APPENDIX H: BASELINE STATUS AND CUMULATIVE EFFECTS FOR THE FAT POCKETBOOK AND NORTHERN RIFFLESHELL MUSSELS

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H.1. CUMULATIVE EFFECTS

Cumulative effects include the effects of future state, tribal, local, private, or other non-federal entity activities on fat pocketbook and northern riffleshell mussels that are reasonably certain to occur in the action area. Future federal actions unrelated to the proposed action are not considered because they are subject to consultation pursuant to section 7 of the ESA. Numerous non-federal actions that could affect the fat pocketbook and northern riffleshell mussels are reasonably certain to occur within the action area. These will typically include silviculture, mining, forestry, agriculture, grazing activities, dredging, construction activities such as bridge construction, and urban development. Many of these activities are linked and create complex effects on listed species or their habitat in the action area. For example, ditch maintenance activities facilitate continued farming activities, as drainage of farmland is an important factor in crop success. Farming contributes to sedimentation and eutrophication in adjacent waters that receive agricultural runoff.

H.2. ENVIRONMENTAL BASELINE

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 environmental baseline is a snapshot of the fat pocketbook and northern riffleshell mussel's status at this time. However, the baseline condition of each of the assessed mussel's habitat varies across locations and within each stream/river. Details of the fat pocketbook and northern riffleshell mussel's habitat description and known locations are included in Appendix C. Given the large number of occupied watersheds and extent of the action area included of this assessment, the discussion of environmental baseline includes a general discussion of factors that may affect freshwater mussels within the action area (USFWS, 2007). This information is presented in Section H.2.1. Additional information on the baseline status of the assessed mussels was gathered from recent USFWS biological opinions. A summary of information gathered from the USFWS biological opinions is provided in Table H.1. Based on the endangered species risk assessment for the three listed mussels, "LAA" determinations were concluded for two of the three listed mussels, including the fat pocketbook and northern riffleshell. Therefore, information provided by the USFWS on the baseline status of the northern riffleshell and fat pocketbook mussels is presented in Sections H.2.2 and H.2.3 of this appendix.

H.2.1. Factors affecting species environment within the action area

The decline, extirpation, and extinction of mussel species is overwhelmingly attributed to habitat alteration and destruction (Neves, 1993). Dredging and channelization activities have profoundly altered riverine habitats nationwide. Channelization impacts a stream's physical (e.g., accelerated erosion, increased bedload, reduced depth, decreased habitat diversity, geomorphic instability, riparian canopy loss) and biological (e.g., decreased fish and mussel diversity, changed species composition and abundance, decreased biomass, and reduced growth rates. Channel construction for navigation has been shown to increase flood heights. This is partially attributed to a decrease in stream length and increase in gradient. Flood events may thus be exacerbated, conveying into streams large quantities of sediment, potentially with adsorbed contaminants. Channel maintenance may result in profound impacts downstream (Stansbery, 1971).

Currently, sedimentation and pollution from agricultural runoff and low water levels in the summer probably have the largest impacts on mussel populations. Siltation has long been associated with reductions in freshwater mussel assemblages (Brim Box and Mossa, 1999). Detrimental effects of fine sediment from runoff and erosion on freshwater mussels have been documented. Heavy sediment loads in the water column can interfere with feeding activity (Brim Box and Mossa, 1999), as mussels in turbid waters remained closed about 50% longer than mussels in silt free water, reducing the time available to feed (Ellis, 1936). Various mussel species have demonstrated a slower growth rate in turbid waters (Stansbery, 1971), which may be related to reduced feeding under high sedimentation levels. Fine sediment plumes may also reduce feeding in mussels by diluting the density of food particles in the water column (Widdows *et al.,* 1979). Impacts may also include increases in turbidity that may impede sight-feeding host fishes and potentially disrupt mussel attractant mechanisms to lure fish hosts and sedimentation that may smother juvenile mussels (Ellis, 1936).

