A SURVEY OF FRESHWATER MUSSELS (MOLLUSCA: BIVALVIA: UNIONIDAE) AT KINGS HYDROELECTRIC PROJECT LOCATED ON THE WISCONSIN RIVER NEAR TOMAHAWK, WISCONSIN

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INTRODUCTION

Tomahawk Power and Pulp Company operates the Kings hydroelectric project located at Wisconsin River mile (WRM) 320.6, 2.3 miles E of the City of Tomahawk, Lincoln County, Wisconsin. The impoundment, known as Lake Alice, extends upstream to the downstream edge of Menard Island (WRM 329.0). Two tributary streams enter the Wisconsin River between Lake Alice and the Hat Rapids dam (WRM 337) which is the next dam upstream of Lake Alice. Trout Creek enters at WRM 328.9 and Noisy Creek enters at WRM 335. An upstream paper mill and municipal wastewater treatment plant, located at Rhinelander (WRM 340), discharge significant quantities of wastewater.

The Federal Energy Regulatory Commission (FERC) requires Tomahawk Power and Pulp Company to submit a dam license application for continued project operation. As part of this application, wildlife, fishery and botanical resources must be described and evaluated in consultation with the Wisconsin Department of Natural Resources (WDNR). This document presents results of a portion of this evaluation with emphasis on the inventory of Wisconsin state listed endangered, threatened and special concern freshwater mussels and uses a river system approach to evaluate findings. Freshwater mussels were selected as a group of concern because

1) they are long lived species and therefore significant indicators of environmental change and are regarded as good environmental biomonitors because of their sensitivity to environmental changes.
2) of the 54 taxa recorded from the state, the WDNR (1992) lists 17 as state or federally threatened or endangered. General aquatic studies often overlook this group while special inventories and assessments provide

better information needed to meet state and federal management goals of species preservation and recovery.

3) they are easily irretrievably eradicated from waterbodies because of their environmental sensitivity, low reproductive rates, inability to avoid environmental changes, extremely low recolonization rate, complex life cycle and inability to recolonize past biological barriers (dams, lacustrine habitats, inhospitable waterbodies).

In addition to the objective of listed mussel evaluation, I present the thesis that several mussel species that once occurred in and near the Kings dam hydroelectric project and are now extirpated. Suitable habitat now exists. To support this thesis the following elements were investigated:

1)Physical evidence suggests that the Hat Rapids to Lake Alice reach supported more species of mussels than it does now

2)Poor water quality until 1977 probably caused the extirpation of these species.

3)Improved water quality conditions since 1977 provides restored mussel habitat.

4)Existing physical habitat in this reach seems excellent

5)The presence and operation of dams and impoundments which serve as biological barriers and the small intervening time since water quality improvements probably explains the lack of full mussel recovery.

METHODS

A total of 6 sites were sampled in and near the Kings project area during June, August and September 1992. Site locations were chosen in order to evaluate the potential effect of the project on mussel distribution. One site

was located immediately downstream of the dam (WRM 320.4). Another site was located within the impoundment (WRM 320.6 to 328). The remaining 4 sites were located upstream of the upstream end of Lake Alice and downstream of Hat Rapids dam (WRM 329.2, 329.4 and 333.5). Two of the upstream sites were located in streams tributary to the Wisconsin River: Trout Creek and Noisy Creek (Trout Creek mile 2, Noisy Creek mile 1). Sampling methods followed the ENDANGERED, THREATENED AND SPECIAL CONCERN AQUATIC INVERTEBRATE SURVEY GUIDELINES FOR WISCONSIN FERC PROJECTS (Appendix 1).

RESULTS AND DISCUSSION

No state or federally threatened or endangered freshwater mussels were found of the 435 living and 90 dead mussels collected. A total of 13 mussel taxa (7 living, 6 dead) was recorded of which three are state special concern species (Table 1). These three special concern species are Anodonta imbecillis, Lasmigona compressa, and Alasmidonta marginata. One special concern (A. marginata) and five other taxa were found dead only (Table 1).

Although population densities were not measured, they seemed surprisingly low. Both upstream and downstream of the Kings project, I visually estimated a population density of less than 1 mussel per m^2. Population densities were so low that incremental collections (see APPENDIX 1) were not completed at 4 of the 6 sampling locations: downstream of Kings dam, Lake Alice, Trout Creek and Noisy Creek. Ideal physical habitat was seen except in Lake Alice. Adequate current was present. Substrate was a mix of rubble, gravel and coarse sand. In other rivers in northern Wisconsin, this type of substrate often supports 20 mussels per m^2.

