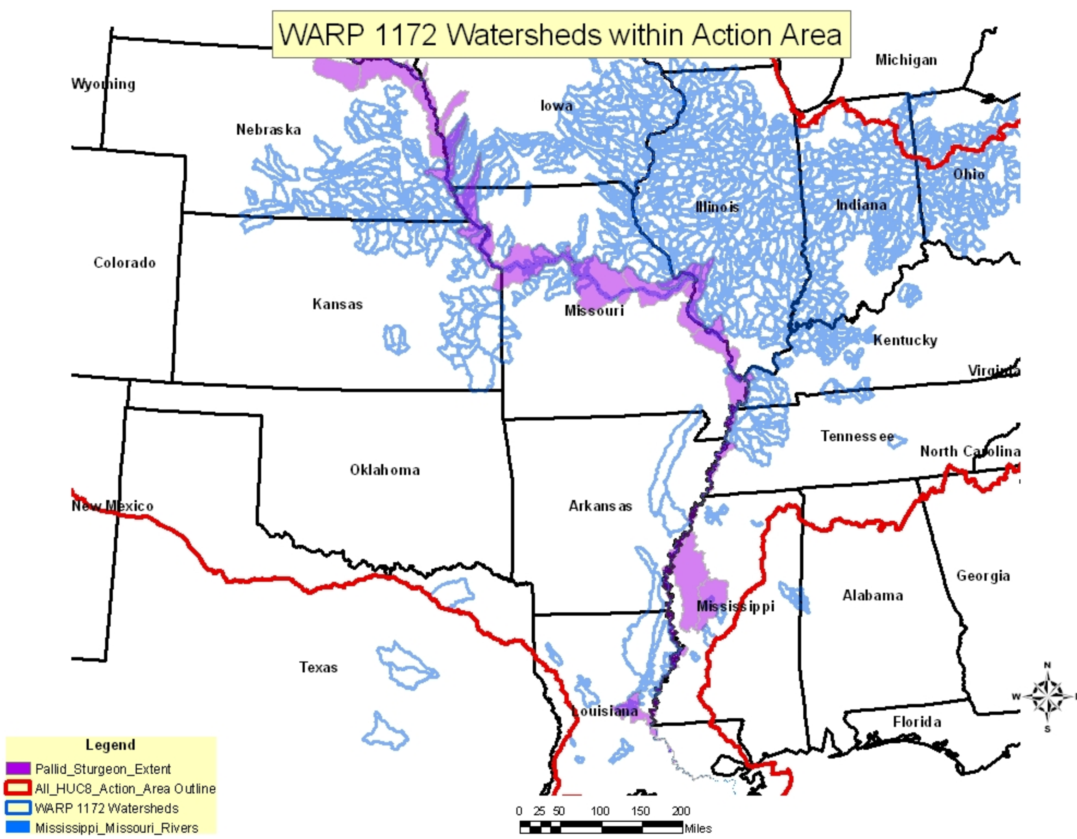


**Figure 3.6 Co-occurrence of WARP Watersheds with the Pallid Sturgeon Action Area**

### 3.2.7 Comparison of Modeling and Monitoring Data

Modeling with the static water body provides screening-level EECs for use in risk estimation (Section 5.1). These screening-level EECs are also refined and used in the risk description to characterize the relevance of predicted screening-level modeled exposures to the rivers that are occupied by the pallid sturgeon. In this case, the listed species resides in major rivers with relatively fast flows. Therefore, additional characterization of the modeled static water body screening-level EECs used for risk estimation is necessary to determine its relevance (and hence the RQs) to the species' habitat. In order to complete this characterization, additional refinement of the screening-level EECs is completed based on evaluation of modeled flow-adjusted EECs and available atrazine monitoring data for larger rivers.

Available monitoring data consist of both targeted and non-targeted data, as described above. Targeted monitoring data (i.e., Ecological Monitoring Program; discussed in Section 3.2.6.3 and LDEQ atrazine monitoring discussed in Section 3.2.6.2) are designed specifically to capture atrazine concentrations in watersheds with high atrazine use and exposure patterns in the most runoff-prone settings. However, these data are representative of low-order headwater streams ($2^{nd}$ and $3^{rd}$ order, generally) and are not useful for direct comparison with effects data where the pallid sturgeon resides in large rivers ($8^{th}$ order or higher). The targeted monitoring data provide context to the screening-level EECs and suggest that peak concentrations are reasonably approximated by modeling (i.e., within a factor of two); however, longer-term exposures are over-predicted by modeling (i.e., by as much as an order of magnitude). Non-targeted data (e.g., USGS NAWQA) are typically designed to capture the general pattern of pollutants in the environment, rather than one specific chemical. A summary of the ranges of values from each data source considered in this exposure assessment is presented in Table 3.9.

**Table 3.9 Comparison of Modeled EEC versus Monitoring Data**

| Data Source | Peak EEC (µg/L) | Annual Average/TWM EEC (µg/L) | 14-day Average EEC (µg/L) | 30-day Average EEC (µg/L) | 60-day Average EEC (µg/L) | 90-day Average EEC (µg/L) |
|---|---|---|---|---|---|---|
| **Static PRZM** | 3 – 110 (408 sugarcane) | 2 – 80 (300 sugarcane) | 1 - 100 | 1 -100 | 1- 100 | 1 -100 |
| **Flow-Adjusted PRZM** | 50 – 100 (130 sugarcane | 0.3 – 0.8 (130 sugarcane) | 6 - 14 | 3 - 8 | 2 - 4 | 1 - 3 |
| **Eco Monitoring Program** | 1 – 200 | < 1 – 4 | <1 - 80 | <1 – 45 | <1 – 25 | <1 - 18 |
| **USGS NAWQA** | 1 – 200 | < 1 – 10 | NA | NA | NA | NA |
| **USGS NASQAN** | 1 - 35 | 0.1 – 7.5 | NA | NA | NA | NA |
| **LDEQ** | 1 - 200 | <1 - 37 | NA | NA | NA | NA |

| Table 3.9 Comparison of Modeled EEC versus Monitoring Data | | | | | | |
|---|---|---|---|---|---|---|
| **Data Source** | **Peak EEC (µg/L)** | **Annual Average/TWM EEC (µg/L)** | **14-day Average EEC (µg/L)** | **30-day Average EEC (µg/L)** | **60-day Average EEC (µg/L)** | **90-day Average EEC (µg/L)** |
| **Heidelberg** | 1 – 50 | <1 - 2 | 28 | 18 | 12 | 9 |
| **Other** | 1 - 100 | NA | NA | NA | NA | NA |

Data from the Ecological Monitoring Program provide a robust data set targeted to the most vulnerable watersheds in areas of atrazine use. However, these data represent low-order streams in those most vulnerable areas that are not considered representative of habitat where the pallid sturgeon is found. The LDEQ data are targeted to the atrazine use pattern on sugarcane in Louisiana, but are limited in sample frequency with most sites having only 4 samples total. In addition, the LDEQ data, while geographically proximate to locations of pallid sturgeon in the Mississippi and Atchafalaya Rivers, are collected from low-order streams/canals/ditches/bayous draining directly from treated fields and are also not directly relevant to the species' location. Similarly, non-targeted monitoring data indicate that the highest concentrations are found in low-order streams and rivers not representative of where the pallid sturgeon is found to reside.

Unlike the targeted data, the non-targeted monitoring data include samples collected from the major rivers of the mid-continent which provide context to the screening-level and refined modeled EECs as they relate to the pallid sturgeon's habitat. Because of the species habitat requirements (large rives with high volume and fast flow), the NASQAN data are considered the most directly relevant to the pallid sturgeon. Specifically, the USGS' NASQAN program targets major river basins and includes data from the 1990s through 2000. In general, the peak exposures seen in the USGS NASQAN monitoring data are lower than those predicted with PRZM/EXAMS using the static water body by roughly a factor of three. In addition, the TWM concentrations from the NASQAN data range from well below 1 µg/L to roughly 7.5 µg/L, while the predicted PRZM/EXAMS annual average concentrations using the static water body range from approximately 2 µg/L to as high as 80 µg/L.

A similar pattern is noted for the peak flow-adjusted concentrations, which are approximately 2 to 3 times higher than the monitored values. This concurrence seems reasonable for peak concentrations, given that most sample sites for the NASQAN data have few samples (generally only 10 to 15 per year). However, comparison of the longer-term annual average concentrations from flow-adjusted modeling with TWM concentrations from the NASQAN data suggests that the longer- term exposures for some locations may be under-represented by the flow-adjusted modeling.

For example, annual average concentrations from the four scenarios modeled using the flow-adjusted approach yield annual average concentrations between 0.3 µg/L and 0.8 µg/L, while the TWM concentrations from the NASQAN sites are as high as 7.5 µg/L. However, the higher TWM NASQAN value should be viewed with caution because only

8 samples were collected from this site, and the next highest NASQAN TWM was 2 µg/L from a site with only 17 samples. It is expected that a more robust data set would yield lower TWM concentrations from the NASQAN sites.

Overall, the comparison suggests that predicted PRZM/EXAMS EECs using the static water body provide a reasonable approximation of peak concentrations in those locations immediately adjacent to treated fields. However, longer-term concentrations (as evidenced by TWM concentrations) are over-predicted relative to the static water body EECs. For the flow-adjusted modeling, it appears that peak concentrations are within a factor of 2 to 3 times the modeled values. It also appears that the long-term concentrations from flow-adjusted modeling may slightly under-represent exposures, but are generally within a factor of 2 to 3 times monitored values. However, reliance on long-term estimates from monitored data is suspect, given the limited sample frequency in these data. In general, it is expected that the refined modeling provides a reasonable estimate of exposure that is representative of the larger rivers where the pallid sturgeon resides.

### 3.2.8 Impact of Typical Usage Information on Exposure Estimates

A final piece of the exposure characterization includes an evaluation of usage information. Label application information was provided by EPA's Biological and Economic Analysis Division and summarized in Table 2.2. This information suggests that atrazine use on corn and sorghum (non-agricultural usage data are not available as part of this analysis) is typically 1.2 lbs/acre and 1.3 lbs/acre in the states considered within the action area of this assessment. This suggests that if typical application rates were used, atrazine exposures would be reduced below those modeled with the label maximum application rate by 40% for corn and 35% for sorghum. Typically usage information is not incorporated into these assessments, but does provide context to the predicted exposures. Caution is used when evaluating "typical" application rate information because this represents the average of all reported applications and thus roughly 50% of the time higher application rates are being used.

## 3.3 Terrestrial Plant Exposure Assessment

Terrestrial plants in riparian areas may be exposed to atrazine residues carried from application sites via surface water runoff or spray drift. Exposures can occur directly to seedlings breaking through the soil surface and through root uptake or direct deposition onto foliage of more mature plants. Riparian vegetation is important to the pallid sturgeon water and stream quality because it serves as a buffer and filters out sediment, nutrients, and contaminants before they enter the watersheds of the Missouri, Mississippi, and Atchafalaya Rivers and tributaries. Riparian vegetation has been shown to be essential in the maintenance of a stable stream (Rosgen, 1996).

Concentrations of atrazine on the riparian vegetation were estimated using OPP's TerrPlant model (U.S. EPA, 2007d; Version 1.2.2), considering use conditions likely to occur in the watersheds where the sturgeon occurs. The TerrPlant model evaluates exposure to plants via runoff and spray drift and is EFED's standard tool for estimating exposure to non-target plants. The runoff loading of TerrPlant is estimated based on the water solubility of the chemical and assumptions about the drainage and receiving areas. As previously discussed in Section 3.2.3 (model inputs), the standard spray drift assumptions were modified using AgDrift to estimate the impact of a setback distance of 66 feet on the fraction of drift reaching a surface water body. These revised spray drift percentages were also incorporated into the TerrPlant model, assuming that non-target terrestrial plants adjacent to atrazine use sites would receive the same percentage of spray drift as an adjacent surface water body. The revised spray drift percentages are 0.6% for ground applications and 6.5% for aerial applications.

Although TerrPlant calculates exposure values for terrestrial plants inhabiting two environments (i.e., dry adjacent areas and semi-aquatic areas), only the exposure values from the dry adjacent areas are used in this assessment. The 'dry, adjacent area' is considered to be representative of a slightly sloped area that receives relatively high runoff and spray drift levels from upgradient treated fields. In this assessment, the 'dry, adjacent area' scenario is used to estimate screening-level exposure values for terrestrial plants in riparian areas. The 'semi-aquatic area' is considered to be representative of depressed areas that are ephemerally flooded, such as marshes, and, therefore, is not used to estimate exposure values for terrestrial riparian vegetation. Plants in 'semi-aquatic areas' are not addressed because potential impacts are unlikely to result in changes to the three riparian vegetation attributes that are evaluated in this assessment (i.e., streambank stability, sediment loading, and thermal stability; discussed further in Section 5.2.4.1).

The following input values were used to estimate terrestrial plant exposure to atrazine from all uses: water solubility = 33 ppm; minimum incorporation depth = 1 (TerrPlant default for incorporation depths ≤ 1 inch; from product labels); application methods: ground boom, aerial, and granular (from product labels). The following agricultural and non-agricultural scenarios were modeled: ground/aerial application to sugarcane and forestry at 4.0 lbs ai/A, fallow/idle land at 2.25 lbs ai/A, and corn/sorghum at 2.0 lbs ai/A; and granular application to residential lawns at 2 lbs ai/A. It should be noted that the TerrPlant model considers only exposures to plants from single pesticide applications. Therefore, predicted EECs for use patterns which allow multiple applications, such as sugarcane, are likely to be underestimated. Sugarcane uses were modeled at the highest single application rate of 4 lbs ai/A, although the maximum yearly rate for sugarcane is 10 lbs ai/A. Uncertainties associated with terrestrial plant exposures based on single pesticide applications are addressed in Section 6.1.4.

Terrestrial plant EECs for non-granular and granular formulations are summarized in Table 3.10. EECs resulting from spray drift are derived for non-granular applications only.

**Table 3.10 Screening-Level Exposure Estimates for Terrestrial Plants to Atrazine**

| Use / App. Rate (lbs/acre) | Application Method | Total Loading to Dry Adjacent Areas (lbs/acre) | Drift EEC (lbs/acre) |
|---|---|---|---|
| Sugarcane and | Aerial | 0.34 | 0.26 |

| | | | |
|---|---|---|---|
| Forestry / 4.0 | Ground | 0.10 | 0.02 |
| Fallow/idle land / 2.25 | Aerial | 0.19 | 0.15 |
| | Ground | 0.06 | 0.01 |
| Corn and Sorghum / 2.0 | Aerial | 0.17 | 0.13 |
| | Ground | 0.05 | 0.01 |
| Residential / 2.0 | Granular | 0.04 | NA |

For non-granular applications of atrazine, the highest off-target aerial loadings of atrazine predicted by TerrPlant are approximately 8.5% of the application rate for dry adjacent areas. As expected, resulting exposure estimates for terrestrial plants are higher for aerial than ground boom applications. Granular applications associated with residential use of atrazine result in estimated exposures, as a percentage of the associated application rate, of 2% for adjacent areas.

# 4. Effects Assessment

This assessment evaluates the potential for atrazine to adversely affect the pallid sturgeon. As previously discussed in Section 2.7, assessment endpoints for the pallid sturgeon include direct toxic effects on the survival, reproduction, and growth of the sturgeon itself, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. Direct effects and indirect dietary effects to the pallid sturgeon, a freshwater fish, are based on toxicity information for freshwater fish. Given that the pallid sturgeon's prey items and habitat requirements are also dependent on the availability of freshwater aquatic invertebrates and aquatic plants in addition to freshwater fish, toxicity information for various freshwater aquatic invertebrates and plants is discussed. In addition, terrestrial plant data are used to evaluate indirect effects on the sturgeon via direct effects to terrestrial vegetation (i.e., riparian habitat) required to maintain acceptable water quality and spawning habitat.

Acute (short-term) and chronic (long-term) effects toxicity information is characterized based on registrant-submitted studies and a comprehensive review of the open literature on atrazine. In addition to registrant-submitted and open literature toxicity information, indirect effects to the pallid sturgeon via impacts to aquatic plant community structure and function are also evaluated based on community-level threshold concentrations. Other methods, including use of the acute probit dose response relationship to establish the probability of an individual effect and reviews of the Ecological Incident Information System (EIIS), are used to further refine the characterization of potential ecological effects associated with exposure to atrazine. A summary of the available freshwater and terrestrial plant ecotoxicity information, the community-level endpoints, use of the probit dose response relationship, and the incident information for atrazine are provided in Sections 4.1 through 4.4, respectively.

With respect to atrazine degradates, including hydroxyatrazine (HA), deethylatrazine (DEA), deisopropylatrazine (DIA), and diaminochloroatrazine (DACT), it is assumed that each of the degradates are less toxic than the parent compound. As shown in Table 4.1, comparison of available toxicity information for HA, DIA, and DACT indicates lesser aquatic toxicity than the parent for freshwater fish, invertebrates, and aquatic plants.

**Table 4.1 Comparison of Acute Freshwater Toxicity Values for Atrazine and Degradates**

| Substance Tested | Fish $LC_{50}$ (µg/L) | Daphnid $EC_{50}$ (µg/L) | Aquatic Plant $EC_{50}$ (µg/L) |
|---|---|---|---|
| Atrazine | 5,300 | 3,500 | 1 |
| HA | >3,000 (no effects at saturation) | >4,100 (no effects at saturation) | >10,000 |
| DACT | >100,000 | >100,000 | No data |
| DIA | 17,000 | 126,000 (NOAEC: 10,000) | 2,500 |
| DEA | No data | No data | 1,000 |

Although degradate toxicity data are not available for terrestrial plants, lesser toxicity is assumed, given the available ecotoxicological information for other taxonomic groups including aquatic plants and the likelihood that the atrazine degradates are expected to lose efficacy as an herbicide.

Therefore, given the lesser toxicity of the degradates as compared to the parent, concentrations of the atrazine degradates are not assessed, and the focus of this assessment is limited to parent atrazine. The available information also indicates that aquatic organisms are more sensitive to the technical grade (TGAI) than the formulated products of atrazine; therefore, the focus of this assessment is on the TGAI. A detailed summary of the available ecotoxicity information for all atrazine degradates and formulated products is presented in Appendix A.

As previously discussed in the problem formulation, the available toxicity data show that other pesticides may combine with atrazine to produce synergistic or additive toxic interactions. The results of available toxicity data for mixtures of atrazine with other pesticides are presented in Section A.7 of Appendix A. According to the available data, other pesticides may combine with atrazine to produce synergistic or additive toxic effects. Based on the results of the available data, study authors claim that synergistic effects with atrazine may occur for a number of organophosphate insecticides including diazinon, chlorpyrifos, and methyl parathion, as well as herbicides including alachlor. If chemicals that show synergistic effects with atrazine are present in the environment in combination with atrazine, the toxicity of the atrazine mixture may be increased relative to the toxicity of each individual chemical, offset by other environmental factors, or even reduced by the presence of antagonistic contaminants if they are also present in the mixture. The variety of chemical interactions presented in the available data set suggest that the toxic effect of atrazine, in combination with other pesticides used in the environment, can be a function of many factors including but not necessarily limited to (1) the exposed species, (2) the co-contaminants in the mixture, (3) the ratio of atrazine and co-contaminant concentrations, (4) differences in the pattern and duration of exposure among contaminants, and (5) the differential effects of other physical/chemical characteristics of the receiving waters (e.g., organic matter present in sediment and suspended water). Quantitatively predicting the combined effects of all these variables on mixture toxicity to any given taxa with confidence is beyond the capabilities of the available data. However, a qualitative discussion of implications of the available pesticide mixture effects data involving atrazine on the confidence of risk assessment conclusions for the pallid sturgeon is addressed as part of the uncertainty analysis for this effects determination.

## 4.1 Evaluation of Aquatic Ecotoxicity Studies

Toxicity endpoints are established based on data generated from guideline studies submitted by the registrant, and from open literature studies that meet the criteria for inclusion in the ECOTOX database maintained by EPA/Office of Research and Development (ORD) (U.S. EPA, 2004). Open literature data presented in this assessment were obtained from the 2003 atrazine IRED as well as from ECOTOX (searched on May 31, 2007). The May 2007 ECOTOX search included all open literature data for atrazine (i.e., pre- and post-IRED). In order to be included in the ECOTOX database, papers must meet the following minimum criteria:

(1) the toxic effects are related to single chemical exposure;
(2) the toxic effects are on an aquatic or terrestrial plant or animal species;
(3) there is a biological effect on live, whole organisms;
(4) a concurrent environmental chemical concentration/dose or application rate is reported; and
(5) there is an explicit duration of exposure.