Excessive sedimentation is a pervasive problem with an estimated 46% of all U.S. streams affected (Judy *et al.*, 1982). Sedimentation, including siltation, has been implicated in the decline of stream mussel populations (Ellis, 1936; Marking and Bills, 1979; Vannote and Minshall, 1982; Dennis, 1985; Brim Box and Mossa, 1999; Fraley and Ahlstedt, 2000). Specific biological impacts on mussels from excessive sediment include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, increased substrate instability, limited burrowing activity, and physical smothering (Ellis, 1936; Stansbery, 1971; Marking and Bills, 1979; Vannote and Minshall, 1982; Waters, 1995). Primary productivity reduction is an indirect impact that affects mussel food supplies (Henley *et al.*, 2000). Studies tend to indicate that the primary impacts of excess sediment levels on mussels are sublethal, with detrimental effects not immediately apparent (Brim Box and Mossa, 1999). The physical effects of sediment on mussels appear to be multifold, and include:

1. changes in suspended and bed material load;
2. bed sediment composition associated with increased sediment production and run-off in the watershed;
3. channel changes in form, position, and degree of stability;
4. changes in depth or the width/depth ratio that affects light penetration and flow regime;
5. actively aggrading (filling) or degrading (scouring) channels; and
6. changes in channel position that may leave mussels high and dry (Vannote and Minshall, 1982; Kanehl and Lyons, 1992; Brim Box and Mossa, 1999).

Interstitial spaces in the substrate provide crucial habitat for juvenile mussels. When clogged, interstitial flow rates and spaces become reduced (Brim Box and Mossa, 1999), thus reducing juvenile habitat. Sediment acts as a vector for delivering contaminants such as nutrients and pesticides to streams. Juveniles can readily ingest contaminants adsorbed to silt particles or in interstitial pore water during normal feeding activities (Yeager *et al.,* 1994; Newton, 2003). These factors may help explain, in part, why so many mussel populations are experiencing recruitment failure.

Agricultural activities produce the most significant amount of sediment that enters streams (Waters, 1995; Henley *et al.,* 2000). Neves *et al.,* (1997) stated that agriculture (including both sediment and chemical run-off) affects 72% of the impaired river miles in the country. Grazing may reduce infiltration rates, decrease filtering capacity of pollutants (thereby increasing sedimentation run-off), and trampling and eventual elimination of woody vegetation reduces bank resistance to erosion and contributes to increased water temperatures (Armour *et al.,* 1991; Trimble and Mendel, 1995; Brim Box and Mossa, 1999; Henley *et al.,* 2000).

Erosion from silvicultural activities accounts for 6% of national sediment pollution (Henley *et al*., 2000). Sedimentation impacts are more the result of logging roads than from the actual harvesting of timber (Waters, 1995; Brim Box and Mossa, 1999). Annual run-off and/or peak flow volumes increase with timber harvests, particularly during the wet season (Allan 1995). This is partially due to the construction of logging roads, and vegetation removal tends to compact soils, reduce infiltration rates, and increase soil erosion. Increased flows and improper harvesting within streamside management zones may result in stream channel changes (Brim Box and Mossa, 1999) that may ultimately affect mussel beds.

Agricultural runoff is frequently laden with chemicals associated with fertilizers and pesticides. The St. Francis River watershed is farmed for several crops including cotton, soybeans, and rice. Numerous fertilizers and pesticides are sprayed on these crops including defoliants and Malathion (for boll weevil eradication). Declines in mussel populations due to chemical water pollution have been documented since the late 19th century (Ortmann, 1918; Baker, 1928). Like sedimentation, mussels can tolerate short term exposures to pollutants by valve closure, but most cannot tolerate long term exposure to contaminated water (Neves, 1997).

Among pollutants, ammonia warrants priority attention for its effects on mussels (Augspurger *et al*., 2003), and has been shown to be lethal at concentrations of 5.0 parts per million (ppm) (Havlik and Marking, 1987). The un-ionized form of ammonia (NH_3) is usually attributed as being the most toxic to aquatic organisms, although the ammonium ion form (NH_4^+) may contribute to toxicity under certain conditions (Newton, 2003). Sources of ammonia are agricultural (e.g., animal feedlots, nitrogenous fertilizers), municipal (e.g., waste water treatment plant effluents), and industrial (e.g., chemical companies) as well as from precipitation and natural processes (e.g., decomposition of organic nitrogen) (Augspurger *et al,*. 2003; Newton, 2003). Atmospheric deposition is one of the most rapidly growing sources of anthropogenic nitrogen entering aquatic ecosystems (Newton, 2003). Agricultural sources of ammonia may be highly variable over time, compounding the determination of accurate concentration readings.