I would expect to see low population densities in small Wisconsin streams

like Trout and Noisy creeks but these low densities in medium and large-sized streams like the Wisconsin River are unexpected especially where suitable physical habitat occurs. In other upstream sections of the Wisconsin River, population densities and species richness are much higher than near the Kings project. Heath (1992) estimated that about 5 to 8 mussels per m^2 occurred upstream and downstream of the Rainbow Flowage dam (WRM 365.2), substantially higher than near the Kings project.

Not only population density but species richness was lower near the Kings project than expected and compared to upstream sites. A total of 13 taxa were collected living around Rainbow Flowage while only 6 survived near Kings (Figure 1). This observed reduction in species richness contradicts the generally accepted idea of higher richness downstream and lower upstream (Baker, 1927). The Kings and Rainbow dams are only 45 miles apart and one should expect at least the same or greater number of species at Kings as was found at Rainbow.

Interestingly, evidence of the former presence at Kings of 6 of these 7 missing species was collected. Subfossil shells of A. p. plicata, L. ventricosa, L. recta, A. l. carinata, A. marginata and L. costata were found either in a terrestrial shell midden located on the upstream end of Menard Island or in the stream bottom or both. No evidence of the seventh species, S. u. undulatus, was found at Kings. It probably occurred here and did not appear in the small subfossil sample.

Based on this evidence, analysis of habitat and interpolations from Figure 1, it is probable or known that A. p. plicata, L. ventricosa, S. u. undulatus, A. l. carinata, L. recta, Pleurobema sintoxia, Elliptio dilatata, L. costata

and A. marginata occurred between Lake Alice and the Hat Rapids dam and that suitable physical habitat presently occurs there.

Habitat fragmentation from dams and impoundments and historic low water quality caused by discharges from the paper mill located upstream at Rhinelander may explain the present absence of these species. Unfavorable water quality characteristics, particularly low dissolved oxygen (DO), high biochemical oxygen demand (BOD) and luxuriant growth of Sphaerotilus natans (Monera: bacteria) is suspected to have eliminated some species. Habitat fragmentation, caused by presence of hydroelectric dams and their impoundments, has prevented recolonization by upstream and downstream populations.

Several studies indicate various minimum DO levels for mussel reproduction, growth, habitation and survival. Imlay (1971) found that 2.5 ppm of DO at normal summer water temperatures was required by several riffle species for survival. Amblema p. plicata, viewed by most malacologist as a highly tolerant pool dwelling species, survived for 10 weeks at 0 DO. Imlay found that most species tested required 6 ppm for normal growth. Ellis (1931b) noted that mussels became inactive when DO was less than 20% of saturation. Grantham (1969) found no living mussels where DO occasionally dropped to 3 ppm while Ellis (1931a) suggested that no mussels could survive below 5 ppm.

Damage to mussel populations from general wood products wastes have been reported. Ortmann (1918) reported a decimated mussel fauna downstream of a wood extracting plant in the Powell River, Virginia. Mackie and Qadri (1973) found mussels limited by wastes from a pulp mill on the Ottawa River, Canada. Heard (1970) reported all flora and fauna completely destroyed for 15 miles downstream of a paper mill on the Fenholloway River, Florida.

The conditions adverse to freshwater mussels described above have been recorded from the Wisconsin River in the Vicinity of the Kings project. The Wisconsin State Board of Health (1927) noted significant water pollution between Tomahawk and the paper mill at Rhinelander during July through November 1926. This study demonstrated "...an immediate decrease of dissolved oxygen and an increase in the solids and oxygen consumed values..." downstream of Rhinelander and "...the dissolved oxygen continues to decrease to Tomahawk". Minimum DO ranged from 2.25 ppm to 7.5 ppm. Monthly means varied from 3.9 to 7.5 ppm. These means were always lower downstream of Rhinelander compared to upstream. Data from 1973-1976 (WDNR, 1977) indicates that from the paper mill at Rhinelander downstream 10 miles, DO was often lower than 3 ppm. At the Hat Rapids dam, 30% to 50% of DO measurements were lower than 3 ppm. It appears that both the 1926 and 1970's DO data show that Wisconsin Rivers water quality conditions are a reasonable cause for the extirpation of the 9 mussel species around the Kings project.

DO values have increased for the same stream segment from 1977 through 1991. Mean DO was 8.08 ppm (N=308) with no measurements less than 3, which had occurred during the earlier two periods (Storet). A minimum DO of 4.4 ppm occurred in 1977. A total of 14 records (4.5 %) were below the 5.0 ppm state standard, and 50 (16.2%) were lower that 6.0 ppm, nearly all of which occurred during 1977. It appears that DO levels have improved and may be acceptable for freshwater mussel survival and adequate for mussel growth and reproduction.