Data that pass the ECOTOX screen are evaluated along with the registrant-submitted data, and may be incorporated qualitatively or quantitatively into this endangered species assessment. In general, effects data in the open literature that are more conservative than the registrant-submitted data are considered. Based on the results of the 2003 IRED for atrazine, potential adverse effects on sensitive aquatic plants and non-target aquatic organisms including their populations and communities, are likely to be greatest when atrazine concentrations in water equal or exceed approximately 10 to 20 μg/L on a recurrent basis or over a prolonged period of time (U.S. EPA, 2003a). Given the large amount of microcosm/mesocosm and field study data for atrazine, only effects data that are less than or more conservative than the 10 μg/L aquatic-community effect level identified in the 2003 atrazine IRED were considered. The degree to which open literature data are quantitatively or qualitatively characterized is dependent on whether the information is relevant to the assessment endpoints (i.e., maintenance of pallid sturgeon survival, reproduction, and growth) identified in the problem formulation. For example, endpoints such as behavior modifications are likely to be qualitatively evaluated, unless it is possible to quantitatively link these endpoints with reduction in species survival, reproduction, and/or growth (e.g., the magnitude of effect on the behavioral endpoint needed to result in effects on survival, growth, or reproduction is known).

Citations of all open literature not considered as part of this assessment because it was either rejected by the ECOTOX screen or accepted by ECOTOX but not used (e.g., the endpoint is less sensitive and/or not appropriate for use in this assessment) are included in Appendix G. Appendix G also includes a rationale for rejection of those studies that did not pass the ECOTOX screen and those that were not evaluated as part of this ESA.

As described in the Agency's Overview Document (U.S. EPA, 2004), the most sensitive endpoint for each taxa is evaluated. For this assessment, evaluated taxa include freshwater fish, freshwater aquatic invertebrates, freshwater aquatic plants, and terrestrial plants. Table 4.2 summarizes the most sensitive ecological toxicity endpoints for the pallid sturgeon, based on an evaluation of both the submitted studies and the open literature, as previously discussed. A brief summary of submitted and open literature data considered relevant to this ecological risk assessment for the pallid sturgeon is presented below. Additional information is provided in Appendix A. It should be noted that Appendix A also includes ecotoxicity data for taxonomic groups that are not relevant to this assessment (i.e., birds, estuarine/marine fish and invertebrates) because the Agency is completing endangered species assessments for other species concurrently with this assessment.

**Table 4.2 Freshwater Aquatic and Terrestrial Plant Toxicity Profile for Atrazine**

| Assessment Endpoint | Species | Toxicity Value Used in Risk Assessment | Citation MRID # (Author, Date) | Comment |
|---|---|---|---|---|
| Acute Direct Toxicity to Sturgeon | Rainbow trout[a] | 96-hour $LC_{50}$ = 5,300 µg/L<br><br>(Probit slope = 2.72) | 000247-16<br><br>(Beliles and Scott, 1965) | Acceptable |
| Chronic Direct Toxicity to Sturgeon | Brook trout[a] | NOAEC = 65 µg/L<br><br>LOAEC = 120 µg/L | 000243-77<br><br>(Macek et al., 1976) | Acceptable: 7.2% reduction in length; 16% reduction in weight |
| Indirect Effects to Sturgeon via Acute Toxicity to Freshwater Invertebrates (i.e., prey items) | Midge | 48-hour $LC_{50}$ = 720 µg/L<br><br>(Probit slope unavailable) | 000243-77<br><br>(Macek et al., 1976) | Supplemental: raw data unavailable |
| Indirect Effects to Sturgeon via Chronic Toxicity to Freshwater Invertebrates (i.e., prey items) | Scud | NOAEC = 60 µg/L<br><br>LOAEC = 140 µg/L | 000243-77<br><br>(Macek et al., 1976) | Acceptable: 25 % reduction in development of $F_1$ to seventh instar |
| Indirect Effects to Sturgeon via Acute Toxicity to Non-vascular Aquatic Plants | 4 Species of Freshwater Algae | 1-week $EC_{50}$ = 1 µg/L | 000235-44<br><br>(Torres & O'Flaherty, 1976) | Supplemental: 41 to 98% reduction in chlorophyll production; raw data unavailable |
| Indirect Effects to Sturgeon via Acute Toxicity to Vascular | Duckweed | 14-day $EC_{50}$ = 37 µg/L | 430748-04<br><br>(Hoberg, 1993) | Supplemental: 50% reduction in biomass; NOAEC |

| | | | | |
|---|---|---|---|---|
| Aquatic Plants | | | | not determined |
| Indirect Effects to Sturgeon via Acute Toxicity to Terrestrial Monocot Plants | Oat | Tier II Seedling Emergence $EC_{25}$ = 0.004 lb ai/A | 420414-03 (Chetram, 1989) | Acceptable: 25% reduction in dry weight |
| Indirect Effects to Sturgeon via Acute Toxicity to Terrestrial Dicot Plants | Carrot | Tier II Seedling Emergence $EC_{25}$ = 0.003 lb ai/A | 420414-03 (Chetram, 1989) | Acceptable: 25% reduction in dry weight |
| [a] Used as a surrogate for the pallid sturgeon. | | | | |

Toxicity to aquatic fish and invertebrates is categorized using the system shown in Table 4.3 (U.S. EPA, 2004). Toxicity categories for aquatic plants have not been defined.

**Table 4.3 Categories of Acute Toxicity for Aquatic Organisms**

| $LC/EC_{50}$ (ppm) | Toxicity Category |
|---|---|
| < 0.1 | Very highly toxic |
| > 0.1 - 1 | Highly toxic |
| > 1 - 10 | Moderately toxic |
| > 10 - 100 | Slightly toxic |
| > 100 | Practically nontoxic |

### 4.1.1 Toxicity to Freshwater Fish

Freshwater fish toxicity data were used to assess potential direct effects of atrazine to the pallid sturgeon. Direct effects to freshwater fish resulting from exposure to atrazine may also indirectly affect the pallid sturgeon via reduction in available food. A summary of acute and chronic freshwater fish data, including data from the open literature, is provided below in Sections 4.1.1.1 through 4.1.1.3.

#### *4.1.1.1 Freshwater Fish: Acute Exposure (Mortality) Studies*

Freshwater fish acute toxicity studies were used to assess potential direct and indirect effects to the pallid sturgeon because the observed range of this species occurs within freshwater of the Missouri, Mississippi, and Atchafalaya Rivers. Atrazine toxicity has been evaluated in numerous freshwater fish species, including rainbow trout, brook trout, bluegill sunfish, fathead minnow, tilapia, zebrafish, goldfish, and carp, and the results of these studies demonstrate a wide range of sensitivity. The range of acute freshwater fish $LC_{50}$ values for atrazine spans one order of magnitude, from 5,300 to 60,000 µg/L; therefore, atrazine is categorized as moderately (>1,000 to 10,000 µg/L) to slightly (>10,000 to 100,000 µg/L) toxic to freshwater fish on an acute basis. The freshwater fish acute $LC_{50}$ value of 5,300 µg/L is based on a static 96-hour toxicity test using rainbow trout (*Oncorhynchus mykiss*) (MRID # 000247-16). No sublethal effects were reported as part of this study. A complete list of all the acute freshwater fish toxicity data for atrazine is provided in Table A-8 of Appendix A.

*4.1.1.2 Freshwater Fish: Chronic Exposure (Growth/Reproduction) Studies*

Chronic freshwater fish toxicity studies were used to assess potential direct and indirect effects via growth and reproduction to the pallid sturgeon and freshwater fish in the diet. Freshwater fish life-cycle studies for atrazine are available and summarized in Table A-12 of Appendix A. Following 44 weeks of exposure to atrazine in a flow-through system, statistically significant reductions in brook trout mean length (7.2%) and body weight (16%) were observed at a concentration of 120 µg/L as compared to the control (MRID # 000243-77). The corresponding NOAEC for this study is 65 µg/L. Although the acute toxicity data for atrazine show that rainbow trout are the most sensitive freshwater fish, available chronic rainbow trout toxicity data indicate that it is less sensitive to atrazine than the brook trout on a chronic exposure basis, , with respective LOAEC and NOAEC values of 1,100 µg/L and 410 µg/L. Further information on chronic freshwater fish toxicity is provided in Section A.2.2 of Appendix A.

*4.1.1.3 Freshwater Fish: Sublethal Effects and Additional Open Literature Information*

In addition to submitted studies, data were located in the open literature that report sublethal effect levels to freshwater fish that are less than the selected measures of effect summarized in Table 4.2. Although these studies report potentially sensitive endpoints, effects on survival, growth, or reproduction were not observed in the four available life-cycle studies at concentrations that induced the reported sublethal effects described below and in Appendix A.

Reported sublethal effects in rainbow trout show increased plasma vitellogenin levels in both female and male fish and decreased plasma testosterone levels in male fish at atrazine concentrations of approximately 50 µg/L (Wieser and Gross, 2002 [MRID 456223-04]). Vitellogenin (Vtg) is an egg yolk precursor protein expressed normally in female fish and dormant in male fish. The presence of Vtg in male fish is used as a molecular marker of exposure to estrogenic chemicals. It should be noted, however, that there is a high degree of variability with the Vtg effects in these studies, which confounds the ability to resolve the effects of atrazine on plasma steroids and vitellogenesis.

Effects of atrazine on freshwater fish behavior, including a preference for the dark part of the aquarium following one week of exposure (Steinberg et al., 1995 [MRID 452049-10]) and a reduction in grouping behavior following 24-hours of exposure (Saglio and Trijase, 1998 [MRID 452029-14]), have been observed at atrazine concentrations of 5 µg/L. In addition, alterations in rainbow trout kidney histology have also been observed at atrazine concentrations of 5 µg/L and higher (Fischer-Scherl et al., 1991 [MRID 452029-07]).

In salmon, atrazine effects on gill physiology and endocrine-mediated olfactory functions have been studied. Data from Waring and Moore (2004; ECOTOX #72625) suggest that salmon smolt gill physiology, represented by changes in Na-K-ATPase activity and increased sodium and potassium levels, was altered at 1 µg/L atrazine and higher. However, the pallid sturgeon occurs in freshwater habitats of the Missouri, Mississippi, and Atchafalaya Rivers; therefore, seawater survival is not a relevant endpoint for this assessment. Moore and Lower (2001; ECOTOX #67727) reported that endocrine-mediated functions of male salmon parr were affected at 0.5 µg/L atrazine. The reproductive priming effect of the female pheromone prostaglandin $F_{2\alpha}$ on the levels of expressible milt in males was reduced after exposure to atrazine at 0.5 µg/L. Although the hypothesis was not tested, the study authors suggest that exposure of smolts to atrazine during the freshwater stage may potentially affect olfactory imprinting to the natal river and subsequent homing of adults. However, no quantitative relationship is established between reduced olfactory response of male epithelial tissue to the female priming hormone in the laboratory and reduction in salmon reproduction (i.e., the ability of male salmon to detect, respond to, and mate with ovulating females). A negative control was not included as part of the study design; therefore, potential solvent effect cannot be evaluated. Furthermore, the study did not determine whether the decreased response of olfactory epithelium to specific chemical stimuli would likely impair similar responses in intact fish.

Tierney et al. (2007) studied the effect of 30-minute exposure to atrazine on behavioral and neurophysiological responses of juvenile rainbow trout to an amino acid odorant (L-histidine at $10^{-7}$ M). L-histidine was chosen because it has been shown to elicit an avoidance response in salmonids; however, control fish exposed to L-histidine at $10^{-7}$ M showed a slight preference (1.2 response ratio). Although the study authors conclude that L-histidine preference behavior was altered by atrazine at exposures ≥ 1 :g/L, no significant decreases in preference behavior were observed at 1 :g/L. Furthermore, no dose response relationship was observed in the behavioral response following pesticide exposure. At 1 and 100 :g/L, non-significant decreases in L-histidine preference were observed; however a statistically significant avoidance of L-histidine was observed at 10 :g/L, but not 100 :g/L. Hyperactivity (measured as the number of times fish crossed the centerline of the tank) was observed in trout exposed to 1 and 10 :g/L atrazine. In the study measuring neurophysiological responses following atrazine exposure, electro-olfactogram (EOG) response was significantly reduced (EOG measures changes in nasal epithelial voltage due to response of olfactory sensory neurons). Although this study produced a more sensitive effects endpoint for freshwater fish, the data were not used quantitatively in the risk assessment because of the following reasons: 1) A negative control was not used; therefore, potential solvent effects cannot be evaluated; 2) The study did not determine whether the decreased response of olfactory epithelium to specific chemical stimuli would likely impair similar responses in intact fish; and 3) A quantitative relationship between the magnitude of reduced olfactory response to an amino acid odorant in the laboratory and reduction in trout imprinting and homing, alarm response, and reproduction (i.e., the ability of trout to detect, respond to, and mate with ovulating females) in the wild is not established.

Although these studies raise questions about the effects of atrazine on plasma steroid levels, behavior modifications, gill physiology, and endocrine-mediated functions in freshwater and anadromous fish, it is not possible to quantitatively link these sublethal effects to the selected assessment endpoints for the pallid sturgeon (i.e., survival, growth, and reproduction of individuals). Also, effects on survival, growth, or reproduction were not observed in the four available life-cycle studies at concentrations that induced these reported sublethal effects. Therefore, potential sublethal effects on fish are not used as part of the quantitative risk characterization, but are qualitatively considered in Section 5.2. Further detail on sublethal effects to fish is provided in Sections A.2.4a and A.2.4b of Appendix A.

### 4.1.2 Toxicity to Freshwater Invertebrates

Freshwater aquatic invertebrate toxicity data were used to assess potential indirect effects of atrazine to the pallid sturgeon. Direct effects to freshwater invertebrates resulting from exposure to atrazine may indirectly affect the pallid sturgeon via reduction in available food. As previously discussed in Section 2.5, the pallid sturgeon is a benthic omnivore, feeding on freshwater fish and invertebrates including aquatic insect larvae. A summary of acute and chronic freshwater invertebrate data, including data published in the open literature, is provided below in Sections 4.1.2.1 through 4.1.2.3.

#### *4.1.2.1 Freshwater Invertebrates: Acute Exposure Studies*

Atrazine is classified as highly toxic to slightly toxic to aquatic invertebrates. There is a wide range of $EC_{50}/LC_{50}$ values for freshwater invertebrates with values ranging from 720 to >33,000 µg/L. The freshwater $LC_{50}$ value of 720 µg/L is based on an acute 48-hour static toxicity test for the midge, *Chironomus tentans* (MRID # 000243-77). Further evaluation of the available acute toxicity data for the midge shows high variability with the $LC_{50}$ values, ranging from 720 to >33,000 µg/L. With the exception of the midge, reported acute toxicity values for the other five freshwater invertebrates (including the water flea, scud, stonefly, leech, and snail) are 3,500 µg/L and higher. All of the available acute toxicity data for freshwater invertebrates are provided in Section A.2.5 and Table A-18 of Appendix A. The $LC_{50}/EC_{50}$ distribution for freshwater invertebrates is graphically represented in Figure 4.1. The columns represent the lowest reported value for each species, and the positive y error bar represents the maximum reported value. Values in parentheses represent the number of studies included in the analyses.

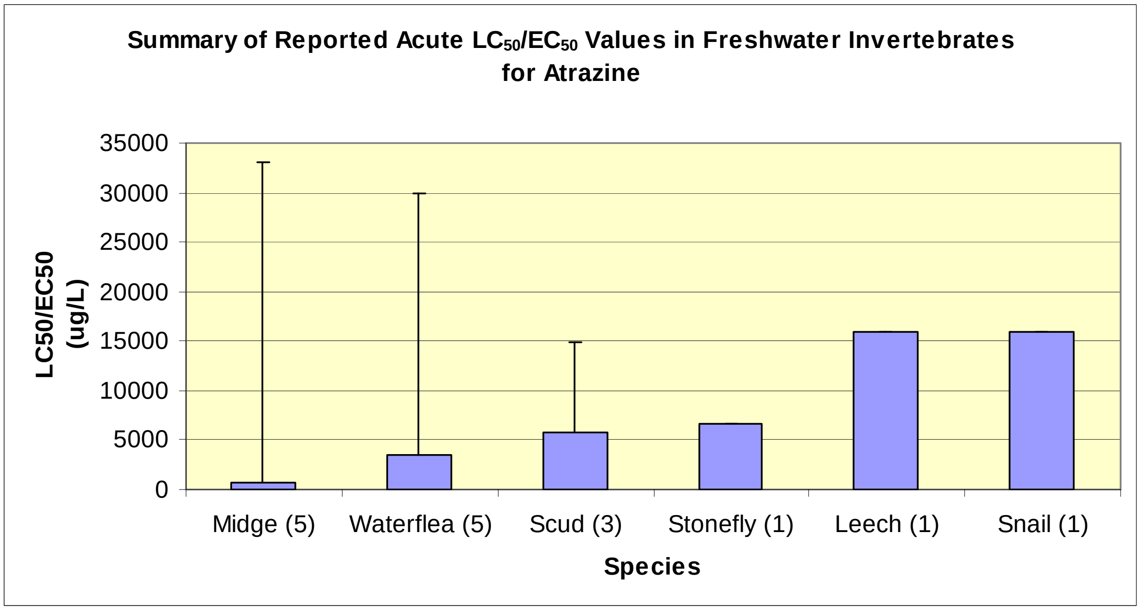


**Figure 4.1 Summary of Reported Acute $LC_{50}$/$EC_{50}$ Values in Freshwater Invertebrates for Atrazine**

*4.1.2.2 Freshwater Invertebrates: Chronic Exposure Studies*

The most sensitive chronic endpoint for freshwater invertebrates is based on a 30-day flow-through study on the scud (*Gammarus fasciatus*), which showed a 25% reduction in the development of $F_1$ to the seventh instar at atrazine concentrations of 140 µg/L; the corresponding NOAEC is 60 µg/L (MRID # 000243-77). Although the acute toxicity data for atrazine show that the midge (*Chironomus tentans*) is the most sensitive freshwater invertebrate, available chronic midge toxicity data indicate that it is less sensitive to atrazine than the scud, on a chronic exposure basis, with respective LOAEC and NOAEC values of 230 µg/L and 110 µg/L. Additional information on the chronic toxicity of atrazine to freshwater invertebrates is provided in Section A.2.6 and Table A-20 of Appendix A.

*4.1.2.3 Freshwater Invertebrates: Open Literature Data*

Two additional acute studies for underrepresented taxa of freshwater mussels were located in the open literature; however, the data are not relevant for the pallid sturgeon. Further information on the results of the freshwater mussel studies obtained from the open literature is summarized in Table A-21 of Appendix A.

4.1.3 Toxicity to Aquatic Plants

Aquatic plant toxicity studies were used as one of the measures of effect to evaluate whether atrazine may affect primary production. In the Missouri, Mississippi, and Atchafalaya Rivers and tributaries, primary productivity is essential for indirectly supporting the growth and abundance of the pallid sturgeon.

Two types of studies were used to evaluate the potential of atrazine to affect primary productivity. Laboratory studies were used to determine whether atrazine may cause direct effects to aquatic plants. In addition, the threshold concentrations, described in Section 4.2, were used to further characterize potential community level effects to pallid sturgeon resulting from potential effects to aquatic plants. A summary of the laboratory data for aquatic plants is provided in Section 4.1.3.1. A description of the threshold concentrations used to evaluate community-level effects is included in Section 4.2.

#### *4.1.3.1 Aquatic Plants: Laboratory Data*

Numerous aquatic plant toxicity studies have been submitted to the Agency. A summary of the data for freshwater vascular and non-vascular plants is provided below. Section A.4.2 and Tables A-40 and A-41 of Appendix A include a more comprehensive description of these data.

The Tier II results for freshwater aquatic plants indicate that atrazine caused a 41 to 98% reduction in chlorophyll production of freshwater algae; the corresponding $EC_{50}$ value for four different species of freshwater algae is 1 µg/L, based on data from a 7-day acute study (MRID # 000235-44). Vascular plants are less sensitive to atrazine than freshwater non-vascular plants with an $EC_{50}$ value of 37 µg/L, based on reduction in duckweed growth (MRID # 430748-04).

Comparison of atrazine toxicity levels for three different endpoints in algae suggests that the endpoints in decreasing order of sensitivity are cell count, growth rate, and oxygen production (Stratton, 1984). Walsh (1983) exposed *Skeletonema costatum* to atrazine and concluded that atrazine is only slightly algicidal at relatively high concentrations (i.e., 500 and 1,000 µg/L). Caux et al. (1996) compared the cell count $IC_{50}$ and fluorescence $LC_{50}$ and concluded that atrazine is algicidal at concentrations affecting cell counts. Abou-Waly et al. (1991) measured growth rates on days 3, 5, and 7 for two algal species. The pattern of atrazine effects on growth rates differs sharply between the two species. Atrazine had a strong early effect on *Anabaena flos-aquae* followed by rapid recovery in clean water (i.e., $EC_{50}$ values for days 3, 5, and 7 are 58, 469, and 766 µg/L, respectively). The $EC_{50}$ values for *Selenastrum capricornutum* continued to decline from day 3 through 7 (i.e., 283, 218, and 214 µg/L). Based on theses results, it appears that the timing of peak effects for atrazine may differ depending on the test species.

It should be noted that recovery from the effects of atrazine and the development of resistance to the effects of atrazine in some vascular and non-vascular aquatic plants have been reported and may add uncertainty to these findings. However, reports of recovery are often based on differing interpretations of recovery. Thus, before recovery can be considered as an uncertainty, an agreed upon interpretation is needed. For the purposes of this assessment, recovery is defined as a return to pre-exposure levels for the *affected population*, not for a replacement population of more tolerant species. Existing research is not adequate to quantify the impact that recovery and resistance may have on aquatic plants.