Stream ecosystems are impacted when nutrients are added at concentrations that cannot be assimilated, resulting in over-enrichment, a condition exacerbated by low-flow conditions. Juvenile mussels utilizing interstitial habitats are particularly affected by depleted dissolved oxygen (DO) levels resulting from over-enrichment (Sparks and Strayer, 1998). Increased risks from bacterial and protozoan infections to eggs and glochidia and to host fishes may also pose a threat. Pesticide runoff commonly ends up in streams where the effects (based on studies with laboratory-tested mussels) may be particularly profound (Havlik and Marking, 1987). Fertilizers and pesticides are also commonly used in developed areas.

Water withdrawals for agricultural irrigation, municipal, and industrial water supplies are an increasing concern for all aquatic resources and are directly correlated with expanding human populations. Impacts include decreased flow velocities and DO levels (Johnson *et al.,* 2001). Such stochastic events may be exacerbated by global climate change and water withdrawals. These primarily anthropogenic activities act insidiously to lower water tables, thus making mussel populations susceptible to depressed stream levels.

Table H.1 Summary of Biological Opinions Relevant for the Fat Pocketbook and Northern Riffleshell Mussel

Description of Federal Action	Citation	Action Area	Mussel Species	Magnitude of Take	Jeopardy Call
Replacement of a highway bridge and mussel relocation project	USFWS 2002	Near Harrisburg in Poinsett County, Arkansas	Fat Pocketbook	one individual or 5% of the number of mussels that were collected and relocated, whichever is greater	Not likely to result in jeopardy
Levee repair involving geotextile material and rock rip rap along 2,400 feet of stream banks from head to toe	USFWS 2003a	St. Francis Floodway and Crow Creek directly adjacent to the Madison, Arkansas sewage treatment lagoons	Fat Pocketbook	≥ 1	Not likely to result in jeopardy
Replacement of a railroad bridge and relocation of 116 individual mussels	USFWS 2003b	St. Francis River near Madison in Saint Francis County, Arkansas	Fat Pocketbook	> 3	Not likely to result in jeopardy
Dike maintenance and expansion	USFWS 2004a	Main channel of the Mississippi River in Issaquena County, Mississippi	Fat Pocketbook	< 20	Not likely to result in jeopardy
Ditch maintenance and dredging	USFWS 2004b	Ditch 10, Craighead and Poinsett Counties, Arkansas	Fat Pocketbook	100 < 10	Not likely to result in jeopardy
Kennerdell Bridge, Pa.	USFWS 1998a	PA (no further details	Northern Riffleshell	875	Not likely to result in jeopardy. (Personal communication with Robert Anderson

Description of Federal Action	Citation	Action Area	Mussel Species	Magnitude of Take	Jeopardy Call
		provided)			U.S. FWS on 7/17/07)
Utica Bridge, Pa.	USFWS 1998b	PA (no further details provided)	Northern Riffleshell	389	Not likely to result in jeopardy. (Personal communication with Robert Anderson U.S. FWS on 7/17/07)
Forest Plan - Allegheny National Forest, Pa.	USFWS 1999	PA (no further details provided)	Northern Riffleshell	unquantified	Not likely to result in jeopardy. (Personal communication with Robert Anderson U.S. FWS on 7/17/07)
Foxburg Bridge, Pa.	USFWS 2001	PA (no further details provided)	Northern Riffleshell	65	Not likely to result in jeopardy. (Personal communication with Robert Anderson U.S. FWS on 7/17/07)
Sugar Creek Pipeline, Pa.	USFWS 2002b	PA (no further details provided)	Northern Riffleshell	20	Not likely to result in jeopardy. (Personal communication with Robert Anderson U.S. FWS on 7/17/07)
East Brady Bridge, Pa.	USGS 2002	PA (no further details provided)	Northern Riffleshell	76[1]	Not likely to result in jeopardy. (Personal communication with Robert Anderson U.S. FWS on 7/17/07)
Warren St. Bridge, Pa.	USFWS 2003c	PA (no further details provided)	Northern Riffleshell	57	Not likely to result in jeopardy. (Personal communication with Robert Anderson U.S. FWS on 7/17/07)

[1] Take estimate revised to 95 individuals harmed or killed by April 26, 2007, biological opinion amendment to the Federal Highway Administration.

