The Freshwater Mussel Fauna (Bivalvia: Unionidae) of the Knife River, Minnesota, Following a Rotenone Treatment

Rick A. Hart and Tim Brastrup
Minnesota Department of Natural Resources
Division of Fisheries, Brainerd, MN 54601 USA

Daniel E. Kelner
Minnesota Department of Natural Resources
Division of Ecological Services, St. Paul, MN 55155 USA
and
Mike Davis
Minnesota Department of Natural Resources
Division of Ecological Services, Lake City, MN 55041 USA

ABSTRACT

In October 1989, the Minnesota Department of Natural Resources (MNDNR), treated the Knife River, its tributaries, and Knife Lake with rotenone to eliminate rough fish in the system. At the time of the treatment it was believed that the rotenone application would not have an adverse impact upon the mussel fauna. Therefore, a pre- and post-treatment survey of the mussel community was not immediately conducted. During 1999 the MNDNR initiated a statewide mussel survey program which included a mussel survey of the Knife River in 2000. Nine sites along the Knife River were surveyed by divers who collected over 900 live and dead mussels, including 17 live species. Catch per unit effort for live mussels was similar in the Knife River when compared to other streams in the same drainage. None of the collected mussel species was represented by dead shells only, indicating no species were lost. Individuals from several of the species were greater than 10 years of age, indicating that they were present prior to rotenone treatment. Mussels less than 10 years of age were also collected, indicating that successful reproduction has occurred since the rotenone application. These results suggest that the mussel species that inhabited the Knife River before the rotenone treatment are still present and comparatively similar in abundance to other streams throughout the drainage.

INTRODUCTION

Large carp (*Cyprinus carpio*) populations usually degrade the aquatic environment in which they live. In feeding near the bottom they commonly roil the water, making it unfavorable for plant growth, fish, and fish food organisms. Carp notoriously destroy aquatic vegetation, compete for benthic food, interfere with spawning, and frequently crowd out other fishes (Calhoun 1966).

According to Magnuson (1976), Moyle (1986), and Courtenay and Robbins (1989), exotic fishes such as carp occasionally became more deleterious than beneficial and required control. Because of the damage that they do it is often important to control carp in aquatic ecosystems. Control methods include the use of fish toxicants, introduction of predator fishes, and mechanical means such as netting, water level manipulation, screens and electric weirs. Chemical control (Lennon et al. 1970, Eschmeyer 1975, Schnick et al. 1986) is the favored control method of 60% of state and provincial conservation agencies (Kohler and Hubert 1999).

During October 1989, The MNDNR treated Knife Lake, Minnesota, and the Knife River tributary system above the Knife Lake dam with a synergized, emulsified rotenone formulation to eliminate carp. Rotenone was applied at a concentration of 3.5 mg/l. Through subsequent fish sampling it was determined that carp as well as other fish

species were successfully eliminated. While concern for molluscs originated during pre-treatment planning and environmental review, it was believed that there was no existing potential for mussel mortality resulting from rotenone toxicity. According to Schnick (1974), rotenone formulations were not generally toxic to mussels, and in fact mussels were reported to be quite tolerant to rotenone treatments.

Unfortunately, in this particular case, mussel surveys were not conducted before the rotenone treatment to test this assumption. This lack of pre-treatment data would normally make it impossible to determine the long term effects of a rotenone treatment on affected organisms. Fortunately, unionid mussels leave a legacy of their existence. Parmalee and Bogan (1998) have shown that mussel shells may remain in place on a river or lake bed long after the living species have been extirpated from the water body. Therefore, we were able to determine if species were lost between the pre- and post-mussel assemblages of the Knife River by collecting both live and dead mussels 11 years after the rotenone treatment. We were also able to compare the general mussel abundance to similar streams in the same drainage that were not treated with rotenone. This approach allowed us to quantify whether or not there was a change in the number of mussel species in the affected areas of the Knife River.