#### 4.1.4 Freshwater Field Studies

Microcosm and mesocosm studies with atrazine provide measurements of primary productivity that incorporate the aggregate responses of multiple species in aquatic plant communities. Because plant species vary widely in their sensitivity to atrazine, the overall response of the plant community may be different from the responses of the individual species measured in laboratory toxicity tests. Mesocosm and microcosm studies allow observation of population and community recovery from atrazine effects and of indirect effects on higher trophic levels. In addition, mesocosm and microcosm studies, especially those conducted in outdoor systems, incorporate partitioning, degradation, and dissipation, factors that are not usually accounted for in laboratory toxicity studies, but that may influence the magnitude of ecological effects.

Atrazine has been the subject of many mesocosm and microcosm studies in ponds, streams, lakes, and wetlands. The durations of these studies have ranged from a few weeks to several years at exposure concentrations ranging from 0.1 µg/L to 10,000 µg/L. Most of the studies have focused on atrazine effects on phytoplankton, periphyton, and macrophytes; however, some have also included measurements on animals.

As described in the 2003 IRED for atrazine (U.S. EPA, 2003a), potential adverse effects on sensitive aquatic plants and non-target aquatic organisms including their populations and communities are likely to be greatest when atrazine concentrations in water equal or exceed approximately 10 to 20 µg/L on a recurrent basis or over a prolonged period of time. A summary of all the freshwater aquatic microcosm, mesocosm, and field studies that were reviewed as part of the 2003 IRED is included in Section A.2.8a and Tables A-22 through A-24 of Appendix A. Given the large amount of microcosm and mesocosm and field study data for atrazine, only effects data less than or more conservative than the 10 µg/L aquatic community effect level identified in the 2003 IRED were considered from the open literature search that was completed in May 2007. Based on the selection criteria for review of new open literature, all of the available studies show effects levels to freshwater fish, invertebrates, and aquatic plants at concentrations greater than 10 µg/L.

It should be noted that the 10 to 20 µg/L community effect level has been further refined since completion of the 2003 IRED. The community-level effects thresholds for various durations of exposure from 14 to 90 days are described in further detail in Section 4.2. In summary, the potential for atrazine to induce community-level effects depends on both atrazine concentration and duration. As the exposure duration increases, atrazine concentrations that may produce community-level effects decrease. For example, 14-day atrazine concentrations of 38 µg/L or lower are not considered likely to result in aquatic community-level effects, whereas 90-day atrazine concentrations of 12 µg/L or lower are not expected to produce community-level effects.

Community-level effects to aquatic plants that are likely to result in indirect effects to the rest of the aquatic community, including the pallid sturgeon, are evaluated based on threshold concentrations. These threshold concentrations, which are discussed in greater detail in Section 4.2 and Appendix B, incorporate the available micro- and mesocosm data included in the 2003 IRED (U.S. EPA, 2003a) as well as additional information gathered following completion of the 2003 atrazine IRED (U.S. EPA, 2003e).

### 4.1.5 Toxicity to Terrestrial Plants

Terrestrial plant toxicity data are used to evaluate the potential for atrazine to affect riparian zone vegetation within the action area for the pallid sturgeon. Riparian zone effects may indirectly affect the pallid sturgeon by resulting in potential impacts to river/streambank stability, thermal stability, and sedimentation. Plant toxicity data from both registrant-submitted studies and studies in the scientific literature were reviewed for this assessment. Registrant-submitted studies are conducted under conditions and with species defined in EPA toxicity test guidelines. Sub-lethal endpoints such as plant growth, dry weight, and biomass are evaluated for both monocots and dicots, and effects are evaluated at both seedling emergence and vegetative life stages. Guideline studies generally evaluate toxicity to ten crop species. A drawback to these tests is that they are conducted on herbaceous crop species only, and extrapolation of effects to other species, such as the woody shrubs and trees and wild herbaceous species, contributes uncertainty to risk conclusions. However, atrazine is labeled for use on conifers and softwoods; therefore, effects to evergreens would not be anticipated. In addition, preliminary data submitted to the Agency (discussed below) suggest that sensitive woody plant species exist; however, damage to most woody species at labeled application rates is not expected.

Commercial crop species have been selectively bred, and may be more or less resistant to particular stressors than wild herbs and forbs. The direction of this uncertainty for specific plants and stressors, including atrazine, is largely unknown. Homogenous test plant seed lots also lack the genetic variation that occurs in natural populations, so the range of effects seen from tests is likely to be smaller than would be expected from wild populations.

Based on the results of the submitted terrestrial plant toxicity tests, it appears that terrestrial plants are more sensitive to the seedling emergence test than the vegetative vigor test. However, all tested plants, with the exception of corn in the seedling emergence and vegetative vigor tests and ryegrass in the vegetative vigor test, exhibited adverse effects following exposure to atrazine. Tables 4.4 and 4.5 summarize the respective seedling emergence and vegetative vigor terrestrial plant toxicity data used to derive risk quotients in this assessment.

In Tier II seedling emergence toxicity tests, the most sensitive monocot and dicot species are oats and carrots, respectively. $EC_{25}$ values for carrots and oats, which are based on a reduction in dry weight, are 0.003 and 0.004 lb ai/A, respectively; NOAEC values for both species are 0.0025 lb ai/A.

For Tier II vegetative vigor studies, the most sensitive dicot and monocot species are the cucumber and onion, respectively. In general, dicots appear to be more sensitive than monocots via foliar routes of exposure with all tested dicot species showing a significant reduction in dry weight at $EC_{25}$ values ranging from 0.008 to 0.72 lb ai/A. In contrast, two of the four tested monocots showed no effect to atrazine (corn and ryegrass), while $EC_{25}$ values for onion and oats were 0.61 and 2.4 lb ai/A, respectively.

**Table 4.4 Non-target Terrestrial Plant Seedling Emergence Toxicity (Tier II) to Atrazine**

| Surrogate Species | % ai | $EC_{25}$ / NOAEC (lbs ai/A) | Endpoint Affected | MRID No. Author, Year | Study Classification |
|---|---|---|---|---|---|
| Monocot - Corn (*Zea mays*) | 97.7 | > 4.0 / 4.0 | No effect | 420414-03 Chetram, 1989 | Acceptable |
| Monocot - Oat (*Avena sativa*) | 97.7 | **0.004 / 0.0025** | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Monocot - Onion (*Allium cepa*) | 97.7 | 0.009 / 0.005 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Monocot - Ryegrass (*Lolium perenne*) | 97.7 | 0.004 / 0.005 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Root Crop - Carrot (*Daucus carota*) | 97.7 | **0.003 / 0.0025** | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Soybean (*Glycine max*) | 97.7 | 0.19 / 0.025 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Lettuce (*Lactuca sativa*) | 97.7 | 0.005 / 0.005 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Cabbage (*Brassica oleracea alba*) | 97.7 | 0.014 / 0.01 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Tomato (*Lycopersicon esculentum*) | 97.7 | 0.034 / 0.01 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Cucumber (*Cucumis sativus*) | 97.7 | 0.013 / 0.005 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |

**Table 4.5 Non-target Terrestrial Plant Vegetative Vigor Toxicity (Tier II) to Atrazine**

| Surrogate Species | % ai | $EC_{25}$ / NOAEC (lbs ai/A) | Endpoint Affected | MRID No. Author/Year | Study Classification |
|---|---|---|---|---|---|
| Monocot - Corn | 97.7 | > 4.0 / 4.0 | No effect | 420414-03 Chetram, 1989 | Acceptable |
| Monocot - Oat | 97.7 | 2.4 / 2.0 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Monocot - Onion | 97.7 | **0.61 / 0.5** | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Monocot - Ryegrass | 97.7 | > 4.0 / 4.0 | No effect | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Carrot | 97.7 | 1.7 / 2.0 | red. in plant height | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Soybean | 97.7 | 0.026 / 0.02 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Lettuce | 97.7 | 0.33 / 0.25 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |

| Table 4.5 Non-target Terrestrial Plant Vegetative Vigor Toxicity (Tier II) to Atrazine | | | | | |
|---|---|---|---|---|---|
| Surrogate Species | % ai | $EC_{25}$ / NOAEC (lbs ai/A) | Endpoint Affected | MRID No. Author/Year | Study Classification |
| Dicot - Cabbage | 97.7 | 0.014 / 0.005 | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Tomato | 97.7 | 0.72 / 0.5 | red. in plant height | 420414-03 Chetram, 1989 | Acceptable |
| Dicot - Cucumber | 97.7 | **0.008 / 0.005** | red. in dry weight | 420414-03 Chetram, 1989 | Acceptable |

In addition, a report on the toxicity of atrazine to woody plants (Wall, 2006; MRID 46870400-01) was reviewed by the Agency. A total of 35 species were tested at application rates ranging from 1.5 to 4.0 lbs ai/A. Twenty-eight species exhibited either no or negligible phytotoxicity. Seven of 35 species exhibited >10% phytotoxicity. However, further examination of the data indicates that atrazine application was clearly associated with severe phytotoxicity in only one species (Shrubby Althea). These data suggest that, although sensitive woody plants exist, atrazine exposure to most woody plant species at application rates of 1.5 to 4.0 lbs ai/A is not expected to cause adverse effects. A summary of the available woody plant data is provided in Table A-39b of Appendix A.

## 4.2 Community-Level Endpoints: Threshold Concentrations

In this endangered species assessment, direct and indirect effects to the pallid sturgeon are evaluated in accordance with the screening-level methodology described in the Agency's Overview Document (U.S. EPA, 2004). If aquatic plant RQs exceed the Agency's non-listed species LOC (because the sturgeon does not have an obligate relationship with any one particular plant species, but rather relies on multiple plant species), based on available $EC_{50}$ data for vascular and non-vascular plants, risks to individual aquatic plants are assumed.

It should be noted, however, that the indirect effects analysis in this assessment is unique, in that the best available information for atrazine-related effects on aquatic communities is far more extensive than for other pesticides. Hence, atrazine effects determinations can utilize more refined data than are generally available to the Agency. Specifically, a robust set of microcosm and mesocosm data and aquatic ecosystem models are available for atrazine that allowed EPA to refine the indirect effects associated with potential aquatic community-level effects (via aquatic plant community structural change and subsequent habitat modification) to the pallid sturgeon. Use of such information is consistent with the guidance provided in the Overview Document (U.S. EPA, 2004), which specifies that "the assessment process may, on a case-by-case basis, incorporate additional methods, models, and lines of evidence that EPA finds technically appropriate for risk management objectives" (Section V, page 31 of EPA, 2004). This information, which represents the best scientific data available, is described in further detail below and in Appendix B of the previous endangered species effects determination for eight listed mussels (U.S. EPA, 2007c). This information is also considered a refinement of the 10-20 µg/L range reported in the 2003 IRED (U.S. EPA, 2003a).

The Agency has selected an atrazine level of concern (LOC) in the 2003 IRED (U.S. EPA, 2003a and b) that is consistent with the approach described in the Office of Water's (OW) draft atrazine aquatic life criteria (U.S. EPA, 2003c). Through these previous analyses (U.S. EPA, 2003a, b, and c), which reflect the current best available information, predicted or monitored aqueous atrazine concentrations can be interpreted to determine if a water body is likely to be affected via indirect effects to the aquatic community. Potential impacts of atrazine to plant community structure and function that are likely to result in indirect effects to the rest of the aquatic community, including the pallid sturgeon, are evaluated as described below.

Responses in microcosms and mesocosms exposed to atrazine were evaluated to differentiate no or slight recoverable effects from significant, generally non-recoverable effects (U.S. EPA, 2003e). Because effects varied with exposure duration and magnitude, there was a need for methods to predict relative differences in effects for different types of exposures. The Comprehensive Aquatic Systems Model (CASM) (Bartell et al., 2000; Bartell et al., 1999; DeAngelis et al., 1989) was selected as an appropriate tool to predict these relative effects, and was configured to provide a simulation for the entire growing season of a 2nd and 3rd order Midwestern stream as a function of atrazine exposure. CASM simulations conducted for the concentration/duration exposure profiles of the micro- and mesocosm data showed that CASM seasonal output, represented as an aquatic plant community similarity index, correlated with the micro- and mesocosm effect scores, and that a 5% change in this index reasonably discriminated micro- and mesocosm responses with slight versus significant effects. The CASM-based index was assumed to be applicable to more diverse exposure conditions beyond those present in the micro- and mesocosm studies.

To avoid having to repeatedly run CASM, simulations were conducted for a variety of actual and synthetic atrazine chemographs to determine 14-, 30-, 60-, and 90-day average concentrations that discriminated among exposures that were unlikely to exceed the CASM-based index (i.e., 5% change in the index). It should be noted that the average 14-, 30-, 60-, and 90-day concentrations were originally intended to be used as screening values to trigger a CASM run (which is used as a tool to identify the 5% index change LOC), rather than actual thresholds to be used as an LOC (U.S. EPA, 2003e). The following threshold concentrations for atrazine were identified (U.S. EPA, 2003e):

- 14-day average = 38 µg/L
- 30-day average = 27 µg/L
- 60-day average = 18 µg/L
- 90-day average = 12 µg/L

Effects of atrazine on aquatic plant communities that have the potential to subsequently pose indirect effects to the pallid sturgeon are best addressed using the robust set of micro- and mesocosm studies available for atrazine and the associated risk estimation techniques (U.S. EPA, 2003a, b, c, and e). The 14-, 30-, 60-, and 90-day threshold concentrations developed by EPA (2003e) are used to evaluate potential indirect effects to aquatic communities for the purposes of this endangered species assessment. Use of these threshold concentrations is considered appropriate because: (1) the CASM-based index meets the goals of the defined assessment endpoints for this assessment; (2) the threshold concentrations provide a reasonable surrogate for the CASM index; and (3) the additional conservatism built into the threshold concentration, relative to the CASM-based index, is appropriate for an endangered species risk assessment (i.e., the threshold concentrations were set to be conservative, producing a low level (1%) of false negatives relative to false positives). Therefore, these threshold concentrations are used to identify potential indirect effects (via aquatic plant community structural change) to the pallid sturgeon. If modeled atrazine EECs exceed the 14-, 30-, 60-, and 90-day threshold concentrations following refinements of potential atrazine concentrations with available monitoring data, the CASM model could be employed to further characterize the potential for indirect effects. A step-wise data evaluation scheme incorporating the use of the screening threshold concentrations is provided in Figure 4.2. Further information on threshold concentrations is provided in Appendix B of the previous endangered species effects determination for eight listed mussels (U.S. EPA, 2007c).

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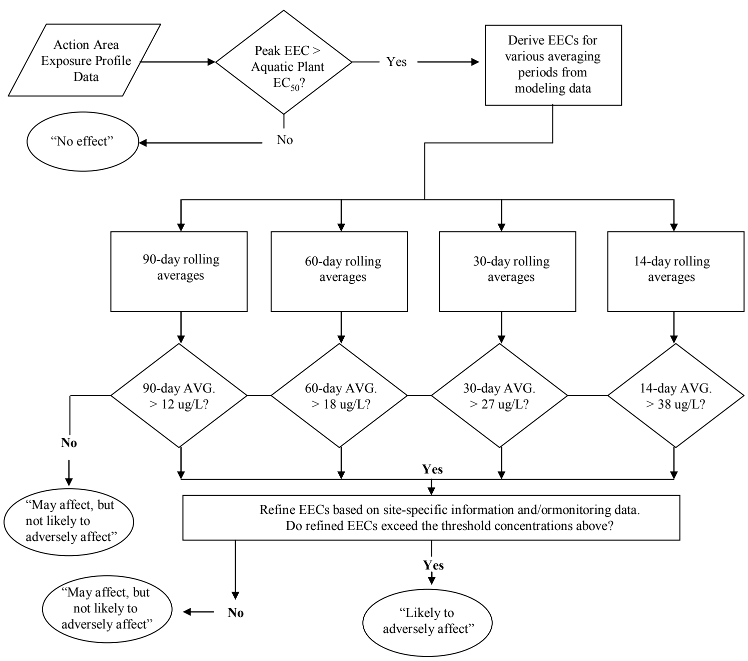


**Figure 4.2 Use of Threshold Concentrations in Endangered Species Assessment**

## 4.3 Use of Dose-Response Probit Slope Relationship to Provide Information on the Endangered Species Levels of Concern

The Agency uses the probit dose response relationship as a tool for providing additional information on the potential for acute direct effects to individual listed species and aquatic animals that may indirectly affect the listed species of concern (U.S. EPA, 2004). As part of the risk characterization, an interpretation of acute RQ for listed species is discussed. This interpretation is presented in terms of the chance of an individual event (i.e., mortality or immobilization) should exposure at the EEC actually occur for a species with sensitivity to atrazine on par with the acute toxicity endpoint selected for RQ calculation. To accomplish this interpretation, the Agency uses the slope of the dose response relationship available from the toxicity study used to establish the acute toxicity measures of effect for each taxonomic group that is relevant to this assessment. The individual effects probability associated with the acute RQ is based on the mean estimate of the slope and an assumption of a probit dose response relationship. In addition to a single effects probability estimate based on the mean, upper and lower estimates of the effects probability are also provided to account for variance in the slope, if available. The upper and lower bounds of the effects probability are based on available information on the 95% confidence interval of the slope. A statement regarding the confidence in the estimated event probabilities is also included. Studies with good probit fit characteristics (i.e., statistically appropriate for the data set) are associated with a high degree of confidence. Conversely, a low degree of confidence is associated with data from studies that do not statistically support a probit dose response relationship. In addition, confidence in the data set may be reduced by high variance in the slope (i.e., large 95% confidence intervals), despite good probit fit characteristics.

Individual effect probabilities are calculated based on an Excel spreadsheet tool IECV1.1 (Individual Effect Chance Model Version 1.1) developed by the U.S. EPA, OPP, Environmental Fate and Effects Division (June 22, 2004). The model allows for such calculations by entering the mean slope estimate (and the 95% confidence bounds of that estimate) as the slope parameter for the spreadsheet. In addition, the acute RQ is entered as the desired threshold.

### 4.4 Incident Database Review

A number of incidents have been reported in which atrazine has been associated with some type of environmental effect. Incidents are maintained and catalogued by EFED in the Ecological Incident Information System (EIIS). Each incident is assigned a level of certainty from 0 (unrelated) to 4 (highly probable) that atrazine was a causal factor in the incident. As of the writing of this assessment, 358 incidents are in EIIS for atrazine spanning the years 1970 to 2005. Most (309/358, 86%) of the incidents involved damage to terrestrial plants, and most of the terrestrial plant incidences involved damage to crops treated directly with atrazine. Of the remaining 49 incidents, 47 involved aquatic animals and 2 involved birds. Because the species included in this effects determination are aquatic species, incidents involving aquatic animals assigned a certainty index of 2 (possible) or higher (N=33) were re-evaluated. Results are summarized below, and additional details are provided in Appendix E. The 33 aquatic incidents were divided into three categories:

1. Aquatic incidents in which atrazine concentrations were confirmed to be sufficient to either cause or contribute to the incident, including directly via toxic effects to aquatic organisms or indirectly via effects to aquatic plants, resulting in depleted oxygen levels;

2. Aquatic incidents in which insufficient information is available to conclude whether atrazine may have been a contributing factor – these may include incidents where there was a correlation between atrazine use and a fish kill, but the presence of atrazine in the affected water body was not confirmed; and
3. Aquatic incidents in which causes other than atrazine exposure are more plausible (e.g., presence of substance other than atrazine confirmed at toxic levels).

The presence of atrazine at levels thought to be sufficient to cause either direct or indirect effects was confirmed in 3 (9%) of the 33 aquatic incidents evaluated. Atrazine use was also correlated with 11 (33%) additional aquatic incidents where its presence in the affected water was not confirmed, but the timing of atrazine application was correlated with the incident. Therefore, a definitive causal relationship between atrazine use and the incident could not be established. The remaining 19 incidents (58%) were likely caused by some factor other than atrazine. Other causes primarily included the presence of other pesticides at levels known to be toxic to affected animals. Although atrazine use was likely associated with some of the reported incidents for aquatic animals, they are of limited utility to this assessment for the following reasons:

- No incidents in which atrazine is likely to have been a contributing factor have been reported after 1998. A number of label changes, including cancellation of certain uses, reduction in application rates, and harmonization across labels to require setbacks for applications near waterbodies, have occurred since that time. For example, several incidents occurred in ponds that are adjacent to treated fields. The current labels require a 66-foot buffer between application sites and water bodies.

- The habitat of the assessed species is not consistent with environments in which incidents have been reported. For example, no incidents in streams or rivers were reported.

Although the reported incidents suggest that high levels of atrazine may result in impacts to aquatic life in small ponds that are in close proximity to treated fields, the incidents are of limited utility to the current assessment. However, the lack of recently reported incidents in flowing waters does not indicate that effects have not occurred. Further information on the atrazine incidents and a summary of uncertainties associated with all reported incidents are provided in Appendix E.