Description of Federal Action	Citation	Action Area	Mussel Species	Magnitude of Take	Jeopardy Call
West Hickory Bridge, Pa.	USFWS 2004c	PA (no further details provided)	Northern Riffleshell	905	Not likely to result in jeopardy. (Personal communication with Robert Anderson U.S. FWS on 7/17/07)
Mill Village Bridge, Pa.	USFWS 2004c	PA (no further details provided)	Northern Riffleshell	9	Not likely to result in jeopardy. (Personal communication with Robert Anderson U.S. FWS on 7/17/07)

H.2.2 Northern Riffleshell Baseline Status

Information on the baseline status of the northern riffleshell was obtained from the USFWS Draft 5-year review (USFWS, 2007 draft). Northern riffleshell mussels are cryptic, with perhaps 50% of a population occurring below the substrate surface; therefore, qualitative population estimates must take into account undetected individuals. Further, where northern riffleshells are found at low population densities, population estimates may have large margins of error due to undetected mussels. In addition, sparsely distributed juveniles used to document successful reproduction are likely even more difficult to detect.

Successful recruitment of northern riffleshell populations is often difficult to detect when densities are very low or surveys are single-day, catch-per-unit efforts. Few intensive, statistically valid surveys have been conducted on northern riffleshell populations outside of French Creek and the Allegheny River. Populations with densities near or below the detection rate may not be practically assessed with quantitative techniques. The difficulty in detecting northern riffleshells results in poorly defined information about the species distribution and abundance, even within the streams where the species is known to occur. A summary of the present range of the northern riffleshell within the U.S. is provided in Table H.2.

Table H.2: Northern riffleshell populations presently known to occur (or possibly extant)

Basin	Population	Stream	Approximate Range	Status[1]
St. Lawrence River System	Maumee River	Fish Creek	Last reported in early 1990’s, 2-mile reach	Status unknown; possibly extirpated
	Detroit River	Detroit River	Freshly dead shells found in 2005	Status unknown; possibly extirpated
Ohio River	Green River	Green River	One to two freshly dead shells found in 1987 and 1989 at two sites	Status unknown; possibly extirpated

	Scioto River	Big Darby Creek	One live female reported in 2000 from one site near river mile 19.	Status unknown; possibly extirpated
	Allegheny River	Allegheny River	scattered over 66 miles –Warren, Forest, Venango, Clarion, Armstrong Counties	Successful recruitment at multiple sites; stable
		Conewango Creek	Near the confluence with the Allegheny River	A few live individuals found in 2005; no recruitment documented; status unknown
	French Creek	French Creek	Scattered over 60 miles --Venango & Crawford Co.	Successful recruitment at multiple sites; stable
		LeBoeuf Creek	3-mile reach	Recruitment documented; stable
		Muddy Creek	1 site near the confluence with the French Creek	Peripheral to French Creek; status unknown
	Kanawha River	Elk River	Two freshly dead shells found in 2003 at one site	Status unknown; possibly extirpated
TOTALS	7 populations	10 streams	2 populations in 5 streams recruiting	

H.2.3 Fat Pocketbook Baseline Status

Since 1970, the fat pocketbook has been collected from the St. Francis River, Right Hand Chute Little River, drainage ditches associated with these streams in Arkansas and Missouri, the lower Wabash and White Rivers in Indiana, the lower Cumberland and Ohio Rivers in Kentucky, and the upper Mississippi River. In 2003, individuals were also collected from a secondary channel in the lower Mississippi River, Mississippi, and the lower White River in Arkansas (Pers. comm., Chris Davidson, USFWS, Conway, AR; Joe Krystofik, USFWS, Augusta, AR). The strongest populations still occur in the St. Francis drainage of Arkansas and Missouri; however, due to their persistence since listing, several other populations are also believed to be viable.

Several fat pocketbook mussels have been collected from the middle Mississippi River in Kentucky (R. Cicerelo, pers. comm., 2004). During the 1990s, the species was documented from Gilliam Chute of Rodney Lake (a cutoff of the Mississippi River), Jefferson County, and St. Catherines Creek near its confluence with the Mississippi River in Adams County, Mississippi (MMNS records). The fat pocketbook continues to persist in Gilliam Chute (R. Jones, Mississippi Museum of Natural Science (MMNS), pers. comm., 2004); however, no live animals or fresh shells have been recently collected from St. Catherines Creek, and the species may have been eliminated by a severe drought in 2000 (Hartfield, 2002).