Since BOD and the subsequent low DO in the receiving waters is a primary paper mill pollutant (Morton, 1976) and since DO levels have improved since 1977, one would expect recovered freshwater mussel populations near the Kings

project. This is especially true since populations of all 9 extirpated species occur both upstream and downstream of the Kings project (Figure 1). Mussel populations have not completely recovered. I propose this is due to habitat fragmentation caused by the presence and operations of Kings dam and other nearby hydroelectric dams and their impoundments.

Fuller (1980) demonstrated the cessation of reproduction of 2 mussel species caused by upstream host fish migration interruption from the construction of a dam on the Mississippi River. Because the Kings dam has to provisions from fish passage, upstream movement of larval mussels on host fish would be nearly impossible. If some fish do move upstream, to carry the appropriate mussel larvae they would have had to bypass several downstream dams during the mussel parasitic period on a host fish, generally 2 to 6 weeks. This is a very unlikely scenario. Even if this should occur, the juvenile mussel would have to be deposited in appropriate non-lacustrine environmental conditions and have several other co-deposited juveniles nearby with which to reproduce and establish a viable population. Even if this unlikely series of events should occur, its frequency through time is so low that viable target mussel populations are unlikely to establish in the next 50 years.

Another possible recolonization conduit would be movement downstream of mussels from populations located upstream of the Rhinelander impoundment. Fuller (1974) demonstrated that impoundments themselves serve as barriers to riverine freshwater mussel habitation. All of the 9 extirpated species are primarily riverine. To recolonize from upstream, a larval mussel and its host fish would have to pass through the Rhinelander impoundment and hydroelectric dam, the Hat Rapids flowage and hydroelectric dam. The survival of a host fish

through these two hydroelectric facilities is not ensured because of the dangers of turbine mortality. If the larval mussel is deposited in either impoundment, its survival is highly questionable. Additionally, the same minimum population size requirements and temporal constraints seen from potential upstream movement apply to downstream movement.

CONCLUSIONS

1)No state or federally threatened or endangered freshwater mussels were found in the 435 living and 90 dead mussels from the vicinity of the Kings project. A total of 13 mussel taxa (7 living, 6 dead) was recorded of which three are state special concern species.

2)Population densities and species richness around Kings are low compared to largely unaffected upstream control locations near the Rainbow Flowage.

3)Evidence of the former occupation of 9 presently locally extirpated mussel species was found near the Kings project.

4)Historically low water quality is the likely explanations for the loss of these 9 species from Kings.

5)Habitat fragmentation from dams and associated impoundments is the most likely explanation for the lack of recolonization of these 9 extirpated species.

6)Aquatic habitat (DO, physical microhabitat) appear adequate for occupation of these 9 extirpated species.

7)Reintroduction of the locally extirpated mussel species would be the only way to mitigate the adverse effects of the project which act as a recolonization barrier. Normal mussel diversity is possible only if stocking efforts are attempted in the near future.

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TABLE 1.TAXONOMIC LIST OF FRESHWATER MUSSELS FOUND AT THE KINGS PROJECT. (*= STATE OF WISCONSIN SPECIAL CONCERN SPECIES)

PHYLUM MOLLUSCA (Linne, 1758) Cuvier, 1797	
CLASS BIVALVIA Linne, 1758 (after Bonnani, 1681)	
ORDER UNIONOIDA Stoliczka, 1871	
FAMILY UNIONIDAE (Fleming, 1828) Ortmann, 1911	
* *Anodonta imbecillis* Say, 1829	living and dead
Anodonta grandis form *grandis* Say, 1829	living and dead
Anodontoides ferussacianus (Lea, 1834)	living and dead
* *Alasmidonta marginata* Say, 1818	dead only
Lasmigona complanata (Barnes, 1823)	living and dead
**Lasmigona compressa* (Lea, 1829)	living and dead
Lasmigona costata (Rafinesque, 1820)	dead only
Amblema plicata plicata (Say, 1817)	dead only
Fusconaia flava (Rafinesque, 1820)	living and dead
Actinonaias ligamentina carinata (Barnes, 1823)	dead only
Ligumia recta (Lamarck, 1819)	dead only
Lampsilis siliqoidea (Barnes, 1823)	living and dead
Lampsilis ventricosa (Barnes, 1823)	dead only

TABLE 2.ABUNDANCE AND LIST OF MUSSELS FOUND IMMEDIATELY DOWNSTREAM OF THE KINGS DAM AT WRM 320.4, T35N, R6E, Sec. 25 SE of SW and SW of SE. (* = STATE OF WISCONSIN SPECIAL CONCERN SPECIES).