## 5. Risk Characterization

Risk characterization is the integration of the exposure and effects characterizations to determine the potential ecological risk from varying atrazine use scenarios within the action area and likelihood of direct and indirect effects on the pallid sturgeon. The risk characterization provides an estimation and a description of the likelihood of adverse effects; articulates risk assessment assumptions, limitations, and uncertainties; and synthesizes an overall conclusion regarding the likelihood of adverse effects to the pallid sturgeon and/or its habitat (i.e., "no effect," "likely to adversely affect," or "may affect, but not likely to adversely affect").

## 5.1 Risk Estimation

Risk was estimated by calculating the ratio of the estimated environmental concentration (Table 3.4) and the appropriate toxicity endpoint (Table 4.2). This ratio is the risk quotient (RQ), which is then compared to established acute and chronic levels of concern (LOCs) for each category evaluated (Appendix F). Screening-level RQs are based on the most sensitive endpoints and the following surface water concentration scenarios for atrazine:

- corn use @ 2 lbs ai/A; 2 applications with 30 days between applications
- sorghum use @ 2 lbs ai/A; 1 application
- fallow/idle land use @ 2.25 lbs ai/A; 1 application
- forestry use @ 4.0 lbs ai/A; 1 application
- sugarcane use @ 4 lbs ai/A; 3 applications (not to exceed 10 lbs/yr) with 60 days between applications
- residential granular use @ 2 lbs ai/A; 2 applications with 30 days between applications
- residential liquid use @ 1 lb ai/A; 2 applications with 30 days between applications
- turf granular use @ 2 lbs ai/A; 2 applications with 30 days between applications
- turf liquid use @ 1 lb ai/A; 2 applications with 30 days between applications
- rights-of-way liquid use @ 1 lb ai/A; 1 application

EECs are also derived for terrestrial plants, as discussed in Section 3.3, based on the highest application rates of atrazine relevant within the action area.

The two highest screening-level EECs (sugarcane and corn in the southern region) were initially used to derive risk quotients. In cases where LOCs were not exceeded based on the two highest EECs, additional RQs were not derived because it was assumed that RQs for lower EECs would also not exceed LOCs. However, if LOCs were exceeded based on both of the two highest EECs, use/region-specific RQs were also derived. Screening-level EECs initially used in the risk estimation are based on atrazine use in the southern region because the highest EECs were associated with this region. It should be noted that sugarcane EECs and associated RQs are relevant for only the southern region because this agricultural crop is not grown in the Great Plains, northern, or western regions of the action area.

In cases where the screening-level RQ exceeds one or more LOCs (i.e., "may affect"), additional factors, including pallid sturgeon life history characteristics, refinement of the screening-level EECs using site-specific information, available monitoring data, and consideration of community-level threshold concentrations, are considered and used to characterize the potential for atrazine to adversely affect the pallid sturgeon. Risk estimations of direct and indirect effects of atrazine to the pallid sturgeon are provided in Sections 5.1.1 and 5.1.2, respectively.

As previously discussed in the effects assessment, the toxicity of the atrazine degradates has been shown to be less than the parent compound based on the available toxicity data for freshwater fish, invertebrates, and aquatic plants; therefore, the focus of the risk characterization is parent atrazine (i.e., RQ values were not derived for the degradates).

### 5.1.1 Direct Effects

Direct effects to the pallid sturgeon associated with acute and chronic exposure to atrazine are based on the most sensitive toxicity data available for freshwater fish. Acute and chronic RQs used to estimate potential direct effects to the pallid sturgeon are provided in Tables 5.1 and 5.2, respectively. These RQs are also used to assess potential indirect effects to the pallid sturgeon based on reduction in freshwater fish food items in Section 5.1.2.1.

With the exception of atrazine use on sugarcane in the southern region of action area, direct effects associated with acute exposure to atrazine are not expected to occur for atrazine uses within the action area. The acute RQ of 0.08 associated with atrazine use on sugarcane, which occurs only in the southern region, exceeds the acute endangered species LOC of 0.05. Peak screening-level EECs based on sugarcane use are approximately four-fold higher than peak EECs for corn use in the same area. Aside from the sugarcane use, the next highest EEC used to derive acute RQs for the pallid sturgeon is representative of the highest modeled EEC from the southern corn use scenario. Based on the southern corn screening-level EEC, acute RQs do not exceed the endangered species LOC of 0.05. Therefore, atrazine use on sugarcane in the southern region may result in acute direct effects to the pallid sturgeon. However, all other uses of atrazine within the pallid sturgeon action area are not expected to result in acute direct effects.

**Table 5.1 Summary of Direct Acute Effect RQs for the Pallid Sturgeon**

| Effect to Pallid Sturgeon | Use (appl. method; rate; # appl.; int. between appl.) | Peak EECs (µg/L)[a] | Freshwater Fish Acute RQ ($LC_{50}$ = 5,300 µg/L)[b] | Probability of Individual Effect[c] | LOC Exceedance and Risk Interpretation |
|---|---|---|---|---|---|
| Acute Direct Toxicity[d] | Sugarcane (aerial liquid; 4 lbs ai/A; 3 appl.; 60 days) | South: 408 | **0.08** | 1 in 702 (1 in 23 to 1 in 1.01E+05) | **Yes (south region only)[e]** |
| | Corn (aerial liquid; 2.5 lbs ai/A; 2 appl; 30 days) | South: 109 | 0.02 | 1 in 5.24E+05 (1 in 249 to 1 in 5.14E+10) | No[f] |

[a] Screening-level EECs from Table 3.4.
[b] Based on a 96-hour $LC_{50}$ value of 5,300 µg/L for the rainbow trout (MRID# 00247-16).
[c] Based on a probit slope of 2.72 for the rainbow trout with 95% confidence intervals of 1.56 and 3.89 (MRID# 000247-16).
[d] RQs associated with acute direct toxicity to the pallid sturgeon are also used to assess potential indirect effects to the sturgeon based on reduction in freshwater fish food items.
[e] RQ > acute endangered species LOC of 0.05. Further evaluation of the RQ is necessary to determine if

| |
|---|
| atrazine is likely to adversely affect the pallid sturgeon.<br>[f] RQ < acute endangered species LOC of 0.05. |

As shown in Table 5.2, the chronic LOC of 1.0 is exceeded for sugarcane uses in the southern region, corn uses in all regions, and fallow/idleland in the west region of the action area with RQs ranging from 1.26 to 6.11. Therefore, atrazine use on sugarcane, corn, and fallow/idleland may result in chronic direct effects to the pallid sturgeon; all other uses have "no effect" relative to chronic direct effects.

**Table 5.2 Summary of Direct Chronic Effect RQs for the Pallid Sturgeon**

| Effect to Pallid Sturgeon | Use (appl. method; rate; # appl.; appl. interval) | 60-day EECs (µg/L)[a] | Freshwater Fish Chronic RQ (NOAEC = 65 µg/L)[b] | LOC Exceedance and Risk Interpretation |
|---|---|---|---|---|
| Chronic Direct Toxicity[c] | Sugarcane (aerial liquid; 4 lbs ai/A; 3 appl.; 60 days) | South: 397 | **6.11** | **Yes (south region only)[d]** |
| | Corn (aerial liquid; 2.5 lbs ai/A; 2 appl; 30 days) | 82 - 104 | **1.26 – 1.60** | **Yes (all regions)[d]** |
| | Sorghum (aerial liquid; 2 lbs ai/A; 1 appl.) | 54 - 60 | 0.83 – 0.92 | No[e] |
| | Fallow/idle land (aerial liquid; 2.25 lbs ai/A; 1 appl.) | South: 57<br>North: 51<br>West: 103<br>UGP: 49 | South: 0.88<br>North: 0.78<br>**West: 1.58**<br>UGP: 0.75 | South: No[e]<br>North: No[e]<br>**West: Yes[d]**<br>UGP: No[e] |
| | Forestry (aerial liquid; 4 lbs ai/A; 1 appl.) | 42 - 58 | 0.65 - 0.89 | No[e] |
| | All other non-agricultural uses | ≤19 | ≤0.29 | No[e] |

[a] Screening-level 60-day EECs from Table 3.4. With the exception of sugarcane, which is used only in the southern region, screening-level 60-day EECs include the range of concentrations from all four regions of the action area. UGP = Upper Great Plains region.
[b] Based on a 44-week NOAEC value of 65 µg/L for the brook trout (MRID# 00243-77).
[c] RQs associated with chronic direct toxicity to the pallid sturgeon are also used to assess potential indirect effects to the sturgeon based on reduction in freshwater fish food items.
[d] RQ ≥ chronic LOC of 1.0. Further evaluation of the RQ is necessary to determine if atrazine is likely to adversely affect the pallid sturgeon.
[e] RQ < chronic LOC of 1.0.

Further characterization of potential direct acute and chronic effects of atrazine to the pallid sturgeon is provided in Section 5.2.1.

### 5.1.2 Indirect Effects

Pesticides have the potential to exert indirect effects upon listed species by inducing changes in structural or functional characteristics of affected communities. Perturbation of forage or prey availability and alteration of the extent and nature of habitat are examples of indirect effects.

In conducting a screen for indirect effects, direct effects LOCs for each taxonomic group (i.e., freshwater fish, invertebrates, aquatic plants, and terrestrial plants) are employed to make inferences concerning the potential for indirect effects upon listed species that rely upon non-listed organisms in these taxonomic groups as resources critical to their life cycle (U.S. EPA, 2004). This approach used to evaluate indirect effects to listed species is endorsed by the Services (USFWS/NMFS, 2004b). If no direct effect listed species LOCs are exceeded for non-endangered organisms that are critical to the pallid sturgeon's life cycle, the concern for indirect effects to the pallid sturgeon is expected to be minimal.

If LOCs are exceeded for freshwater fish and invertebrates that are prey items of the pallid sturgeon, there is a potential for atrazine to indirectly affect the sturgeon by reducing available food supply. In such cases, the dose response relationship from the toxicity study used for calculating the RQ of the surrogate prey item is analyzed to estimate the probability of acute effects associated with an exposure equivalent to the EEC. The greater the probability that exposures will produce effects on a taxa, the greater the concern for potential indirect effects for listed species dependant upon that taxa (U.S. EPA, 2004).

As an herbicide, indirect effects to the pallid sturgeon from potential effects on primary productivity of aquatic plants are a principle concern. If plant RQs fall between the endangered species and non-endangered species LOCs, a no effect determination for listed species that rely on multiple plant species to successfully complete their life cycle (termed plant dependent species) is determined. If plant RQs are above non-endangered species LOCs, this could be indicative of a potential for adverse effects to those listed species that rely either on a specific plant species (plant species obligate) or multiple plant species (plant-dependent) for some important aspect of their life cycle (U.S. EPA, 2004). Based on the information provided in Appendix C, the pallid sturgeon does not rely on a specific plant species (i.e., the sturgeon does not have an obligate relationship with a specific species of aquatic plant).

Direct effects to riparian zone vegetation could also indirectly affect the pallid sturgeon by reducing the amount of available spawning habitat via increased sedimentation. Direct impacts to the terrestrial plant community (i.e., riparian habitat) are evaluated using available terrestrial plant toxicity data. If terrestrial plant RQs exceed the Agency's LOC for direct effects to non-endangered plant species, based on EECs derived using EFED's TerrPlant model (Version 1.2.2) and submitted guideline terrestrial plant toxicity data, a conclusion that atrazine may affect the pallid sturgeon via potential indirect effects to the riparian habitat (and resulting impacts to spawning habitat due to increased sedimentation) is made. Further analysis of the potential for atrazine to affect the pallid sturgeon via reduction in riparian habitat includes a description of the relative importance of riparian vegetation to the sturgeon, types of riparian vegetation that may be potentially impacted by atrazine use, and the potential effects of sedimentation on the pallid sturgeon.

In summary, the potential for indirect effects to the pallid sturgeon was evaluated using methods outlined in U.S. EPA (2004) and described below in Sections 5.1.2.1 through 5.1.2.3.

#### *5.1.2.1 Evaluation of Potential Indirect Effects via Reduction in Food Items (Freshwater Fish and Invertebrates)*

According to a recent study of hatchery-reared pallid sturgeon that are released in the wild, the majority of the sturgeon diet (90% by wet weight) is comprised of fish including cyprinid prey, such as the sturgeon chub and sicklefin chub (Gerrity et al., 2006). However, other studies (Warner, 2006) indicate that the composition of the pallid sturgeon diet is more evenly distributed between fish and aquatic insects. In addition to fish, pallid sturgeon consume a wide range of aquatic insects including mayflies, caddisflies, midges, dragonflies/damselflies, and aquatic sow bugs, as well as detritus (Gerrity et al., 2006; Warner, 2006). Although data on the relative percentages of each type of freshwater fish and aquatic invertebrate in the adult sturgeon's diet are unavailable, the available information indicates that they are opportunistic suctorial feeders on benthic organisms (Held, 1969; Carlson et al., 1985; Kennlyne, 1997). Potential indirect effects from direct effects on animal food items (i.e., freshwater fish and invertebrates) are evaluated by considering the diet of the pallid sturgeon and the effects data for the most sensitive freshwater fish and aquatic invertebrate food items.

The RQs used to characterize potential indirect effects to the pallid sturgeon from direct acute and chronic effects on freshwater fish food sources are previously discussed in Section 5.1.1 and summarized in Tables 5.1 and 5.2. Based on this information, indirect effects to the pallid sturgeon diet via direct acute and chronic effects to freshwater fish may occur based on sugarcane use of atrazine in the southern region; chronic effects to freshwater fish may also occur based on corn use throughout the entire action area and fallow/idleland use in the western region.

The acute RQs used to characterize potential indirect effects to the pallid sturgeon from direct acute effects on freshwater invertebrates are provided in Table 5.3. Acute LOCs are exceeded for all agricultural uses of atrazine within the action area (i.e., sugarcane, corn, sorghum, and fallow/idleland) as well as the non-agricultural forestry use in the southern, northern, and upper Great Plains regions. Therefore, indirect effects to the pallid sturgeon via direct acute effects to invertebrate dietary items may occur based on sugarcane, corn, sorghum, fallow/idleland, and forestry uses of atrazine. Based on the information presented in Tables 5.1 and 5.3, indirect dietary effects to the sturgeon via direct acute effects to freshwater fish and invertebrates are not expected for non-agricultural residential, turf, and rights-of-way uses.

| Table 5.3 Summary of Acute RQs Used to Estimate Indirect Effects for the Pallid Sturgeon via Direct Effects on Freshwater Invertebrate Dietary Items | | | | |
|---|---|---|---|---|
| **Use (appl. method; rate; # appl.; int. between appl.)** | **Peak EECs (µg/L)[a]** | **Freshwater Invertebrate Acute RQ ($LC_{50}$ = 720 µg/L)[b]** | **Probability of Individual Effect[b]** | **LOC Exceedance and Risk Interpretation** |
| Sugarcane (aerial liquid; 4 lbs ai/A; 3 appl.; 60 days) | South: 408 | **0.57** | 1in 7 | **Yes (south region only)[c]** |
| Corn (aerial liquid; 2.5 lbs ai/A; 2 appl.; 30 days) | 85 - 109 | **0.12 – 0.15** | 1 in 692 to 1 in 4.76E+05 | **Yes (all regions)[c]** |
| Sorghum (aerial liquid; 2 lbs ai/A; 1 appl.) | 57 - 64 | **0.08 – 0.09** | 1 in 4.76E+05 to 1 in 1.44E+06 | **Yes (all regions)[c]** |
| Fallow/idle land (aerial liquid; 2.25 lbs ai/A; 1 appl.) | 49 - 103 | **0.07 – 0.14** | 1 in 1,160 to 1 in 5.33E+06 | **Yes (all regions)[c]** |
| Forestry (aerial liquid; 4 lbs ai/A; 1 appl.) | South: 46<br>North: 49<br>West: 27<br>UGP: 65 | **South: 0.06**<br>**North: 0.07**<br>West: 0.04<br>**UGP: 0.09** | 1 in 4.76E+05 to 1 in 2.56E+09 | **South: Yes[c]**<br>**North: Yes[c]**<br>West: No[d]<br>**UGP: Yes[c]** |
| All other non-agricultural uses | ≤ 20 | ≤ 0.03 | >1 in 9.59E+10 | No[d] |

[a] Screening-level EECs from Table 3.4. With the exception of sugarcane, which is used only in the southern region, screening-level peak EECs include the range of concentrations from all four regions of the action area. UGP = Upper Great Plains region.
[b] Based on a 48-hour $LC_{50}$ value of 720 µg/L for the midge (MRID# 00243-77). Slope information on the toxicity study that was used to derive the RQ for the midge is not available. Therefore, the probability of an individual effect was calculated using the probit slope of 4.4, which is the only technical grade atrazine value reported in the available freshwater invertebrate studies; 95% confidence intervals could not be calculated based on the available data (MRID #452029-17; Table A-18).
[c] RQ > acute endangered species LOC of 0.05. Further evaluation of the RQ is necessary to determine if atrazine is likely to adversely affect the pallid sturgeon.
[d] RQ < acute endangered species LOC of 0.05.

Chronic RQs used to characterize potential indirect effects to the pallid sturgeon from direct chronic effects on freshwater invertebrates are summarized in Table 5.4. Chronic LOCs are exceeded for corn use within the entire action area, sugarcane and sorghum in the south, fallow/idleland in the west, and forestry in the upper Great Plains. Therefore, indirect effects to the pallid sturgeon via direct chronic effects to invertebrate dietary items may occur based on sugarcane, corn, sorghum, fallow/idleland, and forestry uses of atrazine. Based on the information presented in Tables 5.2 and 5.4, indirect effects to the sturgeon via direct chronic effects to freshwater fish and invertebrates are not expected to occur for non-agricultural residential, turf, and rights-of-way uses because RQs associated with these use patterns are less than LOCs.

| Table 5.4 Summary of Chronic RQs Used to Estimate Indirect Effects for the Pallid Sturgeon via Direct Effects on Freshwater Invertebrate Dietary Items | | | |
|---|---|---|---|
| **Use (appl. method; rate; # appl.; int. between appl.)** | **21-day EECs (µg/L)[a]** | **Freshwater Invertebrate Chronic RQ (NOAEC = 60 µg/L)[b]** | **LOC Exceedance and Risk Interpretation** |
| Sugarcane (aerial liquid; 4 lbs ai/A; 3 appl.; 60 days) | South: 405 | **6.75** | **Yes (south region only)[c]** |
| Corn (aerial liquid; 2.5 lbs ai/A; 2 appl.; 30 days) | 84 - 107 | **1.40 – 1.78** | **Yes (all regions)[c]** |
| Sorghum (aerial liquid; 2 lbs ai/A; 1 appl.) | South: 62<br>North: 57<br>West: 59<br>UGP: 56 | **South: 1.03**<br>North: 0.95<br>West: 0.98<br>UGP: 0.93 | **South: Yes[c]**<br>North: No[d]<br>West: No[d]<br>UGP: No[d] |
| Fallow/idle land (aerial liquid; 2.25 lbs ai/A; 1 appl.) | South: 58<br>North: 52<br>West: 103<br>UGP: 49 | South: 0.97<br>North: 0.87<br>**West: 1.72**<br>UGP: 0.82 | South: No[d]<br>North: No[d]<br>**West: Yes[c]**<br>UGP: No[d] |
| Forestry (aerial liquid; 4 lbs ai/A; 1 appl.) | South: 45<br>North: 47<br>West: 27<br>UGP: 61 | South: 0.75<br>North: 0.78<br>West: 0.45<br>**UGP: 1.02** | South: No[d]<br>North: No[d]<br>West: No[d]<br>**UGP: Yes[c]** |
| All other non-agricultural uses | ≤ 19 | ≤ 0.32 | No[d] |

[a] With the exception of sugarcane, which is used only in the southern region, screening-level 21-day EECs include the range of concentrations from all four regions of the action area. UGP = Upper Great Plains region.
[b] Based on a 30-day NOAEC value of 60 µg/L for the scud (MRID# 00243-77).
[c] RQ > chronic LOC of 1.0. Further evaluation of the RQ is necessary to determine if atrazine is likely to adversely affect the pallid sturgeon.
[d] RQ < chronic LOC of 1.0.

Screening-level RQs associated with indirect effects to the pallid sturgeon via a reduction in freshwater fish and invertebrate food items are further characterized in Section 5.2.2.