In October 2003, the MMNS notified the Service of the collection of fresh dead fat pocketbook shells from the State’s Shipland Wildlife Management Area (approximately Mississippi River

Mile (MRM) 485). On October 28 and 30, 2003, cursory surveys of the main and secondary channels were conducted between MRM 481-489 by Service personnel. River stage was low, approximately eight (8) feet on the Vicksburg gauge. The area is a long bend of the Mississippi River, with the main channel running along the west bank, and vegetated sand “islands” separating a large low water secondary channel along the east bank. The secondary channel is dissected by dikes (raised rock levees usually constructed perpendicular to the bank) in the Ben Lomond and Ajax Dike Fields. Survey efforts resulted in the collection of one (1) live fat pocketbook, along with 14 fresh dead, and several weathered dead shells of this species. Most fat pocketbook shells were collected on or immediately below the dikes in the secondary channel, including three on Ben Lomond Dike 1L, one on Ben Lomond Dike 2L, four on Ajax Dike 1, and one between Ajax Dike 2L and Ajax 1. The live fat pocketbook was found in the secondary channel in gravelly sand along the upstream face of Ajax Dike 1 (MRM ~482.5). A single fresh dead individual was collected from the main channel side of the island between Ben Lomond Dikes 3 and 4. On the dikes where they occurred, fat pocketbook mussels composed 9 to 50% of the native mussels collected. However, native mussels were generally rare on all dikes examined.

On November 4 and 21, 2003, personnel of U.S. Army Engineer Research and Development Center (ERDC) conducted mussel surveys in the Baleshed, Ben Lomond, and Ajax Dike complexes within this reach of the Mississippi River (Payne and Miller, 2004). ERDC was unable to locate any evidence of the fat pocketbook. Based on their previous experience with the species in the St. Francis floodway of Arkansas,they concluded that there was little suitable habitat for the fat pocketbook in the project area. Although ERDC biologists believe that the backwater depositional pools appear to be more suitable habitat for the fat pocketbook, their surveys of these areas failed to locate any evidence of the species.

In Arkansas, the fat pocketbook has been collected only once from the White River since the 1960’s. Its present distribution in Arkansas includes the St. Francis River and its tributaries and the lower White River. Based upon extensive surveys, the known range of the fat pocketbook includes approximately 200 miles in the St. Francis drainage (Jenkinson and Ahlstedt 1994). A quantitative survey of the work area estimated a population of 874±1,748 individuals in the reach located 1,900 meters to 3,800 meters downstream of Highway 69 (Dunn and Lee 2003). It should be noted that this estimate was based on the collection of only one live individual during quantitative sampling and is almost certainly an overestimate of the actual population. However, at least fifteen live fat pocketbooks were recorded in Craighead and Poinsett Counties, Arkansas during qualitative surveys and by casual observation (pers. comm., Leighann Gipson, USACE 2003; Dunn and Lee 2003). .

A survey of the population in the work area near Madison, Arkansas resulted in a population estimate of approximately 116 individuals (Harris 2003). Water levels in the St. Francis River near Madison, Arkansas, fluctuate greatly and have a large impact on the resident mussel fauna. Drought or near drought conditions in recent years have caused mortality of great numbers of mussels in this area (Bill Posey, Arkansas Game and Fish Commission, personal communication). This dewatering restricts mussel communities to the deepest portions of the channel that remain within the wetted portion of the channel year round.

H.3: REFERENCES

Allan, J.D. 1995. Stream ecology: structure and function of running waters. Chapman and Hall, London, JK. xii + 388 p.

Anderson, R. 2007. USFWS. Personal communication with U.S. EPA. (July 17, 2007)

Armour, C.L., D.A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16(1):7-11.

Augspurger, T., A.E. Keller, M.C. Black, W.G. Cope, and F.J. Dwyer. 2003. Derivation of water quality guidance for protection of freshwater mussels (Unionidae) from ammonia exposure. Environmental Toxicology and Chemistry.

Baker, F.C. 1928. The fresh water Mollusca of Wisconsin, Part 2: Pelecypoda. Bull. Univ. Wisconsin 1527 (1301): vi + 495 p. + 77 pl.

Brim Box, J. and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. J.N. Amer. Benthol. Soc. 18(1):99-117.

Cicerelo, R. 2004. Kentucky Nature Preservation Commission. Frankfort, KY. Personal communication with USFWS.

Davidson, C. 2004. USFWS, Conway, AR. Personal communication with USFWS.

Dunn, H. and J. Lee. 2003. Unionid survey of Ditch 10, Craighead and Poinsett Counties, Arkansas. Final report to U.S. Army Corps of Engineers, Memphis District. Ecological Specialist, Inc., O'Fallon, MO. Report # 03-026.

Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17(1):29-42.

Gipson, L. 2003. USACE, Memphis District. Personal communication with USFWS.

Harris, J. L. 2003. Biological assessment of *Potamilus capax* (Green, 1832) fat pocketbook. Union Pacific Railroad Bridge Replacement near Madison, AR.

Hartfield, Emily. 2002. A mussel survey of St. Catherine Creek National Wildlife Refuge. U.S. Fish and Wildlife Service. Jackson, MS.

Havlik, M.E. and L.L. Marking. 1987. Effects of contaminants on naiad mollusks (Unionidae): a review. U.S. Dept. Interior, Fish and Wildlife Service, Resource Publication 164. Washington, D.C. ii + 20 p

Henley, W.F., M.A. Patterson, R.J. Neves, and A.D. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs: a concise review for natural resource managers. Reviews in Fishery Science 8(2):125-139.

Jenkinson, J.J. and S.A. Ahlstedt. 1994. A search for additional populations of *Potamilus capax* in the St. Francis and Cache River watersheds, Arkansas and Missouri, U.S.A. Walkerana 7(17/18):71-157.

Johnson, P.M., A.E. Liner, S.W. Golladay, and W.K. Michener. 2001. Effects of drought on freshwater mussels and instream habitat in Coastal Plain tributaries of the Flint River, southwest Georgia (July-October, 2000). Unpublished report, by the Jones Ecological Research Center for The Nature Conservancy, Tallahassee, Florida. 45 pp.

Jones, Robert. 2004. Mississippi Museum of Natural Science. Jackson, MS. Personal communication with USFWS.

Judy, R.D., Jr., P.N. Seeley, T.M. Murray, S.C. Svirsky, M.R. Whitworth, and L.S. Ischinger. 1982. National fisheries survey. Volume I. Technical report: initial findings. Unpublished report, U.S. Fish and Wildlife Service Report No. FWS/OBS-84/06, Washington DC.

Kanehl, P., and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Wisconsin Department of Natural Resources Research Report 155. 32 pp.

Krystofik, J. 2004. USFWS, Augusta, AR. Personal communication with USFWS.

Marking, L.L., and T.D. Bills. 1979. Acute effects of silt and sand sedimentation on freshwater mussels. Pp. 204-211 *in*: J.R. Rasmussen, ed. Proceedings of the UMRCC symposium on Upper Mississippi River bivalve mollusks. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Neves, R.J. 1993. A state-of-the unionid address. Pp. 1-10 *in*: K.S. Cummings, A.C. Buchanan, and L.M. Koch, eds. Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium, October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Newton, T., J. O'Donnell, M. Bartsch, L.A. Thorson, and B. Richardson. 2003. Effects of un-ionized ammonia on juvenile unionids in sediment toxicity tests.

Unpublished report, Ellipsaria 5(1):17.

Ortmann, A.E. 1918. The nayades (freshwater mussels) of the upper Tennessee drainage with notes on synonymy and distribution. Proceedings of the American Philosophical Society 77:521-626.

Payne, Barry S. and A. C. Miller. 2004. Evaluation of two dike fields in the lower Mississippi River for the endangered mussel, *Potamilus capax*.

Posey, B. 2004. Arkansas Game and Fish Commission. Personal communication with USFWS.

Sparks, B.L. and D.L. Strayer. 1998. Effects of low dissolved oxygen on juvenile *Ellipitio complanata* (Bivalvia: Unionidae). J.N. Amer.Bentol. Soc. 17(1):129-134.

Stansbery, D.H. 1971. Rare and endangered molluscs in the eastern United States. Pp. 5-18 *in*: S.E. Jorgensen and R.W. Sharpe, eds. Proceedings of a Symposium on Rare and Endangered Mollusks (Naiads) of the United States, April 1971, Columbus, Ohio. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Trimble, S.W., and A.C. Mendel. 1995. The cow as a geomorphic agent: a critical review. Geomorphology 13:233-253.

U.S. Fish and Wildlife Service. 1989a. Recovery plan for the fat pocketbook pearly mussel *Potamilus capax* (Green 1832). U.S. Fish and Wildlife Service. Atlanta, Georgia. 22pp.

U.S. Fish and Wildlife Service. 1989b. Biological Opinion for the proposed replacement of Kennerdell Bridge (S.R. 3008, Section B00), located over the Allegheny River in Clinton and Rockland Townships, Venago County, Pennsylvania. Prepared for the Federal Highway Administration. U.S. Fish and Wildlife Service, Pennsylvania Field Office, State College,Pennsylvania. 32 pp.