	# living	% Rel. Abun.	# dead
******A. imbecillis*			2**
A g. f. grandis	42	73.7	4
A. ferussacianus			
******A. marginata*			
L. complanata			
L. costata			
******L. compressa*			
A. p. plicata			
F. flava			
A. l. carinata			
L. recta			
L. siliqoidea	15	26.3	7
L. ventricosa			1
TOTAL	57	100.0	14

**= found freshly dead and probably occurs here living.

TABLE 3.ABUNDANCE AND LIST OF MUSSELS FOUND IN LAKE ALICE, WRMS 320.6 TO 328, T34N, T35N, R7E, R6E. (* = STATE OF WISCONSIN SPECIAL CONCERN SPECIES).

	# living	% Rel. Abun.	# dead
******A. imbecillis*			
A g. f. *grandis*			
A. ferussacianus			
******A. marginata*			
L. complanata			
L. costata			
******L. compressa*			
A. p. plicata			
F. flava			
A. l. carinata			
L. recta			
L. siliqoidea			
L. ventricosa			
TOTAL	0		0

TABLE 4.ABUNDANCE AND LIST OF MUSSELS FOUND UPSTREAM OF LAKE ALICE AT MENARD ISLAND AND CAMP TEN, WRMS 329.2, 329.4 AND 333.5, T35N, R7E, Sections 1, 12 and T36N R8E Section 4. (* = STATE OF WISCONSIN SPECIAL CONCERN SPECIES).

	# living	% Rel. Abun.	# dead
******A. imbecillis*	1	0.4	2
A g. f. *grandis*	178	75.4	1
A. ferussacianus	3	1.3	
******A. marginata*			2
L. complanata	27	11.4	
L. costata			8
******L. compressa*	3	1.3	
A. p. plicata			3
F. flava	11	4.7	
A. l. carinata			15
L. recta			9
L. siliqoidea	13	5.5	4
L. ventricosa			12
TOTAL	236	100.0	56

TABLE 5.ABUNDANCE AND LIST OF MUSSELS FOUND AT TROUT CREEK MILE 2 (T35N R7E. Section 3), A TRUBUTARY STREAM TO THE WISONCISN RIVER UPSTREAM OF LAKE ALICE (* = STATE OF WISCONSIN SPECIAL CONCERN SPECIES).

	# living	% Rel. Abun.	# dead
******A. imbecillis*			
A g. f. *grandis*	1		
A. ferussacianus	2		
******A. marginata*			
L. complanata			
L. costata			
******L. compressa*			
A. p. plicata			
F. flava			
A. l. carinata			
L. recta			
L. siliqoidea			
L. ventricosa			
TOTAL	3		

TABLE 6.ABUNDANCE AND LIST OF MUSSELS FOUND NOISY CREEK MILE 1.0 (T35N, R8E, Section 2), UPSTREAM OF LAKE ALICE. (* = STATE OF WISCONSIN SPECIAL CONCERN SPECIES).

	# living	% Rel. Abun.	# dead
******A. imbecillis*			
A g. f. *grandis*	7	5.0	2
A. ferussacianus	107	77.0	
******A. marginata*			
L. complanata	12	8.6	
L. costata			
******L. compressa*			
A. p. plicata			
F. flava			
A. l. carinata			
L. recta			
L. siliqoidea	13	9.4	
L. ventricosa			
TOTAL	139	100.0	

APPENDIX 1

ENDANGERED, THREATENED AND SPECIAL CONCERN AQUATIC INVERTEBRATE SURVEY GUIDELINES FOR WISCONSIN FERC PROJECTS

Compiled by the Wisconsin Department of Natural Resources (Nov. 1991).

I. Identify state and federal endangered, threatened and special concern species that may be present based on historic records and zoogeography. The Natural Heritage Inventory Program of the WDNR Bureau of Endangered Resources in Madison or the FERC Endangered Resources Coordinator can help provide this information. This preliminary species screening will provide a list of anticipated bird species.

II. Record all field and laboratory data on standard survey forms. These data should include: date, exact location (to quarter of quarter section), habitat description (include substrate, current, water and air temperature), USGS quadrangle name, county, copy of map with location that contains listed species, number of listed invertebrates observed, any evidence of threats to population, name of taxon, whether or not specimens were collected, and the museum at which specimens were deposited.