#### *5.1.2.2 Evaluation of Potential Indirect Effects via Reduction in Habitat and/or Primary Productivity (Freshwater Aquatic Plants)*

Potential indirect effects to the pallid sturgeon based on impacts to habitat and/or primary production were assessed using RQs from freshwater aquatic vascular and non-vascular plant data as a screen. If aquatic plant RQs exceed the Agency's non-endangered species LOC (because the pallid sturgeon relies on multiple plant species), potential community-level effects are evaluated using the threshold concentrations, as described in Section 4.2. RQs used to estimate potential indirect effects to the pallid sturgeon from effects on aquatic plant primary productivity are summarized in Table 5.5.

| Table 5.5 Summary of RQs Used to Estimate Indirect Effects to the Pallid Sturgeon via Effects to Aquatic Plants | | | | | |
|---|---|---|---|---|---|
| **Indirect Effect to Pallid Sturgeon** | **Use (appl. method; rate; # appl.; interval between appl.)** | **Range of Peak EECs (µg/L)[a]** | **Non-vascular plant RQ ($EC_{50}$ = 1 µg/L) [b]** | **Vascular plant RQ ($EC_{50}$ = 37 µg/L) [c]** | **LOC Exceedance** |
| Reduced Habitat and/or Primary Productivity via Direct Toxicity to Aquatic Plants | Sugarcane (aerial liquid; 4 lbs ai/A; 3 appl.; 60 days) | 408 | **408** | **11.03** | **Yes[d]** |
| | Corn (aerial liquid; 2.5 lbs ai/A; 2 appl.; 30 days) | 85 - 109 | **85 - 109** | **2.30 – 2.95** | **Yes[d]** |
| | Sorghum (aerial liquid; 2 lbs ai/A; 1 appl.) | 57 - 64 | **57 - 64** | **1.54 – 1.73** | **Yes[d]** |
| | Fallow/Idle land (aerial liquid; 2.25 lbs ai/A; 1 appl.) | 49 - 103 | **49 - 103** | **1.32 – 2.78** | **Yes[d]** |
| | Forestry (aerial liquid; 4 lbs ai/A; 1 appl.) | South: 46<br>North: 49<br>West: 27<br>UGP: 65 | **South: 46**<br>**North: 49**<br>**West: 27**<br>**UGP: 65** | **South: 1.24**<br>**North: 1.32**<br>West: 0.73<br>**UGP: 1.76** | **South: Yes[d]**<br>**North: Yes[d]**<br>**West: Yes[e]**<br>**UGP: Yes[d]** |
| | Residential (granular; 2 lbs ai/A; 2 appl.; 30 days) and (liquid; 1 lb ai/A; 1 appl.) | 7.6 – 20 | **7.6 – 20** | 0.21 – 0.54 | **Yes[e]** |
| | Turf (granular; 2 lbs ai/A; 2 appl.; 30 days) and (liquid; 1 lb ai/A; 1 appl.) | 6.6 – 18 | **6.6 – 18** | 0.18 – 0.49 | **Yes[e]** |
| | Rights-of-way (liquid; 1 lb ai/A; 1 appl.) | 2.4 – 3.8 | **2.4 – 3.8** | 0.06 – 0.10 | **Yes[e]** |

[a] With the exception of sugarcane, which is used only in the southern region, screening-level peak EECs include the range of concentrations from all four regions of the action area. UGP = Upper Great Plains region.
[b] Based on a 1-week $EC_{50}$ value of 1 µg/L for four species of freshwater algae (MRID# 000235-44).
[c] Based on a 14-day $EC_{50}$ value of 37 µg/L for duckweed (MRID# 430748-08).
[d] RQ > non-endangered aquatic plant species LOC of 1.0 for non-vascular and vascular plants. Direct effects to both non-vascular and vascular aquatic plants are possible. Further evaluation of the EECs relative to the threshold concentrations (for community-level effects) is necessary.
[e] RQ > non-endangered aquatic plant species LOC of 1.0 for non-vascular plants; RQ < non-endangered plant species LOC of 1.0 for vascular plants. Direct effects to non-vascular aquatic plants are possible. Further evaluation of the EECs relative to the threshold concentrations (for community-level effects) is necessary.

Based on the results shown in Table 5.5, LOCs for direct effects to aquatic non-vascular and vascular plants are exceeded for all modeled atrazine agricultural use scenarios as well as non-agricultural uses for forestry (with the exception of forestry uses in the western region for vascular plants); however, RQs for aquatic vascular plants are less than LOCs for residential, turf, and rights-of-way uses. Therefore, atrazine may indirectly affect the pallid sturgeon via direct effects on non-vascular aquatic plants for all modeled use scenarios and on vascular plants for agricultural and forestry uses. However, this screening-level analysis was based on the most sensitive $EC_{50}$ values from all of the available freshwater non-vascular and vascular plant toxicity information. No known obligate relationship exists between the pallid sturgeon and any single freshwater non-vascular and/or vascular plant species; therefore, endangered species RQs using the NOAEC/$EC_{05}$ values for aquatic plants were not derived. Further analyses of the 14-, 30-, 60-, and 90-day time-weighted EECs relative to their respective threshold concentrations were completed to determine whether effects to individual non-vascular and vascular plant species would likely result in community-level effects to the pallid sturgeon. This analysis is presented as part of the risk description in Section 5.2.3.

*5.1.2.3 Evaluation of Potential Indirect Effects via Reduction in Terrestrial Plant Community (Riparian Habitat)*

Potential indirect effects to the pallid sturgeon resulting from direct effects on riparian vegetation were assessed using RQs from terrestrial plant seedling emergence and vegetative vigor $EC_{25}$ data as a screen. Based on the results of the submitted terrestrial plant toxicity tests, it appears that emerging seedlings are more sensitive to atrazine via soil/root uptake than emerged plants via foliar routes of exposure. However, all tested plants, with the exception of corn in the seedling emergence and vegetative vigor tests and ryegrass in the vegetative vigor test, exhibited adverse effects following exposure to atrazine. The results of these tests indicate that a variety of terrestrial plants that may inhabit riparian zones may be sensitive to atrazine exposure. RQs used to estimate potential indirect effects to the pallid sturgeon from seedling emergence and vegetative vigor effects on terrestrial plants within riparian areas are summarized in Tables 5.6 and 5.7, respectively.

As shown in Table 5.6, terrestrial plant RQs are above the Agency's LOC for all species except corn. For species with LOC exceedances, RQ values based on aerial application of atrazine to sugarcane and forestry at 4.0 lbs ai/A range from 1.8 to 113; the maximum RQ value based on an equivalent ground application is 35, approximately a three-fold reduction as compared to aerial applications. Granular application of atrazine to residential lawns at 2.0 lbs ai/A could also impact terrestrial plants via runoff with RQs ranging from <1 (corn and soybeans) to 13 (carrots). Monocots and dicots show similar sensitivity to atrazine; therefore, RQs are similar across both taxa.

**Table 5.6 Non-target Terrestrial Plant Seedling Emergence RQs**

| **Surrogate Species** | **$EC_{25}$ (lbs ai/A)[a]** | **EEC Dry adjacent areas[b]** | **RQ Dry adjacent areas[b]** |
|---|---|---|---|
| Monocot - Corn | > 4.0 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | <LOC |
| Monocot - Oat | 0.004 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | **Aerial: 43 - 85**<br>**Ground: 13 - 26**<br>**Granular: 10** |
| Monocot - Onion | 0.009 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | **Aerial: 19 - 38**<br>**Ground: 5.8 - 12**<br>**Granular: 4.4** |
| Monocot - Ryegrass | 0.004 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | **Aerial: 43 - 85**<br>**Ground: 13 - 26**<br>**Granular: 10** |

| Table 5.6 Non-target Terrestrial Plant Seedling Emergence RQs | | | |
|---|---|---|---|
| **Surrogate Species** | **$EC_{25}$ (lbs ai/A)[a]** | **EEC Dry adjacent areas[b]** | **RQ Dry adjacent areas[b]** |
| Dicot - Carrot | 0.003 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | **Aerial: 57 - 113**<br>**Ground: 17 - 35**<br>**Granular: 13** |
| Dicot - Soybean | 0.19 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | **Aerial: < LOC – 1.8**<br>Ground: < LOC<br>Granular: < LOC |
| Dicot - Lettuce | 0.005 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | **Aerial: 34 - 68**<br>**Ground: 10 - 21**<br>**Granular: 8** |
| Dicot - Cabbage | 0.014 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | **Aerial: 12 - 24**<br>**Ground: 3.7 – 7.4**<br>**Granular: 2.9** |
| Dicot - Tomato | 0.034 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | **Aerial: 5.0 - 10**<br>**Ground: 1.5 – 3.1**<br>**Granular: 1.2** |
| Dicot - Cucumber | 0.013 | Aerial: 0.17 – 0.34<br>Ground: 0.05 – 0.10<br>Granular: 0.04 | **Aerial: 13 - 26**<br>**Ground: 4.0 – 8.0**<br>**Granular: 3.1** |

[a] From Chetram (1989); MRID 420414-03.
[b] Range of EECs and RQs based on use scenarios presented in Table 3.13 (i.e., aerial and ground: sugarcane, forestry, fallow/idleland, corn, sorghum; and granular residential).

Vegetative vigor studies indicate that terrestrial plants are generally less sensitive to foliar exposure of atrazine as compared to soil/root uptake. As shown in Table 5.7, vegetative vigor RQs exceed the Agency's LOC for only three dicot species (soybeans, cabbage, and cucumber), based on aerial application of atrazine at 2 to 4 lbs ai/A, with RQs ranging from 5 to 33. For ground applications, LOCs are exceeded for two dicot species, cabbage and cucumber, with RQs ranging from 1.5 to 3. Vegetative vigor RQs do not exceed LOCs for any of the tested monocot species.

| Table 5.7 Non-target Terrestrial Plant Vegetative Vigor Toxicity RQs | | | |
|---|---|---|---|
| **Surrogate Species** | **$EC_{25}$ (lbs ai/A)[a]** | **Drift EEC (lbs ai/A)[b]** | **Drift RQ[b]** |
| Monocot - Corn | > 4.0 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | <LOC |
| Monocot - Oat | 2.4 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | <LOC |
| Monocot - Onion | 0.61 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | <LOC |
| Monocot - Ryegrass | > 4.0 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | <LOC |
| Dicot - Carrot | 1.7 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | <LOC |
| Dicot - Soybean | 0.026 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | **Aerial: 5.0 - 10**<br>Ground: <LOC |
| Dicot - Lettuce | 0.33 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | <LOC |
| Dicot - Cabbage | 0.014 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | **Aerial: 9.3 - 19**<br>**Ground:** <LOC **– 1.7** |

| Table 5.7 Non-target Terrestrial Plant Vegetative Vigor Toxicity RQs | | | |
|---|---|---|---|
| **Surrogate Species** | **$EC_{25}$ (lbs ai/A)[a]** | **Drift EEC (lbs ai/A)[b]** | **Drift RQ[b]** |
| Dicot - Tomato | 0.72 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | <LOC |
| Dicot - Cucumber | 0.008 | Aerial: 0.13 – 0.26<br>Ground: 0.01 – 0.02 | **Aerial: 16 - 33**<br>**Ground: 1.5 – 3.0** |
| [a] From Chetram (1989); MRID 420414-03.<br>[b] Range of EECs and RQs based on use scenarios presented in Table 3.13 (i.e., aerial and ground: sugarcane, forestry, fallow/idleland, corn, and sorghum). | | | |

Further analysis of the potential for atrazine to affect the pallid sturgeon via reduction in riparian habitat, including a description of the importance of riparian vegetation to the sturgeon, types of riparian vegetation that may potentially be impacted by atrazine use, and the potential effects of sedimentation on the sturgeon, is discussed in Section 5.2.4.

## 5.2 Risk Description

The risk description synthesizes an overall conclusion regarding the likelihood of adverse impacts leading to an effects determination (i.e., "no effect," "may affect, but not likely to adversely affect," or "likely to adversely affect") for the pallid sturgeon.

If the RQs presented in the Risk Estimation (Section 5.1) show no indirect effects and LOCs for the pallid sturgeon are not exceeded for direct effects (RQs < LOC), a "no effect" determination is made, based on atrazine's use within the action area. If, however, indirect effects are anticipated and/or exposure exceeds the LOCs for direct effects (RQs > LOC), the Agency concludes a preliminary "may affect" determination for the FIFRA regulatory action regarding atrazine. A summary of the results of the risk estimation (i.e., "no effect" vs. "may affect" finding) presented in Sections 5.1.1 and 5.1.2 is provided in Table 5.8 for direct and indirect effects to the pallid sturgeon. Conclusions of "may affect" based on RQs presented in Section 5.1 are further evaluated to distinguish actions that are likely to adversely affect ("LAA") from those that are not likely to adversely affect ("NLAA") the pallid sturgeon.

| Table 5.8 Preliminary Effects Determination Summary for the Pallid Sturgeon Based on Risk Estimation | | |
|---|---|---|
| **Assessment Endpoint** | **Preliminary Effects Determination** | **Basis for Preliminary Determination[a]** |
| 1. Survival, growth, and reproduction of pallid sturgeon individuals via direct effects<br><br>2. Indirect effects to pallid sturgeon individuals via reduction in freshwater fish food items | Acute direct effects: May affect | Acute LOCs for freshwater fish are exceeded for sugarcane use (south region) (Table 5.1). |
| | Chronic direct effects: May affect | Chronic LOCs for freshwater fish are exceeded for sugarcane (south region), corn (all regions), and fallow/idle land (west region) uses (Table 5.2). |
| 3. Indirect effects to pallid sturgeon individuals via reduction in freshwater invertebrate food items | Acute indirect effects: May affect | Acute LOCs for freshwater invertebrates are exceeded for sugarcane (south region); corn, sorghum, and fallow/idle land (all regions); and |

| Table 5.8 Preliminary Effects Determination Summary for the Pallid Sturgeon Based on Risk Estimation | | |
|---|---|---|
| **Assessment Endpoint** | **Preliminary Effects Determination** | **Basis for Preliminary Determination[a]** |
| | | forestry (south, north, and UGP) uses (Table 5.3). |
| | Chronic indirect effects: May effect | Chronic LOCs for freshwater invertebrates are exceeded for sugarcane (south region), corn (all regions), sorghum (south region), fallow/idle land (west region), and forestry (UGP region) uses (Table 5.4). |
| 4. Indirect effects to pallid sturgeon individuals via reduction of habitat and/or primary productivity | May affect | LOCs are exceeded for non-vascular aquatic plants for all modeled atrazine use scenarios (Table 5.5).<br><br>LOCs are exceeded for vascular plants for sugarcane (south); corn, sorghum, and fallow/idle land (all regions); and forestry (south, north, and UGP) (Table 5.5). |
| 5. Indirect effects to pallid sturgeon individuals via reduction of terrestrial vegetation (i.e., riparian habitat) required to maintain acceptable water quality and habitat | May affect | LOCs are exceeded for all tested species except corn based on seedling emergence (Table 5.6).<br><br>LOCs are exceeded for soybeans, cabbage, and cucumbers based on vegetative vigor (Table 5.6). |

[a] All screening-level EECs for the preliminary effects determination are based on modeled scenarios for surface water (Table 3.4) and terrestrial plants (Table 3.13); toxicity values are based on the most sensitive endpoint summarized in Table 4.2.

Following a "may affect" determination, additional information is considered to refine the potential for exposure at the predicted levels based on additional modeling and monitoring data, the life history characteristics (i.e., habitat range, feeding preferences, etc.) of the pallid sturgeon, and potential community-level effects to aquatic plants. Based on the best available information, the Agency uses the refined evaluation to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that are "likely to adversely affect" the pallid sturgeon.

The criteria used to make determinations that the effects of an action are "not likely to adversely affect" the pallid sturgeon include the following:

- Significance of Effect: Insignificant effects are those that cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where "take" occurs for even a single individual. "Take" in this context means to harass or harm, defined as the following:
    - Harm includes significant habitat modification or degradation that results in death or injury to listed species

by significantly impairing behavioral patterns such as breeding, feeding, or sheltering.

  - Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering.

- Likelihood of the Effect Occurring: Discountable effects are those that are extremely unlikely to occur. For example, use of dose-response information to estimate the likelihood of effects can inform the evaluation of some discountable effects.

- Adverse Nature of Effect: Effects that are wholly beneficial without any adverse effects are not considered adverse.

A description of the risk and effects determination for each of the established assessment endpoints for the pallid sturgeon is provided in Sections 5.2.1 through 5.2.4.

### 5.2.1 Direct Effects to the Pallid Sturgeon

Of all modeled atrazine uses within the pallid sturgeon action area, only the acute RQ associated with sugarcane use (RQ = 0.08) in the southern portion of the action area exceeds the Agency's endangered species LOC for freshwater fish. Therefore, atrazine use on sugarcane may result in acute direct effects to the pallid sturgeon in the southern region of the action area. The acute RQ of 0.08 is based on a screening-level peak EEC of 408 μg/L for sugarcane uses.

Screening-level EECs were estimated using PRZM/EXAMS and the non-flowing standard water body scenario, which is intended to represent exposure in static ponds and headwater streams. However, the pallid sturgeon occurs in large rivers with strong currents and high dilution potential; therefore, screening-level EECs are likely to overestimate exposure in flowing water bodies. Screening-level EECs were refined based on site-specific flow information from occupied pallid sturgeon river locations in the vicinity of sugarcane use sites in Louisiana. In addition, available monitoring data from large rivers where pallid sturgeon may occur and Louisiana watersheds in the vicinity of sugarcane use sites were also considered to provide further context to the modeled EECs. Further information on the impact of flowing water on modeled screening-level EECs and available monitoring data are provided in Sections 3.2.5.1 and 3.2.6, respectively.

Based on the information presented in Section 3.2.5.1 and summarized in Table 3.5, consideration of site-specific flow rates for Louisiana watersheds where the pallid sturgeon occurs results in a refined peak EEC of 133 μg/L, a three-fold reduction from the screening-level sugarcane EEC of 408 μg/L. Consideration of the flow-adjusted EEC would result in a similar three-fold reduction in the acute RQ from 0.08 to 0.03 (EEC of

133 μg/L / freshwater fish $LC_{50}$ of 5,300 μg/L = RQ of 0.03), which is less than the endangered species LOC of 0.05.

To provide additional information on the potential for acute direct effects to the pallid sturgeon, the probability of an individual mortality to the pallid sturgeon was calculated for acute RQs of 0.08 (based on the screening-level EECs for sugarcane use) and 0.03 (based on flow-adjusted EECs), based on the dose response curve slope from the acute toxicity study for the rainbow trout of 2.72 (MRID # 000247-16). The corresponding estimated chance of an individual acute mortality to the pallid sturgeon at an RQ level of 0.08 (based on the acute toxic endpoint for surrogate freshwater fish) is 1 in 702; at an RQ level of 0.03, the estimated chance of an individual acute mortality drops to 1 in 58,100. It is recognized that extrapolation of very low probability events is associated with considerable uncertainty in the resulting estimates. In order to explore the possible bounds to such estimates, the upper and lower default values for the rainbow trout dose response curve slope estimate (95% C.I.: 1.56 to 3.89) were used to calculate upper and lower estimates of the effects probability associated with the acute RQs. The respective lower and upper effects probability estimates at an RQ of 0.08 are 1 in 23 (4.3%) and 1 in 1.0E+05 (0.001%); at an RQ of 0.03, the lower and upper effects probability estimates are 1 in 114 (0.87%) and 1 in 6.4E+08 (1.6E-07%).

Further characterization of the sugarcane screening-level EEC of 408 μg/L was conducted based on the available monitoring data from USGS for large rivers and from LDAF/LDEQ for the Upper Terrebonne watershed basin in Louisiana. As discussed in Section 3.2.6.1, a peak atrazine concentration of 34 μg/L was reported from USGS NASQAN monitoring data collected from 1995 to 2000 in the Mississippi River basin. However, this peak concentration was reported from the Platte River in Nebraska (station # 6805500 from Table 3.6 and Figure 3.3), which is located in the upper Great Plains region of the action area where no acute LOCs for freshwater fish were exceeded. Further analysis of the USGS NASQAN data from the Mississippi and Atchafalaya Rivers in Louisiana (stations # 7373420 and 7381495) shows that peak atrazine concentrations in these watersheds range from 1.64 to 4.71 μg/L. LDAF/LDEQ monitoring data were also considered because the sampling locations are targeted to atrazine use patterns on sugarcane in Louisiana. The maximum reported concentration of atrazine from the LDAF/LDEQ data is 216 μg/L; however, samples from this data set were collected from lower order streams (bayous, canals, and ditches) than those occupied by the pallid sturgeon. As shown in Table 3.8, the highest reported peak concentrations of atrazine from the LDAF/LDEA data were reported in bayous where the pallid sturgeon does not occur. Therefore, atrazine concentrations based on the LDAF/LDEQ data are not considered to be representative of peak exposures for the pallid sturgeon. A refined acute RQ based on the peak USGS NASQAN value for Louisiana watersheds would be well below the Agency's LOC of 0.05 (EEC of 4.71 μg/L/freshwater fish $LC_{50}$ of 5,300 μg/L = RQ of <0.01). Furthermore, consideration of LDAF/LDEQ data, which are likely to overestimate exposure, would also result in a refined RQ that is less than the LOC.

Chronic RQs, which are based on modeled screening-level 60-day EECs and the surrogate freshwater fish chronic endpoint value for the brook trout (NOAEC = 65 μg/L), exceed the Agency's LOC for sugarcane, corn, and fallow/idle land uses with RQ values ranging from 1.26 to 6.11 (see Table 5.2). However, as previously discussed, chronic RQs based on screening-level EECs (derived using the PRZM/EXAMs pond scenario) are likely to be overestimated given that pallid sturgeon are known to occur in larger rivers with flowing water, where chronic atrazine exposures are expected to be lower than 60-day exposure concentrations in a static pond. Based on the analysis conducted in Section 3.2.5.1, flow-adjusted 60-day EECs are approximately 96 to 99% lower than 60-day EECs modeled using the static water body. As shown in Table 3.5, 60-day flow-adjusted EECs range from 2 to 4 μg/L. The refined chronic RQ value based on the maximum 60-day flow-adjusted EEC is 0.06, well below the Agency's LOC of 1.0 for chronic risk to freshwater fish. However, as discussed in Section 3.2.7, longer- term flow-adjusted EECs may under-represent exposure concentrations based on the available monitoring data. Comparison of longer-term annual average concentrations from the flow-adjusted modeling with time-weighted means (TWM) from the USGS NASQAN data suggests that flow-adjusted EECs are 2 to 3 times lower than the monitored values. Even if the 60-day flow-adjusted EECs were under-predicted by a factor of 3 (resulting in longer-term EECs of 6 to 12 μg/L), revised exposure levels would be well below the freshwater fish NOAEC value of 65 μg/L. Therefore, consideration of the flow-adjusted EECs and available monitoring data for rivers where the pallid sturgeon occurs shows that expected long-term exposure concentrations of atrazine are well below chronic LOCs.