U.S. Fish and Wildlife Service. 1998a. Biological Opinion of the Replacement of the Utica Bridge over French Creek (S.R. 3017, Section B00), Venango County, Pennsylvania. U.S. Fish and Wildlife Service, Pennsylvania Field Office, State College, Pennsylvania. 28 pp.

U.S. Fish and Wildlife Service. 1998b. Biological Opinion of the Replacement of the Bicycle Bridge over the Tippecanoe River, Carroll County, Indiana. U.S. Fish and Wildlife Service, Indiana Field Office, Bloomington, Indiana. 10 pp.

U.S. Fish and Wildlife Service. 1999. Biological opinion on the impacts of forest Management and other activities to the bald eagle, Indiana bat, clubshell and northern riffleshell on the

Allegheny National Forest, Pennsylvania. U.S. Fish and Wildlife Service, Pennsylvania Field Office, State College, Pennsylvania. 87 pp.

U.S. Fish and Wildlife Service. 2001. Biological Opinion, Replacement of the Foxburg Bridge over the Allegheny River (S.R. 0058, Section 150), Armstrong and Clarion Counties, Pennsylvania. Prepared for the Federal Highway Administration. U.S. Fish and Wildlife Service, Pennsylvania Field Office, State College, Pennsylvania. 30 pp.

U.S. Fish and Wildlife Service, 2002a. Letter to Mr. Randal Looney at the Federal Highway Administration, Arkansas Division from Margaret Harney, Acting Field Supervisor dated 10/31/2002.

U.S. Fish and Wildlife Service. 2002b. Biological Opinion, Impacts of the Sugarcreek Borough Pipeline Stabilization Project on the Northern Riffleshell and Clubshell. Prepared for Sugarcreek Borough, Venango County. U.S. Fish and Wildlife Service, Pennsylvania Field Office, State College, Pennsylvania. 23 pp.

U.S. Fish and Wildlife Service 2003a. Letter to Colonel Jack V. Scherer at the U.S. Army Corps of Engineers dated 6/10/2003.

U.S. Fish and Wildlife Service 2003b. Letter to Colonel Jack V. Scherer at the U.S. Army Corps of Engineers dated 10/29/2003.

U.S. Fish and Wildlife Service 2003c. Biological opinion, Replacement of the Hickory Street Bridge Over the Allegheny River (S.R. 3005, Section B00), City of Warren, Warren County, Pennsylvania. U.S. Fish and Wildlife Service, Pennsylvania Field Office, State College, Pennsylvania. 52 pp.

U.S. FWS 2004a. Letter to Colonel Frederick L. Clapp, Jr. at the U.S. Army Corps of Engineers Dated 3/22/2004

U.S. FWS 2004b. Letter to Colonel Jack V. Scherer at the U.S. Army Corps of Engineers dated 4/28/2004.

U.S. Fish and Wildlife Service. 2004c. Biological Opinion, Effects of the West Hickory and Mill Village Bridge Replacements over the Allegheny River and French Creek on the Clubshell and Northern Riffleshell, Forest and Erie Counties, Pennsylvania. U.S. Fish and Wildlife Service, Pennsylvania Field Office, State College, Pennsylvania. 54 pp.

U.S. FWS 2007. Draft of Five Year Review for Northern Riffleshell from Robert Anderson U.S. FWS on 7/17/07.

U.S. Geological Survey. 2002. Summary report on monitoring of freshwater mussels relocated from the direct impact areas of the bridge at Kennerdell on the Allegheny River and the bridge at Utica on French Creek. U.S. Geological Survey, Kearneysville, WV. 26 pp.

Vannote, R.L. and G.W. Minshall. 1982. Fluvial processes and local lithology controlling abundance, structure, and composition of mussel beds. Proc. Natl. Acad. Sci. USA 79(13):4103-4107.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7. 251 pp

Widdows, J., P. Fieth, and C.M. Worrall. 1979. Relationships between seston, available food, and feeding activity in the common mussel *Mytilus edulis*. Marine Biology 50:195-207.

Yeager, M.M., D.S. Cherry, and R.J. Neves. 1994. Feeding and burrowing behaviors of juvenile rainbow mussels, *Villosa iris* (Bivalvia: Unionidae). Journal of the North American Benthological Society 13(2):217-222.