III. Conduct field survey at times of the year and day and under conditions when animals or their remains are likely to be present and are the most easily identified. For most insects, this would be during May and June prior to emergence or during the hatching time if exuviae are collected. If more than one listed species is potentially present and are most easily identified at different times of the year, the project will have to be surveyed multiple times during the year.

IV. The survey should be conducted using a qualified invertebrate zoologist who is familiar with local fauna and can recognize listed and common invertebrates in the field.

V. All invertebrates should be identified to species where possible and those that are of uncertain identification and could be listed species should be preserved using standard techniques for later laboratory identification. One voucher specimen of each listed fish species should be kept for museum deposition if its removal will not permanently harm the population.

VI. Any listed species observed incidentally should be recorded.

VII. Secure any endangered resource or Scientific Collectors permits that are needed. Contact WDNR Bureau of Endangered Resources, Madison Wisconsin.

VIII. **Additional Survey Guidelines for Aquatic Insects.**

1). For the collection of nymphs and other listed aquatic

invertebrates, a net of mesh size appropriate for target organisms should be used. A 3/16" or 1/8" bar mesh should be used for odonates. Smaller (500 or 600 microns) should be used for smaller invertebrates. Hand picking of rocks is needed for some insects (some coleoptera, tricoptera).

2).Kick net samples should be taken in a number of different microhabitats but microhabitats that are preferred for listed species should be sampled the most. A total of at least 200 members of each listed group (dragonflies, mayflies etc.) should be collected if possible.

3).Samples of exuviae are the easiest way to sample and provide the most information per unit effort. This method should be use where ever possible and should be done at the time of the year and under conditions that exuviae are present. The entire shoreline of the tailwater from the dam downstream 2 miles and at least 5% of the suitable habitat of the reservoir shoreline should be searched. Emergence time of each listed species that could be potentially present should be taken into account when designing a survey. In addition, previous weather conditions that do affect exuviae preservation should be considered. For example, exuvial samples should not be collected during August for a species that emerges in early June and should not be surveyed for immediately after a rain storm or high water which destroys exuviae.

IX.**Additional Survey Guidelines for Mussels.**

1).The entire shoreline of the reservoir should be surveyed for shell accumulations. The entire shoreline of the tailwater extending from the dam downstream 2 miles should be thoroughly searched. These shoreline searches should be conducted during low or normal water levels to ensure that shell remains are not inundated.

2).Collections of living and dead mussels using SCUBA, snorkeling gear or wading should be done within the reservoir and tailwater. The technique used depends on water conditions. Within each of the tailwater and reservoir, at least three sampling stations should be established based on results of the shoreline surveys. Within each station, mussels should be

gathered incrementally. Incremental collections are defined as collections of mussels off all species present in groups of 20 individuals. The collection of all mussel species as opposed to just collecting listed species, will provide community information. It will also assure that specimens are identified to the species level out of the water where it is easier that making identifications underwater. Mussels should be gathered at a station until a plateau of six points is reached when the cumulative number of mussels is plotted against the cumulative number of species for each station. Exceptions to this amount of collection effort include: a) the total absence of any mussels and b) the inability to secure the required amount of specimens in one-half person day of collecting effort.

3).During both shoreline and in-stream collecting, any living or dead mussels or any other listed species should be noted if observed incidentally.

4).All listed mussels should be measured by total length, total height and externally aged. Gravidity should be determined by examination of the marsupia. The purpose of collecting this information is to collect data on presence or absence of reproduction to determine population viability.

APPENDIX1

SUMMARY

The Kings hydroelectric project, licensed by the FERC (Federal Energy Regulatory Commission) is located in northcentral Wisconsin on the Wisconsin River, Lincoln County. Using a river system approach, a freshwater mussel survey (Mollusca: Bivalvia: Unionidae) was conducted in waterbodies surrounding Kings to evaluate project operations on benthos and to determine presence or absence of endangered or threatened species. A total of 13 mussel taxa (7 living, 6 dead) was recorded including three state special concern species (Anodonta imbecillis, Lasmigona compressa, and Alasmidonta marginata). Mussel occurrence information from Kings was compared 320 Wisconsin River miles upstream and downstream of the project and locally collected subfossil shells. The river reach surrounding Kings showed much lower species richness and is presumed due to historic adverse water quality. Presence of dams have prevented reoccupation of missing species into areas with improved water quality by fragmenting habitat. My major management recommendation is the active reintroduction of nine presently absent species near Kings.