As discussed in Section 4.1.1.3, several open literature studies raise questions about sublethal effects of atrazine on plasma steroid levels, behavior modifications, gill physiology, neurophysiological, and endocrine-mediated functions in freshwater and anadromous fish. Consideration of the sublethal data indicates that effects associated with alteration of gill physiology and endocrine-mediated olfactory functions may occur in anadromous fish including salmon at atrazine concentrations as low as 0.5 μg/L (Waring and Moore, 2004; Moore and Lower, 2001). In addition, Tierney et al. (2007) observed hyperactivity and neurophysiological responses in juvenile rainbow trout exposed to atrazine at 1 and 10 μg/L, respectively. However, there are a number of limitations in the design of these studies, which are addressed in detail in Sections A.2.4 of Appendix A, that preclude quantitative use of the data in this risk assessment. For example, Moore and Lower (2001) and Tierney et al. (2007) exposed epithelial tissue (after removal of skin and cartilage) and not intact fish to atrazine, and potential solvent effects could not be reconciled (i.e., no negative control was tested). Furthermore, no quantitative relationship is established between reduced olfactory response (measured as electrophysiological response) of male epithelial tissue to the female priming hormone in the laboratory and reduction in salmon reproduction (i.e., the ability of male salmon to recognize and mate with ovulating females). Other sublethal effects observed in fish studies have included behavioral modifications, alterations of plasma steroid levels, and changes in kidney histology at atrazine concentrations ranging from 5 to 35 μg/L (see Section 4.1.2.3). However, a number of uncertainties were also identified with each of the studies, which are discussed in Section A.2.4 of Appendix A.

In summary, it is not possible to quantitatively link the sublethal effects to the selected assessment endpoints for the pallid sturgeon (i.e., survival, growth, and reproduction of individuals). Also, effects to reproduction, growth, and survival were not observed in the four submitted fish life-cycle studies at levels that produced the reported sublethal effects (Appendix A). In addition, there are a number of limitations in the design of these studies, which are addressed in detail in Sections A.2.4a and A.2.4b of Appendix A, that preclude quantitative use of the data in risk assessment.

Peak exposure concentrations associated with atrazine use on sugarcane, including flow-adjusted EECs and consideration of relevant monitoring data, are unlikely to cause direct acute effects to the pallid sturgeon because refined RQs are less than the endangered species LOC. Therefore, the Agency concludes a “may affect, but not likely to adversely affect” or “NLAA” determination for acute direct effects to the pallid sturgeon within the southern region of the action area. This finding is based on discountable effects (i.e., acute effects to atrazine at the refined levels of exposure are not likely to occur and/or result in a “take” of a single pallid sturgeon within the southern portion of the action area). For all other regions of the action area (i.e., north, west, and upper Great Plains), the effects determination for direct acute effects to the pallid sturgeon is “no effect” because screening-level RQs are less than LOCs.

Use of atrazine within the action area is also not likely to adversely affect the pallid sturgeon via direct chronic effects because flow-adjusted EECs and available monitoring data indicate that atrazine concentrations are unlikely to cause adverse chronic effects in fish. Therefore, the effects determination for the assessment endpoint of direct chronic effects to the pallid sturgeon is “may affect, but not likely to adversely affect” or “NLAA.” This finding is based on discountable effects (i.e., chronic effects to atrazine at refined levels of exposure are not likely to occur and/or result in a “take” of a single listed pallid sturgeon).

### 5.2.2 Indirect Effects via Reduction in Food Items (Freshwater Fish and Invertebrates)

Although data on the relative percentages of each type of food item in the adult pallid sturgeon’s diet are not available, the best available information indicates that it consumes both freshwater fish, such as cyprinid prey, as well as aquatic insects including mayflies, caddisflies, midges, dragonflies/damselflies, and aquatic sowbugs (Gerrity et al., 2006; Wanner, 2006).

Potential indirect effects to the pallid sturgeon via reduction in freshwater fish food items are characterized based on the direct effects analysis in Section 5.1.2. Although atrazine acute and chronic RQs based on the static water body EECs exceed LOCs for a number of use patterns, refined RQs based on flow-adjusted EECs indicate that direct acute and chronic effects for freshwater fish are not likely to occur. Available atrazine monitoring data provides an additional line of evidence that peak exposure concentrations are unlikely to result in LOC exceedances. Therefore, the effects determination for the assessment endpoint of indirect effects to the pallid sturgeon via direct acute and chronic effects on freshwater fish as food items is "may affect, but not likely to adversely affect" or "NLAA." This finding is based on insignificance of effects (i.e., acute and chronic exposure to atrazine is not likely to result in a "take" of a single pallid sturgeon via a reduction in freshwater fish as food items).

With respect to freshwater invertebrates, screening-level acute and chronic RQs exceed the respective LOCs for all agricultural and forestry uses of atrazine. Screening-level acute RQs were based on the lowest $LC_{50}$ value across all aquatic invertebrate taxa of 720µg/L for the midge (*Chironomus* spp.). Consideration of all acute toxicity data for the midge shows a wide range of sensitivity within and between species of the same genus (2 orders of magnitude) with values ranging from 720 to >33,000 µg/L. The highest screening-level acute RQ value, based on $LC_{50}$ data for the midge and modeled EECs for sugarcane, is 0.57. A probit slope was not available from the available midge studies; therefore, a probit slope of 4.4 was used based on the most conservative (lowest) freshwater invertebrate value for daphnids (MRID# 420414-01). The probability of an individual effect to freshwater invertebrates at an RQ of 0.57 and a slope of 4.4 would be approximately 1 in 7. Assuming that the pallid sturgeon consumes aquatic invertebrates that are equally as sensitive as the most sensitive midge, potential reduction in abundance of aquatic invertebrates as food would be approximately 14 percent.

However, as previously discussed, consideration of flow-adjusted peak EECs would result in a three-fold reduction in exposure (from 408 µg/L to 133 µg/L) and in the RQ value (from 0.57 to 0.18) for aquatic invertebrates. The probability of an individual effect to freshwater invertebrates at a refined acute RQ of 0.18 and a slope of 4.4 would be approximately 1 in 1,900. Interpolation of the dose response curve shows an acute effect level (i.e., death or immobilization) for freshwater invertebrates of 0.05% at a peak exposure concentration of 133 µg/L.

Further characterization of the modeled peak EECs was conducted based on available monitoring data from USGS for large rivers where pallid sturgeon are known to occur. The highest reported peak atrazine concentration from the USGS NASQAN monitoring data is 34 µg/L. This value was reported in 1996 for the Platte River in Louisville, Nebraska. As shown in Table 3.6, further evaluation of data collected from the same location for the years 1997 through 2000 shows a decreasing trend of atrazine concentrations, with the most recent peak value reported as 3.14 µg/L. Furthermore, reported peak atrazine concentrations for the remaining site years of USGS NASQAN data range from 0.002 to 20.7 µg/L. A refined acute RQ based on the peak USGS NASQAN value for large rivers would be less than the Agency's LOC of 0.05 (EEC of 34 µg/L/freshwater invertebrate $LC_{50}$ of 720 µg/L = RQ of 0.047). The probability of an individual effect to freshwater invertebrates at an RQ of 0.047 and a slope of 4.4 would be approximately 1 in 390 million. At a peak exposure concentration of 34 µg/L, the corresponding effect level for freshwater invertebrates is 2.6E-07 percent.

Although the midge is a component of the pallid sturgeon's diet, the sturgeon reportedly consumes a wide range of freshwater invertebrates that also includes mayflies, caddisflies, midges, dragonflies, and aquatic sowbugs (Gerrity et al., 2006; Wanner, 2006). Reported acute atrazine toxicity data are not available for all of these specific food items; however, the available information for other freshwater invertebrates indicates that $LC_{50}$ values are 3,500 μg/L and higher.

The potential for atrazine to elicit indirect effects to the pallid sturgeon via effects on food items is dependent on several factors including: (1) the potential magnitude of effect on freshwater fish and invertebrate individuals and populations; and (2) the number of prey species potentially affected relative to the expected number of species needed to maintain the dietary needs of the pallid sturgeon. Together, these data provide a basis to evaluate whether the number of individuals within a prey species is likely to be reduced such that it may indirectly affect the pallid sturgeon.

Atrazine may affect sensitive food items, such as the midge; however, the low probability (<0.05 percent) of an individual effect to the midge is not likely to indirectly affect the pallid sturgeon, given the wide range of other types of freshwater invertebrates that the species consumes. Based on the non-selective nature of feeding behavior in the pallid sturgeon, the low magnitude of anticipated acute individual effects to aquatic invertebrate prey species, and available monitoring data, atrazine is not likely to indirectly affect the pallid sturgeon via reduction in freshwater invertebrate food items. Therefore, the effects determination for indirect effects to the pallid sturgeon via direct acute effects on freshwater invertebrates as prey is "may affect, but not likely to adversely affect" or "NLAA". This finding is based on discountable and insignificant effects. The effects are discountable, given that refined exposures are not likely to cause acute effects to the majority of freshwater invertebrate food items and the corresponding probability of an individual effect level is low. Based on the extremely low level of effect (< 0.05 percent at predicted levels of exposure) and the expectation that the sensitivity of the most sensitive species of freshwater invertebrate species is likely to overestimate the sensitivity of the majority of freshwater invertebrate food items, any predicted effects are also expected to be insignificant in the context of a "take" of a single pallid sturgeon via direct acute effects on prey (i.e., freshwater invertebrates).

Screening-level chronic RQs for aquatic invertebrates, based on the modeled 21-day screening-level EECs ranging from 61 to 405 μg/L and the most sensitive chronic freshwater invertebrate NOAEC of 60 μg/L for the scud, exceed the Agency's LOC (see Table 5.4). However, as previously discussed, longer-term exposure concentrations based on the PRZM/EXAMS static water body are likely to overestimate exposure in the larger rivers where pallid sturgeon occur. As shown in Table 3.5, the flow-adjusted 21-day EECs for all regions of the action area range from 4 to 12 μg/L, well below the freshwater invertebrate NOAEC value of 60 μg/L. Use of the flow-adjusted 21-day EECs would result in refined chronic RQs (0.06 – 0.2) which are less than the Agency's chronic LOC of 1.0. However, comparison of longer-term annual average concentrations from the flow-adjusted modeling with time-weighted means (TWM) from the NASQAN data suggests that flow-adjusted EECs may under-predict longer-term exposures by a factor of 2 to 3 times as compared to the monitored values. If the 21-day flow-adjusted EECs were under-predicted by a factor of 3 (resulting in longer-term EECs of 12 to 36 μg/L), revised exposure levels would also be well below the freshwater invertebrate

NOAEC value of 60 µg/L. Therefore, consideration of the flow-adjusted EECs and available monitoring data for rivers where the pallid sturgeon occurs shows that expected long-term exposure concentrations of atrazine are less than chronic LOCs for freshwater invertebrates.

Given that all refined measures of exposure (i.e., 21-day flow adjusted EECs and available monitoring data) are well below levels that produced chronic effects for the most sensitive freshwater invertebrate species, the indirect effects determination for the pallid sturgeon via direct chronic effects on freshwater invertebrates as dietary food items is "may affect, but not likely to adversely affect" or "NLAA". This finding is based on discountable effects (i.e., chronic effects to atrazine at the refined levels of exposure are not likely to occur and/or result in a "take" of a single listed pallid sturgeon via a reduction in freshwater invertebrates as food items).

### 5.2.3 Indirect Effects via Reduction in Habitat and/or Primary Productivity (Freshwater Aquatic Plants)

Direct adverse effects to non-vascular aquatic plants are possible, based on all modeled atrazine uses within the action area. In addition, direct effects to vascular plants are also possible, based on all agricultural uses and forestry use patterns for atrazine. Based on these direct effects, atrazine may indirectly affect the pallid sturgeon via direct effects on aquatic plants. Therefore, the time-weighted EECs (for 14-day, 30-day, 60-day, and 90-day averages) were compared to their respective time-weighted threshold concentrations to determine whether potential effects to individual plant species would likely result in community-level effects. As discussed in Section 4.2, concentrations of atrazine from the exposure profile at a particular use site and/or action area that exceed any of the following time-weighted threshold concentrations indicate that changes in the aquatic plant community structure could be affected:

- 14-day average = 38 µg/L
- 30-day average = 27 µg/L
- 60-day average = 18 µg/L
- 90-day average = 12 µg/L

A comparison of the 14-, 30-, 60-, and 90-day EECs for the pallid sturgeon with the atrazine threshold concentrations representing potential aquatic community-level effects is provided in Table 5.9.

| Table 5.9 Summary of Modeled Scenario Time-Weighted EECs with Threshold Concentrations for Potential Community-Level Effects | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Use Scenario** | **14-day** | | **30-day** | | **60-day** | | **90-day** | |
| | **EEC (µg/L)** [a] | **Threshold Conc. (µg/L)** | **EEC (µg/L)** [a] | **Threshold Conc. (µg/L)** | **EEC (µg/L)** [a] | **Threshold Conc. (µg/L)** | **EEC (µg/L)** [a] | **Threshold Conc. (µg/L)** |
| Sugarcane | **405** | 38 | **405** | 27 | **397** | 18 | **393** | 12 |
| Corn | **84 - 108** | | **84 - 106** | | **82 - 104** | | **81 - 101** | |
| Sorghum | **57 - 63** | | **56 - 62** | | **54 - 60** | | **53 - 57** | |
| Fallow / idle land | **49 - 103** | | **49 - 103** | | **49 - 103** | | **49 - 103** | |
| Forestry | 27 - **61** | | **27 - 60** | | **26 - 58** | | **25 - 57** | |
| Residential | 7.5 - 20 | | 7.5 - 19 | | 7.5 – **19** | | 7.4 - **18** | |
| Turf | 7.1 - 18 | | 6.6 - 18 | | 6.5 - **18** | | 6.5 - **17** | |
| Rights-of-Way | 2.4 – 3.8 | | 2.4 – 3.8 | | 2.3 – 3.6 | | 2.2 – 3.5 | |

[a] Screening-level EECs from Table 3.4. Sugarcane EECs are representative of only the southern region of the action area. For all other atrazine use patterns, a range of EECs that is representative of all four regions of the action area is presented.

Based on the results of this comparison, predicted screening-level 14-, 30-, 60-, and 90-day EECs for sugarcane, corn, sorghum, fallow/idle land, and forestry modeled uses exceed their respective threshold concentrations for community-level effects. In addition, predicted screening-level 60- and 90-day EECs for residential and turf uses of atrazine exceed their respective threshold concentrations. These screening-level EECs were estimated using PRZM/EXAMS and the non-flowing standard water body scenario, which is intended to be representative of exposures in headwater streams. As previously discussed in Section 3.2.5.1, these screening-level chronic EECs are expected to over-estimate exposure in major rivers with moderate to swift flowing water, including the current range of the pallid sturgeon in the Mississippi and Missouri Rivers. Pallid sturgeon require large, turbid, free-flowing riverine habitat with rocky or sandy substrate for feeding and spawning (Appendix C); therefore, chronic EECs based on a non-flowing water body are expected to over-estimate actual exposure concentrations of atrazine for the sturgeon in its expected range. Additional information on the impact of flowing water on the modeled EECs, including available monitoring data, was used to refine exposure concentrations of atrazine for the pallid sturgeon, relative to those presented for the standard water body scenario. Analyses of flow-adjusted EECs and relevant monitoring data are presented in detail in Sections 3.2.5.1 and 3.2.6, respectively, and summarized below.

The results of this analysis show that consideration of seasonal flow rates yields longer-term EECs that are reduced as compared to screening-level EECs derived using the standard water body. A comparison of the maximum flow-adjusted 14-, 30-, 60-, and 90-day EECs for two atrazine use scenarios that yield the highest EECs (i.e., sugarcane and corn in the southern region of the action area) with the atrazine threshold concentrations representing potential aquatic community-level effects is provided in Table 5.10.

**Table 5.10 Summary of Flow-Adjusted EECs with Threshold Concentrations for Potential Community-Level Effects**

| Use Scenario | 14-day | | 30-day | | 60-day | | 90-day | |
|---|---|---|---|---|---|---|---|---|
| | EECs (µg/L) | Threshold Conc. (µg/L) | EECs (µg/L) | Threshold Conc. (µg/L) | EECs (µg/L) | Threshold Conc. (µg/L) | EECs (µg/L) | Threshold Conc. (µg/L) |
| Sugarcane[a] | 13 | 38 | 6 | 27 | 3 | 18 | 2 | 12 |
| Corn[a] | 14 | | 7 | | 3 | | 2 | |

[a] Flow-adjusted EECs for sugarcane and corn are shown in Table 3.5.

As shown in Table 5.10, refined flow-adjusted 14-, 30-, 60- and 90-day EECs based on atrazine use patterns that yield the highest screening-level EECs (i.e., sugarcane and corn in the southern region), are well below their respective threshold concentrations.

Although it is not possible to derive 14-, 30-, 60-, and 90-day exposure concentrations from the available monitoring data, a comparison of longer-term annual average concentrations from the flow-adjusted modeling with time-weighted means (TWM) from the NASQAN data suggests that flow-adjusted EECs may under-represent longer-term exposure by a factor of 2 to 3 times the monitored values. Increasing the 30-, 60-, and 90-day flow-adjusted EECs by a factor of 3 would result in exposure levels less than their respective threshold concentrations. Although three times the maximum 14-day flow-adjusted EEC of 14 µg/L (42 µg/L) exceeds the 14-day threshold concentration of 38 µg/L, further evaluation of the peak monitored atrazine concentrations from rivers where the pallid sturgeon occurs shows that measured maximum values (0.002 to 34 µg/L) are less than the 14-day threshold concentration. Therefore, consideration of the flow-adjusted EECs and available monitoring data for rivers that are occupied by the pallid sturgeon shows that expected long-term exposure concentrations of atrazine are less than their respective threshold concentrations indicative of aquatic community-level effects.

Although atrazine use may directly affect individual aquatic vascular and non-vascular plants in the large rivers of the pallid sturgeon's range, its use within the action area is not likely to adversely affect the pallid sturgeon via indirect community-level effects to aquatic vegetation. This finding is based on insignificance of effects (i.e., although effects to individual plants may occur, community-level effects to aquatic plants cannot be meaningfully measured, detected, or evaluated in the context of a "take" of a single pallid sturgeon. Therefore, the effects determination for the assessment endpoint of indirect effects on the pallid sturgeon via direct effects on habitat and/or primary productivity of aquatic plants is "may affect, but not likely to adversely affect" or "NLAA".

#### 5.2.4 Indirect Effects via Alteration in Terrestrial Plant Community (Riparian Habitat)

As shown in Tables 5.6 and 5.7, seedling emergence and vegetative vigor RQs exceed LOCs for a number of the tested plant species. Based on exceedance of the seedling emergence LOCs for all species tested except corn, the following general conclusions can be made with respect to potential harm to riparian habitat via runoff exposures:

- Atrazine may enter riparian areas via runoff where it may be taken up through the root system of sensitive plants.

- Comparison of seedling emergence $EC_{25}$ values to EECs estimated using TerrPlant suggests that existing vegetation may be affected, or inhibition of new growth may occur. Inhibition of new growth could result in degradation of high quality riparian habitat over time because as older growth dies from natural or anthropogenic causes, plant biomass may be prevented from being replenished in the riparian area. Inhibition of new growth may also slow the recovery of degraded riparian areas that function poorly due to sparse vegetation because atrazine deposition onto bare soil would be expected to inhibit the growth of new vegetation.

- Because LOCs were exceeded for most species tested (9/10) in the seedling emergence studies, it is likely that many species of herbaceous plants may be potentially affected by exposure to atrazine in runoff.

A number of dicots in riparian habitats may also be impacted via foliar exposure from atrazine in spray drift as evidenced by vegetative vigor LOC exceedances in three dicots. Therefore, riparian habitats comprised of herbaceous plants sensitive to atrazine may be adversely affected by spray drift. However, comparison of the seedling emergence and vegetative vigor RQs indicates that runoff, and not spray drift, is a larger contributor to potential risk for riparian vegetation. Vegetative vigor risk quotients were not exceeded for monocots; therefore, drift would not be anticipated to affect riparian zones comprised primarily of monocot species such as grasses.

Because RQs for terrestrial plants are above the Agency's LOCs, atrazine use is considered to have the potential to directly impact plants in riparian areas, potentially resulting in degradation of water quality via sedimentation. The importance of riparian habitat to the pallid sturgeon, sensitivity of forested and grassy riparian zones to atrazine, and the potential for sedimentation to indirectly affect the pallid sturgeon via atrazine-related effects on riparian vegetation are discussed below in Sections 5.2.4.1 through 5.2.4.3, respectively.

#### *5.2.4.1 Importance of Riparian Habitat to the Pallid Sturgeon*

Riparian vegetation provides a number of important functions in the stream/river ecosystem, including the following:

- serves as an energy source;
- provides organic matter to the watershed;
- provides shading, which ensures thermal stability of the stream; and
- serves as a buffer, filtering out sediment, nutrients, and contaminants before they reach the stream.

The specific characteristics of a riparian zone that are optimal for the pallid sturgeon are expected to vary with developmental stage, the use of the reach adjacent to the riparian zone, and the hydrology of the watershed. Criteria developed by Fleming et al. (2001) have been used to assess the health of riparian zones and their ability to support fish habitat. These criteria, which include the width of vegetated area (i.e., distance from cropped area to water), structural diversity of vegetation, and canopy shading are summarized in Table 5.11.

**Table 5.11 Criteria for Assessing the Health of Riparian Areas to Support Aquatic Habitats (adapted from Fleming et al., 2001)**

| Criteria | Quality | | | |
|---|---|---|---|---|
| | Excellent | Good | Fair | Poor |
| Buffer width | >18m | 12 - 18m | 6 - 12m | <6m |
| Vegetation diversity | >20 species | 15 - 20 species | 5 - 14 species | <5 species |
| Structural diversity | 3 height classes grass/shrub/tree | 2 height classes | 1 height class | sparse vegetation |
| Canopy shading | mixed sun/shade | sparse shade | 90% sun | no shade |

To maintain at least "good" water quality for fish in general, riparian areas should contain at least a 12-m (~40-ft) wide vegetated area, 15 plant species, vegetation of at least two height classes, and provide at least sparse shade (>10% shade). In general, higher quality riparian zones (wider vegetated areas with greater plant diversity) are expected to have a lower probability of being affected by atrazine than poor quality riparian areas (narrower areas with less vegetation and little diversity).

The following three attributes of riparian vegetation habitat quality were evaluated for this assessment: water temperature, stream bank stability, and sediment loading. Each of these attributes and its relevance to the pallid sturgeon is discussed briefly below.

<u>Streambank Stabilization:</u> Riparian vegetation typically consists of three distinct types of plants, which include a groundcover of grasses and forbs, an understory of shrubs and young trees, and an overstory of mature trees. These plants serve as structural components for streams, with the root systems helping to maintain stream stability, and the large woody debris from the mature trees providing instream cover. Riparian vegetation has been shown to be essential to maintenance of a stable stream (Rosgen, 1996). Destabilization of the stream can have a severe impact on aquatic habitat quality. Following a disturbance, the stream may widen, releasing sediment from the stream banks and scouring the stream bed. Destabilization of the stream can have severe effects on aquatic habitat quality by increasing sedimentation within the watershed. The effects of sedimentation and its potential impact on the pallid sturgeon are summarized below.

<u>Sedimentation:</u> Sedimentation refers to the deposition of particles of inorganic and organic matter from the water column. Increased sedimentation is caused primarily by disturbances to river bottoms and streambeds and by soil erosion. Riparian vegetation is important in moderating the amount of sediment loading from upland sources. The roots and stems of riparian vegetation can intercept eroding upland soil (USDA NRCS, 2000), and riparian plant foliage can reduce erosion from within the riparian zone by covering the soil and reducing the impact energy of raindrops onto soil (Bennett, 1939).

As previously described in the life history information for the pallid sturgeon, this species requires large, free-flowing, turbid rivers. Within its range, pallid sturgeon tend to select main channel habitats (Sheehan et al., 1998) in the Mississippi River and main channel areas with islands or sand bars in the upper Missouri River (Bramblett, 1996). While sedimentation may cause a change in substrate type necessary for spawning, sediment transport within larger river systems is critical for stream shape, channel morphology, and the formation of naturally occurring pallid sturgeon habitat features like sandbars (Kellerhals and Church, 1989). Lack of sediment transport and availability is likely to negatively impact the pallid sturgeon because some level of sedimentation is necessary for habitat development and maintenance. In addition, lack of turbidity associated with a reduction in suspended sediments may adversely affect the pallid sturgeon by increasing the potential for predation, competition from other fish species, and the ability of prey to avoid capture (USFWS, 2003).

<u>Thermal stability</u>. Riparian habitat provides stream shading, resulting in thermal stability. Thermal stability is generally considered to be an important variable for most river sturgeons (*Scaphirhynchus* spp.) (USFWS, 2000). Pallid sturgeon inhabit areas where the water temperature ranges from $0^{o}C$ to $30^{o}C$ ($32^{o}F$ to $86^{o}F$), which is the range

of water temperature in the Missouri and Mississippi Rivers (USFWS, 1993). However, the sensitivity of the pallid sturgeon to fluctuations in temperature is unknown.

#### *5.2.4.2 Sensitivity of Forested Riparian Zones to Atrazine*

As previously summarized in Table 5.11, the parameters used to assess riparian quality include buffer width, vegetation diversity, vegetation cover, structural diversity, and canopy shading. Buffer width, vegetation cover, and/or canopy shading may be reduced if atrazine exposure impacts plants in the riparian zone or prevents new growth from emerging. Plant species diversity and structural diversity may also be affected if only sensitive plants are impacted (Jobin et al., 1997; Kleijn and Snoeijing, 1997), leaving non-sensitive plants in place. Atrazine may also affect the long-term health of high quality riparian habitats by affecting seed germination.

Because woody plants are generally not sensitive to environmentally-relevant atrazine concentrations (MRID 46870400-01), effects on shading, streambank stabilization, and structural diversity (height classes) of woody forested vegetation are not expected. Effects are expected to be limited to herbaceous (non-woody) plants, which are not generally associated with shading or considered to represent vegetation of higher height classes. Therefore, plant diversity, vegetation cover, and buffer width are expected to be the most sensitive riparian quality criteria for herbaceous plants.

The riparian health criteria described in Fleming et al. (2001; Table 5.11) and the characteristics associated with effective vegetative buffer strips suggest that healthy riparian zones would be less sensitive to the impacts of atrazine runoff than poor riparian zones. Although riparian zones rich in species diversity and woody species may contain sensitive species, it is unlikely that they would consist of a high proportion of very sensitive plants. Wider buffers have more potential to reduce atrazine residues over a larger area, resulting in lower levels. In addition, trees and woody plants in a healthy riparian area act to filter spray drift (Koch et al., 2003) and push spray drift plumes over the riparian zone (Davis et al., 1994), thus reducing exposure to herbaceous plants, which tend to be more sensitive. Therefore, high quality riparian zones are expected to be less sensitive to atrazine than riparian zones that are narrow, low in species diversity, and comprised of young herbaceous plants or unvegetated areas. The available data suggest that riparian zones comprised largely of herbaceous plants and grasses would likely be most sensitive to atrazine effects, while woody vegetation within forested riparian areas would be tolerant of exposure to atrazine. Bare ground riparian areas could also be adversely affected by prevention of new growth of grass, which can be an important component of riparian vegetation for maintaining water quality.

#### *5.2.4.3 Potential for Atrazine to Affect the Pallid Sturgeon via Effects on Riparian Vegetation*

It is difficult to estimate the magnitude of potential impacts of atrazine use on riparian habitat and the magnitude of potential effects on stream water quality from such impacts as they relate to survival, growth, and reproduction of the pallid sturgeon. The level of exposure and any resulting magnitude of effect on riparian vegetation is expected to be highly variable and dependent on many factors. The extent of runoff and/or drift into stream corridor areas is affected by the distance the atrazine use site is offset from the stream, local geography, weather conditions, and quality of the riparian buffer itself. The sensitivity of the riparian vegetation is dependent on the susceptibility of the plant species present to atrazine and composition of the riparian zone (e.g., vegetation density, species richness, height of vegetation, width of riparian area).

Quantification of risk to the pallid sturgeon is precluded by the following factors:

- Locations of pallid sturgeon spawning habitat within its current range are not known;

- The relationship between distance of soil input into the river and sediment deposition in spawning areas critical to survival and reproduction of the pallid sturgeon is not known; and

- Riparian areas are highly variable in their composition and location with respect to atrazine use; therefore, their sensitivity to potential damage is also variable.

In addition, even if plant community structure was quantifiably correlated with riparian function, it may not be possible to discern the effects of atrazine on species composition separate from other agricultural actions or determine if atrazine is a major factor in altering community structure. Plant community composition in agricultural field margins is likely to be modified by many agricultural management practices. Vehicular impact and mowing of field margins and off-target movement of fertilizer and herbicides are all likely to cause changes in plant community structure of riparian areas adjacent to agricultural fields (Jobin et al., 1997; Kleijn and Snoeijing, 1997; Schippers and Joenje, 2002). Although herbicides are commonly identified as a contributing factor to changes in plant communities adjacent to agricultural fields, some studies identify fertilizer use as the most important factor affecting plant community structure near agricultural fields (e.g., Schippers and Joenje, 2002) and community structure is expected to be affected by a number of other factors (de Blois et al., 2002). Thus, the effect of atrazine on riparian community structure would be expected to be one influence complicated by a myriad of other factors. Although the data do not allow for a quantitative estimation of risk from potential riparian habitat alteration, a qualitative discussion is presented below.

The magnitude of potential impacts of atrazine use on riparian habitat within the Missouri, Mississippi, and Atchafalaya River systems and resulting indirect effects to pallid sturgeon water quality via sedimentation are evaluated by considering life history characteristics of the sturgeon, the habitat in which they occur, and likely impacts on available spawning habitat.

Based on the preceeding evaluation of the three attributes of riparian vegetation, stream bank stability and water temperature are unlikely to be impacted. Mature woody plants, which provide stability and shading to river/stream banks, are not sensitive to atrazine.

With respect to sediment loading, increases in suspended sediment levels as a result of atrazine-related impacts to grassy riparian vegetation may occur in areas where atrazine use sites and herbaceous riparian areas are adjacent to occupied watersheds. Although the pallid sturgeon occupies large, fast-flowing rivers, it is uncertain what level of atrazine-related sedimentation may cause adverse modification to available spawning habitat. Pallid sturgeon have adhesive eggs; therefore, spawning is thought to occur over hard substrates of gravel or cobble accompanied by moderate flow. The location of pallid sturgeon spawning habitat is unknown, reproduction in the wild is reported to be a rare event, and recruitment from reproduction in the wild has not been documented (McKean, 2003; USFWS, 2003). The fish that are reproductively mature today were all spawned prior to dam construction (Gilbrath et al., 1988; June, 1976), and are thought to be nearing the end of their lifespans (USFWS, 2003). Hatcheries have been successful in spawning pallid sturgeon since 1997 (Krentz et al., 2005), and recaptures of released fish indicate that these young are surviving (Shuman et al., 2005). Therefore, maintenance of spawning habitat is critical for the continued reproductive success of hatchery-reared sturgeon. There is also evidence to suggest that flow is a critical component in inducing spawning. The 2003 USFWS Biological Opinion notes the importance of an appropriately timed high spring flow, with suitable temperatures during and after the rise, to promote spawning and larval survival (USFWS, 2003). According to the USFWS draft 5-year review for the pallid sturgeon (USFWS, 2007 draft), impoundments, such as dams, and channelization of rivers for navigation have restricted the life cycle requirements of the pallid sturgeon by blocking movements to spawning and feeding areas, destroying spawning areas, altering conditions and flows of potential remaining spawning areas, and reducing food sources by lowering productivity. Given that historical data regarding populations of pallid sturgeon is lacking or incomplete, and information on spawning sites, spawning behavior, and juvenile and adult habitat needs and uses is lacking, the significance and effects of changes in riverine habitats on pallid are not entirely clear (USFWS, 2007 draft).

It should be noted that, although sedimentation may cause adverse effects to the pallid sturgeon's spawning habitat, some level of turbidity and/or sedimentation is required for habitat development and maintenance. Lack of turbidity associated with a reduction in suspended sediments may adversely affect the pallid sturgeon by increasing the potential for predation, competition from other fish species, and the ability of prey to avoid capture (USFWS, 2003).

An analysis of 2001 National Land Cover Data (NLCD) surrounding the Missouri and Mississippi Rivers was completed to provide a spatial sense of the types of riparian vegetation that may be adjacent to watersheds occupied by the pallid sturgeon. As previously discussed, the action area for the sturgeon is large, encompassing 17 states from Montana to Louisiana. Given the large spatial scale of the action area, a spatially-explicit analysis of the riparian vegetation within the entire reach of the pallid sturgeon's range was not completed. However, a general description (and large-scale maps) of common types of riparian land cover adjacent to these watersheds is provided. Aerial imagery of the land cover adjacent to the Mississippi and Missouri Rivers (shown in

Figures H.1 through H.5 of Appendix H) indicates variability in the type of riparian vegetation adjacent to occupied watersheds. In the northern and Great Plains states (Montana, North Dakota, South Dakota, and portions of Nebraska; shown in Figure I.5), the majority of riparian land cover appears to be comprised of sensitive herbaceous vegetation, while riparian vegetation in the mid-western states (Iowa, Kansas, Missouri; Figure I.5) is predominantly cropland and hay/pasture. Analysis of land cover surrounding the Mississippi River in Arkansas and Mississippi shows that the majority of riparian vegetation surrounding this watershed is comprised of decidous forest in Illinois and Missouri (see Figure 5.1), woody wetlands in Arkansas and Mississippi (see Figures 5.2 and 5.63), and a mixture of cultivated crop, hay/pasture, and woody wetlands in Louisiana (Figure 5.4). Therefore, analysis of riparian land cover data adjacent to the Missouri and Mississippi River indicates that the riparian vegetation includes a mix of both sensitive herbaceous vegetation as well as tolerant forested and woody wetland areas. It is expected that potential atrazine-related impacts to pallid sturgeon spawning habitat (via effects to herbaceous vegetation and resulting sedimentation) would be most likely to occur in segments of the watershed that are in close proximity to, or downstream from atrazine use sites and herbaceous riparian areas. However, the extent to which atrazine use sites and herbaceous riparian areas co-occur with occupied river segments is unknown, given the large range of the species and spatial extent of the action area.

In summary, terrestrial plant RQs are above LOCs; therefore, riparian vegetation may be affected. However, woody plants are generally not sensitive to environmentally-relevant atrazine concentrations; therefore, effects on shading, streambank stabilization, and structural diversity (height classes) of vegetation are not expected. With respect to sedimentation, the potential for atrazine to affect the spawning habitat of the pallid sturgeon via impacts on riparian vegetation depends primarily on the extent of potentially sensitive (herbaceous and grassy) riparian areas and their impact on water quality in the rivers where the sturgeon is known to occur. Because woody plants are generally not sensitive to atrazine at expected exposure concentrations, riparian areas which have predominantly forested vegetation containing woody shrubs and trees are not likely to be impacted by atrazine use. Therefore, atrazine is not likely to adversely affect the pallid sturgeon in watersheds with predominantly forested riparian areas.

Conversely, atrazine may affect grassy and herbaceous riparian vegetation, resulting in increased sedimentation which could impact the pallid sturgeon's spawning habitat. However, the extent to which herbaceous or grassy riparian area versus forested riparian areas are present within the action area surrounding the pallid sturgeon's range is uncertain. In addition, the extent of specific land management practices, which may result in reduced sedimentation to occupied watersheds, is unknown. Until further analysis on specific land management practices and sensitivity of riparian vegation adjacent to pallid sturgeon habitat is completed, potential effects to riparian vegetation are presumed to potentially adversely affect the pallid sturgeon.

Therefore, there are separate effects determinations for indirect effects to pallid sturgeon via direct atrazine effects on riparian vegetation, depending on the presence of forested (woody shrubs and trees) versus herbaceous (grassy and non-woody) riparian vegetation adjacent to the rivers within the pallid sturgeon's action area. For areas where the riparian habitat is predominantly forested with shrubs and trees, the effects determination is "may affect, but not likely to adversely affect" or "NLAA". This finding is based on insignificance of effects (i.e., although effects to individual plants may occur, effects to forested riparian vegetation cannot be meaningfully measured, detected, or evaluated in the context of a "take" of a single pallid sturgeon). For habitats of the pallid sturgeon that are in close proximity to potential atrazine use sites and where the riparian vegetation is comprised of grasses and non-woody plants, the effects determination is "may affect and likely to adversely affect" or "LAA". A graphic representation of the effects determination for this assessment endpoint, based on evaluation of the sedimentation, streambank stability, and thermal stability attributes for riparian vegetation is provided in Figure 5.1.

While an "LAA" determination is concluded based on siltation resulting from potential alteration of herbaceous riparian vegetation, the extent to which these effects may adversely affect the spawning habitat of the pallid sturgeon is uncertain. As previously discussed, the pallid sturgeon requires some level of turbidity and/or sedimentation for habitat development/maintenance, predator avoidance, foraging, and reduction in competition from other fish species. Therefore the "LAA" determination is based on the potential negative impacts of siltation, rather than balancing the potentially negative and positive impacts of siltation on the species.

Given the "LAA" finding for areas where herbaceous and grassy riparian vegetation is predominant, the Agency has completed a summary of the environmental baseline and cumulative effects for the listed mussel species included in this assessment in Appendix I. The environmental baseline is defined as the effects of past and ongoing human induced and natural factors leading to the status of the species, its habitat, and ecosystem, within the action area. The baseline information provides a snapshot of the pallid sturgeon at this time. A summary of all USFWS biological opinions that are relevant to the pallid sturgeon that have been made available to EPA included in this assessment is also provided as part of the baseline status. Cumulative effects include the effects of future state, tribal, local, private, or other non-federal entity activities on endangered and threatened species and their critical habitat that are reasonably expected to occur in the action area.

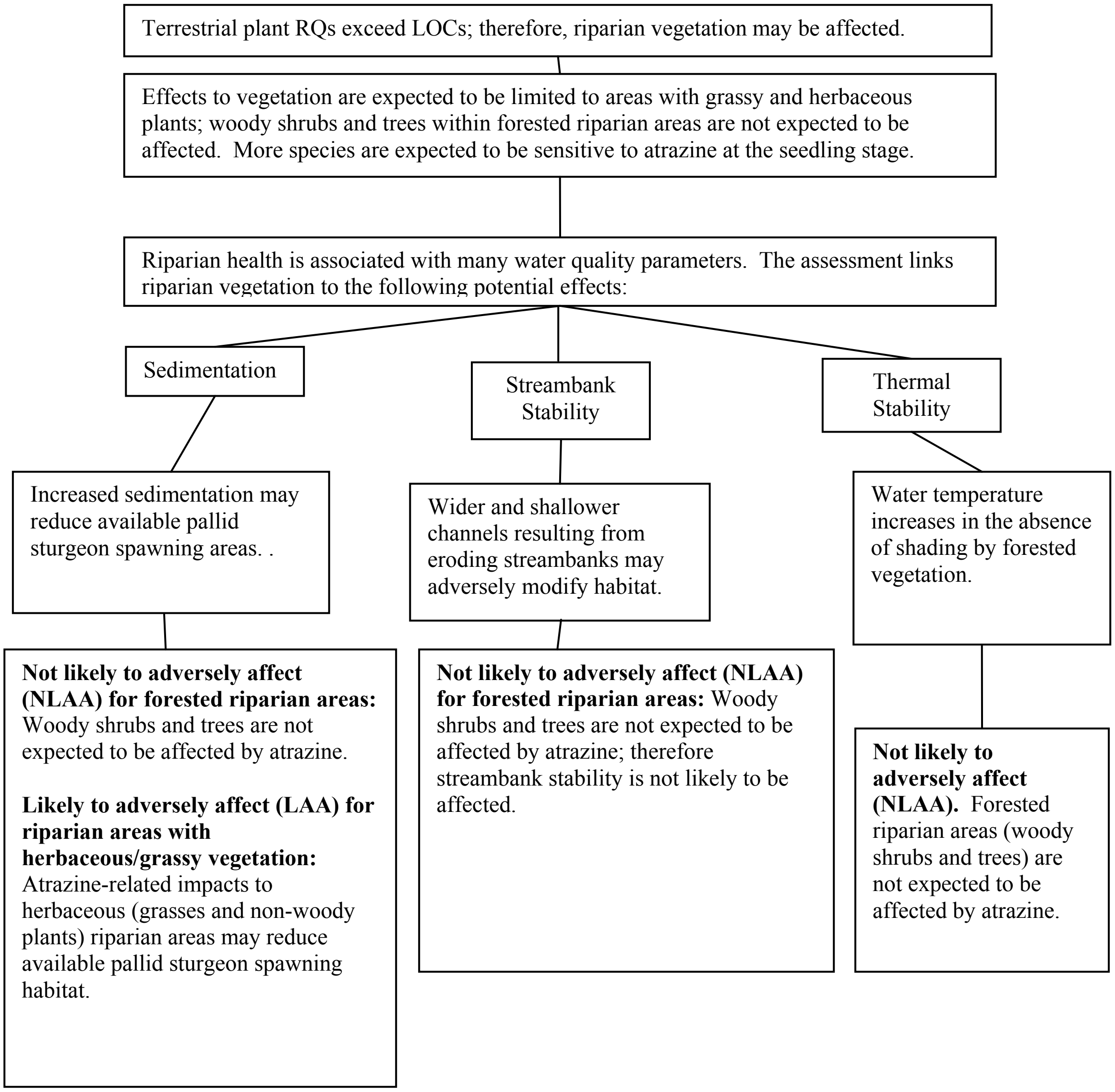


**Figure 5.1 Summary of the Potential of Atrazine to Affect the Pallid Sturgeon via Riparian Habitat Effects**

# 6. Uncertainties

## 6.1 Exposure Assessment Uncertainties

### 6.1.1 Aquatic Exposure Assessment

A number of factors add uncertainty to the direct comparison of flow-adjusted modeling EECs with the monitoring data (including other sources discussed previously). For example, the selection process for the ecological monitoring sites was focused on the most vulnerable sites relative to atrazine runoff, and the sites do not directly correlate with the majority of major rivers that are occupied by the pallid sturgeon. The ecological monitoring sites represent highly vulnerable 2$^{nd}$ and 3$^{rd}$ order streams (by the Strahler system), while the pallid sturgeon-occupied rivers are dominated by higher order water bodies (8th order and higher). Therefore, the monitoring data from the ecological monitoring sites provide context to modeling with the static water body but are not representative of exposures expected in major rivers where the pallid sturgeon lives. This is important because the flow values used in the flow-adjusted modeling are generally from higher-order streams with flow rates that are higher than those found in all of the ecological monitoring sites.

There are also uncertainties associated with modeling using the Index Reservoir water body (used principally for human health exposure assessments) because the water body volume of the Index Reservoir may not be representative of the larger rivers where the pallid sturgeon lives. The Index Reservoir was developed to represent a small drinking water reservoir, and flow representative of major rivers is higher than flow rates that could typically be routed through a small reservoir.

Additional uncertainties should be considered when comparing the modeled static water body EECs with various habitat types and monitoring data. Specifically, the modeled water body represents static water; however, in reality, many water bodies have some amount of flow. For the action area, it is expected that no-flow and low-flow water bodies are representative of the headwater streams adjacent to an agricultural field. In general, it is expected that modeled atrazine concentrations in the static water body will over-estimate exposure in settings where flow is greater than those modeled and where the volume of the water body is greater than that modeled (20,000,000 liters). As demonstrated in the various comparisons between modeling and monitoring data described above, it is apparent that peak concentrations are well represented by modeling with both the static water body and flow-adjusted modeling using the Index Reservoir although some of the more vulnerable sites may be under-represented. However, longer-term concentrations (e.g., 14-, 30-, 60-, and 90-day averages) appear to be over-represented by modeling with the static water body, while these same-duration exposure concentrations may be under-represented by flow-adjusted modeling in the most vulnerable watersheds with low flow rates.

#### 6.1.2 Impact of Vegetative Setbacks on Runoff

Unlike spray drift, modeles are currently not available to evaluate the effectiveness of a vegetative setback on runoff and loadings. The effectiveness of vegetative setbacks is highly dependent on the condition of the vegetative strip. For example, a well-established, healthy vegetative setback can be a very effective means of reducing runoff and erosion from agricultural fields (USDA, NRCS, 2000). Alternatively, a setback of poor vegetative quality or a setback that is channelized can be ineffective at reducing loadings. Until such time as a quantitative method to estimate the effect of vegetative setbacks on various conditions on pesticide loadings becomes available, the aquatic exposure predictions are likely to overestimate exposure where healthy vegetative setbacks exist and underestimate exposure where poorly developed, channelized, or bare setbacks exist.

### 6.1.3 PRZM Modeling Inputs and Predicted Aquatic Concentrations

In general, the linked PRZM/EXAMS model produces estimated aquatic concentrations that are expected to be exceeded once within a ten-year period. The Pesticide Root Zone Model (PRZM) is a process or "simulation" model that calculates what happens to a pesticide in a farmer's field on a day-to-day basis. It considers factors such as rainfall and plant transpiration of water, as well as how and when the pesticide is applied. It has two major components: hydrology and chemical transport. Water movement is simulated by the use of generalized soil parameters, including field capacity, wilting point, and saturation water content. The chemical transport component can simulate pesticide application on the soil or on the plant foliage. Dissolved, adsorbed, and vapor-phase concentrations in the soil are estimated by simultaneously considering the processes of pesticide uptake by plants, surface runoff, erosion, decay, volatilization, foliar wash-off, advection, dispersion, and retardation.

Uncertainties associated with each of these individual components add to the overall uncertainty of the modeled concentrations. Additionally, model inputs from the environmental fate degradation studies are chosen to represent the upper confidence bound on the mean, values that are not expected to be exceeded in the environment 90 percent of the time. Mobility input values are chosen to be representative of conditions in the environment. The natural variation in soils adds to the uncertainty of modeled values. Factors such as application date, crop emergence date, and canopy cover can also affect estimated concentrations, adding to the uncertainty of modeled values. Factors within the ambient environment such as soil temperatures, sunlight intensity, antecedent soil moisture, and surface water temperatures can cause actual aquatic concentrations to differ for the modeled values.

Additionally, the rate at which atrazine is applied and the percent of crops that are actually treated with atrazine may be lower than the Agency's default assumption of the maximum allowable application rate being used and the entire crop being treated. The geometry of a watershed and limited meteorological data sets also add to the uncertainty of estimated aquatic concentrations.

### 6.1.4 Terrestrial Plant Exposure Concentrations

The TerrPlant model considers only exposures to plants from single pesticide applications. It is assumed that each single application would expose different plants due to initial plant mortality, different drift patterns, or phenologic timing. Sugarcane uses of atrazine were modeled at the highest single application rate of 4 lbs ai/A, although the maximum yearly rate for sugarcane is 10 lbs ai/A. Because plants may be impaired but not killed, the modeling of EECs from single pesticide applications rather than multiple applications could result in underestimating pesticide exposures to plants because multiple applications of atrazine are common for this use pattern. Although modeled terrestrial plant EECs based on single applications may underestimate exposure for uses which allow multiple applications, the terrestrial plant toxicity data are based on single pesticide applications; therefore, single application-based EECs are appropriate for deriving RQs based on the available effects data for terrestrial plants. Extrapolation of the available toxicity data to multiple applications is not possible, given the number of variables that may affect plant toxic response.

## 6.2 Effects Assessment Uncertainties

### 6.2.1 Age Class and Sensitivity of Effects Thresholds

It is generally recognized that test organism age may have an impact on the observed sensitivity to a toxicant. The acute toxicity data for fish are collected on juvenile fish weighing between 0.1 and 5 grams. Aquatic invertebrate acute testing is performed on recommended immature age classes (e.g., first instar for daphnids, second instar for amphipods, stoneflies, mayflies, and third instar for midges).

Testing of juveniles may overestimate toxicity at older age classes for pesticidal active ingredients, such as atrazine, that act directly (without metabolic transformation) because younger age classes may not have the enzymatic systems associated with detoxifying xenobiotics. In so far as the available toxicity data may provide ranges of sensitivity information with respect to age class, this assessment uses the most sensitive life-stage information as measures of effect for surrogate aquatic animals, and is therefore, considered as protective of the pallid sturgeon.

### 6.2.2 Use of Acute Freshwater Invertebrate Toxicity Data for the Midge

The initial acute risk estimate for freshwater invertebrates was based on the lowest toxicity value from *Chironomus* studies, which showed a wide range of sensitivity within and between species of the same genus (2 orders of magnitude). Further evaluation of the species sensitivity distribution shows that the majority of freshwater invertebrate species are unaffected by atrazine at environmentally relevant concentrations. Therefore, acute RQs based on the most sensitive toxicity endpoint for freshwater invertebrates may represent an overestimation of potential direct risks to freshwater invertebrates and indirect effects to the pallid sturgeon via a reduction in available food.

### 6.2.3 Impact of Multiple Stressors on the Effects Determination

The influence of length of exposure and concurrent environmental stressors to the pallid sturgeon (i.e., construction of dams and locks, fragmentation of habitat, change in flow regimes, lack of suitable spawning habitat) will likely affect the species response to atrazine. Additional environmental stressors may increase the pallid sturgeon's sensitivity to the herbicide, although there is the possibility of additive/synergistic reactions. Timing, peak concentration, and duration of exposure are critical in terms of evaluating effects, and these factors will vary both temporally and spatially within the action area. Overall, the effect of this variability may result in either an overestimation or underestimation of risk. However, as previously discussed, the Agency's LOCs are set to be protective given the wide range of possible uncertainties.

### 6.2.4 Use of Threshold Concentrations for Community-Level Endpoints

For the purposes of this endangered species assessment, threshold concentrations are used to predict potential indirect effects (via aquatic plant community structural change) to the pallid sturgeon. The conceptual aquatic ecosystem model used to develop the threshold concentrations is intended to simulate the ecological production dynamics in a 2$^{nd}$ or 3$^{rd}$ order Midwestern stream; however, the model has been correlated to the micro- and mesocosm studies, which were derived from a wide range of experimental studies (i.e., jar studies to large enclosures in lentic and lotic systems), that represent the best available information for atrazine-related community-level endpoints.

The threshold concentrations are predictive of potential atrazine-related community-level effects in aquatic ecosystems, such as those that occur in the known locations for the pallid sturgeon, where the species composition may differ from those included in the micro- and mesocosm studies. Although it is not possible to determine how well the responses observed in the micro- and mesocosm studies reflect the Missouri and Mississippi River Basin aquatic communities, estimated chronic atrazine exposure concentrations in the action area (from modeled EECs assuming flow) are predicted to be between 2 to 6 times lower than the community-level threshold concentrations, depending on the modeled atrazine use and averaging period. An evaluation of monitoring data suggests that concentrations of atrazine could be even further removed from these threshold concentrations. Given that threshold concentrations were derived based on the best available information from available community-level data for atrazine, these values are intended to be protective of the aquatic community, including the pallid sturgeon. Additional uncertainties associated with use of the screening thresholds to estimate community-level effects are discussed Appendix B (Section B.8) of the previous atrazine endangered species assessment for eight listed mussels (U.S. EPA, 2007c).

### 6.2.5. Sublethal Effects

The assessment endpoints used in ecological risk assessment include potential effects on survival, growth, and reproduction of the pallid sturgeon. A number of studies were located that evaluated potential sublethal effects to fish from exposure to atrazine. Although many of these studies reported toxicity values that were less sensitive than the submitted studies, they were not considered for use in risk estimation. In particular, fish studies were located in the open literature that reported effects on endpoints other than survival, growth, or reproduction at concentrations that were considerably lower than the most sensitive endpoint from submitted studies.

Upon evaluation of the available studies, however, the most sensitive NOAEC from the submitted life-cycle studies was considered to be the most appropriate chronic endpoint for use in risk assessment. In the life cycle study, fish are exposed to atrazine from one stage of the life cycle to at least the same stage of the next generation (e.g., egg to egg). Therefore, exposure occurs during the most sensitive life stages and during the entire reproduction cycle. Four life cycle studies have been submitted in support of atrazine registration. Species tested include brook trout, bluegill sunfish, and fathead minnows. The most sensitive NOAEC from these studies was 65 µg/L.

Reported sublethal effects including changes in hormone levels, behavioral effects, kidney pathology, gill physiology, and potential olfaction effects have been observed at concentrations lower than 65 µg/L (see Appendix A and Section 4.1.2.). In accordance with the Overview Document (U.S. EPA, 2004) and the Services Evaluation Memorandum (USFWS/NMFS, 2003), these studies were not considered appropriate for risk estimation in place of the life cycle studies because quantitative relationships between these effects and the ability of fish to survive, grow, and reproduce has not been established. The magnitude of the reported sublethal effect associated with reduced survival or reproduction has not been established; therefore, it is not possible to quantitatively link sublethal effects to the selected assessment endpoints for this ESA. In addition, in the fish life cycle studies, no effects were observed to survival, reproduction, and/or growth at levels associated with the sublethal effects. Also, there were limitations to the studies that reported sublethal effects that preclude their quantitative use in risk assessment (see Appendix A and Section 4.2.1). Nonetheless, if future studies establish a quantitative link between the reported sublethal effects and fish survival, growth, or reproduction, the conclusions with respect to potential effects to the pallid sturgeon may need to be revisited.

### 6.2.6. Exposure to Pesticide Mixtures

In accordance with the Overview Document and the Services Evaluation Memorandum (U.S. EPA, 2004; USFWS/NMFS, 2004), this assessment considers the single active ingredient of atrazine, as well as available information on registered products containing multiple active ingredients in addition to atrazine. However, the assessed species and its environments may be exposed to multiple pesticides simultaneously. Interactions of other toxic agents with atrazine could result in additive effects, synergistic effects, or antagonistic effects. The available data suggest that pesticide mixtures involving atrazine may produce either synergistic or additive effects. Mixtures that have been studied include atrazine with insecticides such as organophosphates and carbamates or with herbicides including alachlor and metolachlor. A number of study authors claim additive or synergistic effects in several taxa including fish, amphibians, invertebrates, and plants.

As previously discussed, evaluation of pesticide mixtures is beyond the scope of this assessment because of the myriad of factors that cannot be quantified based on the available data. Those factors include identification of other possible co-contaminants and their concentrations, differences in the pattern and duration of exposure among contaminants, and the differential effects of other physical/chemical characteristics of the receiving waters (e.g. organic matter present in sediment and suspended water). Evaluation of factors that could influence additivity/synergism is beyond the scope of this assessment and is beyond the capabilities of the available data to allow for an evaluation. However, it is acknowledged that not considering mixtures could over- or under-estimate risks depending on the type of interaction and factors discussed above.

## 6.3 Assumptions Associated with the Acute LOCs

The risk characterization section of this endangered species assessment includes an evaluation of the potential for individual effects. The individual effects probability associated with the acute RQ is based on the mean estimate of the slope and an assumption of a probit dose response relationship for the effects study corresponding to the taxonomic group for which the LOCs are exceeded.

Sufficient dose-response information was not available to estimate the probability of an individual effect on the midge (one of the dietary food items of the pallid sturgeon). Acute ecotoxicity data from the midge were used to derive RQs for freshwater invertebrates. Based on a lack of dose-response information for the midge, the probability of an individual effect was calculated using the only probit dose response curve slope value reported in available freshwater invertebrate ecotoxicity data for technical grade atrazine. Therefore, a probit slope value of 4.4 for the amphipod was used to estimate the probability of an individual effect on the freshwater invertebrates. It is unclear whether the probability of an individual effect for freshwater invertebrates other than amphipods would be higher or lower, given a lack of dose-response information for other freshwater invertebrate species. However, the assumed probit dose response slope for freshwater invertebrates of 4.4 would have to decrease to approximately 1.8 to 3.2 to cause an effect probability ranging between 1 in 10 and 1 in 100, respectively, for freshwater invertebrates.

## 6.4. Uncertainty in the Potential Effect to Riparian Vegetation vs. Water Quality Impacts via Increased Sedimentation

Effects to riparian vegetation were evaluated using submitted guideline seedling emergence and vegetative vigor studies and non-guideline woody plant effects data. LOCs were exceeded for seedling emergence and vegetative vigor endpoints with the seedling emergence endpoint being considerably more sensitive. Based on LOC exceedances and the lack of readily available information to allow for characterization of riparian areas of the pallid sturgeon, it was concluded that atrazine use is likely to adversely affect the pallid sturgeon via potential impacts on grassy/herbaceous riparian vegetation resulting in increased sedimentation. However, soil retention/sediment loading is dependent on a number of factors including land management and tillage practices. Use of herbicides (including atrazine) may be incorporated into a soil conservation plan. Therefore, although this assessment concludes that atrazine is likely to adversely affect the pallid sturgeon by potentially impacting sensitive herbaceous riparian areas, it is possible that adverse impacts on sediment loading may not occur in areas where soil retention strategies are used.

# 7. Summary of Direct and Indirect Effects to the Pallid Sturgeon

In fulfilling its obligations under Section 7(a)(2) of the Endangered Species Act, the information presented in this endangered species risk assessment represents the best data currently available to assess the potential risks of atrazine to the pallid sturgeon. The best available data suggest that atrazine is not likely to adversely affect the pallid sturgeon by direct toxic effects or by indirect effects resulting from effects to aquatic plants and aquatic animals. An "LAA" determination was concluded for the pallid sturgeon based on indirect effects to habitat and water quality via direct effects to herbaceous/grassy riparian vegetation. However, atrazine is not likely to adversely affect the pallid sturgeon in watersheds with predominantly forested riparian areas because woody shrubs and trees are generally not sensitive to environmentally-relevant concentrations of atrazine. A summary of the risk conclusions and effects determination for the pallid sturgeon, given the uncertainties discussed in Section 6, is presented in Table 7.1.

**Table 7.1 Effects Determination Summary for the Pallid Sturgeon**

| Assessment Endpoint | Effects determination | Basis for Determination |
|---|---|---|
| 1. Survival, growth, and reproduction of pallid sturgeon individuals via direct effects | May affect, but not likely to adversely affect (NLAA) | Acute and chronic LOCs are exceeded based on screening-level EECs from the non-flowing standard water body. However, flow-adjusted EECs and available monitoring data indicate that atrazine concentrations are expected to be lower than concentrations that would result in LOC exceedances for freshwater fish. This finding is based on insignificance of effects (i.e., acute and chronic effects cannot be meaningfully measured, detected, or evaluated in the context of a "take" of a single listed pallid sturgeon). |
| 2. Indirect effects to the pallid sturgeon via reduction of prey (i.e., freshwater fish and invertebrates) | May affect, but not likely to adversely affect (NLAA) | <u>Fish:</u> Although acute and chronic LOCs are exceeded for freshwater fish for some uses (based on screening-level EECs), consideration of flow-adjusted EECs and available monitoring indicate that refined exposure concentrations are not of concern for freshwater fish (see effects determination for assessment endpoint #1).<br><br><u>Invertebrates:</u> Potential acute impact to the most sensitive freshwater invertebrate species is expected to be low (1 in 390 million). Given the low impact to abundance of the most sensitive aquatic invertebrate tested, the wide range of sensitivities of aquatic invertebrates to atrazine, and the generalist feeding behavior of the assessed species, labeled use of atrazine is not likely to adversely affect the pallid sturgeon via an acute reduction in invertebrate prey items. In addition, atrazine levels in large rivers, such as those inhabited by the pallid sturgeon, are not expected to exceed reproduction NOAECs for freshwater invertebrates. Therefore, reduction in invertebrate prey items via chronic effects is also not likely to adversely affect the pallid sturgeon. These findings are based on insignificance of effects (i.e., acute and chronic effects cannot be meaningfully measured, detected, or evaluated in the context of a "take" of a single listed pallid sturgeon). |
| 3. Indirect effects to the pallid sturgeon via reduction of habitat and/or primary productivity (i.e., aquatic plants) | May affect, but not likely to adversely affect (NLAA) | Individual aquatic plant species within the Missouri, Mississippi, and Atchafalaya Rivers may be affected. However, 14-, 30-, 60-, and 90-day EECs, which consider the impact of flow, are well below the threshold concentrations representing community-level effects. In addition, the |

| | | |
|---|---|---|
| | | available monitoring data for large rivers where the sturgeon occurs indicate that peak detected concentrations are < the 14-day threshold concentration representing aquatic community-level impacts. This finding is based on insignificance of effects (i.e., community-level effects to aquatic plants are not likely to result in "take" of a single pallid sturgeon). |
| 4. Indirect effects to the pallid sturgeon via reduction of terrestrial vegetation (i.e., riparian habitat) required to maintain acceptable water quality | Direct effects to forested riparian vegetation: May affect, but not likely to adversely affect (NLAA)<br><br>Direct effects to grassy/herbaceous riparian vegetation: Likely to adversely affect (LAA) | Riparian vegetation may be affected because terrestrial plant RQs are above LOCs. However, woody plants are generally not sensitive to environmentally-relevant concentrations of atrazine; therefore, effects on shading, streambank stabilization, and structural diversity of riparian areas in the action area are not expected. With respect to sedimentation, the potential for atrazine to affect the spawning habitat of the pallid sturgeon via impacts on riparian vegetation depends primarily on the extent of potentially sensitive (herbaceous and grassy) riparian areas and their impact on water quality in the rivers where the sturgeon is known to occur. Because woody plants are generally not sensitive to atrazine at expected exposure concentrations, riparian areas which have predominantly forested vegetation containing woody shrubs and trees are not likely to be impacted by atrazine use. This finding is based on insignificance of effects (i.e., although effects to individual plants may occur, effects to forested riparian vegetation cannot be meaningfully measured, detected, or evaluated in the context of a "take" of a single pallid sturgeon). For habitats of the pallid sturgeon that are in close proximity to potential atrazine use sites and where the riparian vegetation is comprised of grasses and non-woody plants, the effects determination is "may affect and likely to adversely affect or LAA". Until further analysis on specific land management practices and sensitivity of riparian vegetation adjacent to pallid sturgeon habitat is completed, potential effects to grassy herbaceous riparian vegetation are presumed to adversely affect the pallid sturgeon. |

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