METHODS

During June 2000, freshwater mussels were sampled from the Knife River, Minnesota, by divers using either snorkeling or scuba gear. Nine sample sites were selected by identifying access points (e.g., canoe landings, bridge crossings, etc.). Local resource agency personnel and landowners were also contacted about where potential mussel communities may exist. Cursory investigations were conducted at each site prior to sampling by searching the stream banks for empty shells. Sites were distributed from the rivers headwaters to its mouth and were spaced no more than 3 km apart.

To accurately assess mussel community structure, timed searches were conducted, spending two person hours searching at each site (Obermeyer 1998). Divers were instructed to examine all microhabitats found within each survey site. All mussels, both those live and dead, encountered were placed in mesh bags until the end of the search period. Specimens were identified, measured for maximum shell length (anterior-posterior axis), and aged by counting external annuli (Neves and Moyer 1988). Mussels were then assigned to one of four age groups; 1-5, 6-10, 11-15, and >15 years of age. This method of aging mussels may underestimate age (Neves and Moyer 1988); however, with few exceptions, annuli on shells in this study were well defined. We are confident our data give us a reasonable indication of the age structure of the community, assuming that growth rest lines are formed annually (see Downing et al. 1992). Catch per unit effort (CPUE) was calculated as the number of individuals collected divided by the time in minutes spent searching for mussels. Mussel nomenclature follows Turgeon et al. (1998). Voucher specimens were reposited into the mollusk collection at the James Ford Bell Museum, University of Minnesota.

RESULTS AND DISCUSSION

Nine hundred eighty-one unionid mussels representing 17 species were collected from nine sites along the Knife River, MN (Table 1). Live mussels were collected from all of the survey sites. Collection effort totaled 18 person hours, resulting in an average CPUE of 54.5 ± (16.4 SE) (range 4.5 - 153.0) mussels per hour. This CPUE falls within the range of other streams surveyed for mussels in the same drainage system using the same methods (MNDNR unpublished data). Individual mussels collected ranged from less than five to greater that 15 years of age (Table 2). A large number of individual mussels representing several species were collected at most sites. The large number of species and the relatively high CPUE, combined with the high numbers of older

individuals (those >10 years), indicate that many mussels survived the rotenone treatment and are still living in the river today.

Lampsilis siliquoidea and *Fusconaia flava* were the dominant mussels species collected among all of the sites, representing 29.0 and 15.5% of the total number of individuals collected, respectively (Table 1). Both of these species were represented by many individuals older than ten years of age which would indicate that they would have been present during the rotenone treatment (Table 2). These two species were followed in abundance by *Pyganodon grandis* which represented 13.5% of the mussels collected. The population of *P. grandis* residing in the Knife River was comprised entirely of individuals under 11 years of age. The high abundance of young *P. grandis* could be due to this species ability to use a wide range of fish hosts (Watters 1994) allowing it to more readily recolonize an area if eliminated.

Four additional relatively short lived mussel species (*Anodontoides ferussacianus*, *Lasmigona compressa*, *Strophitus undulatus*, and *Utterbackia imbecillis*) were also dominated by individuals younger than 10 years of age (Table 2). As with *P. grandis*, the low number of older individuals in the populations of these species in the Knife River is most likely a consequence of their natural life history traits (Baker 1928) rather than these species having been adversely affected by the rotenone treatment. Regardless, if short lived species were adversely affected by the rotenone treatment, it appears they have successfully recolonized their former habitats within the stream.

Two mussel species (*Actinonaias ligamentina* and *Alasmidonta marginata*) that were collected are currently listed as threatened in the state of Minnesota (MNDNR 1996). These two species represented only 1.8 and 1.3% of the mussel assemblage within the Knife River, respectively. While these species were rare in the Knife River, they probably have been for many decades as large numbers of dead shells of either of these species were not collected, indicating that they were probably not abundant prior to the rotenone treatment. Consequently, it appears that these two species were not greatly affected by the rotenone treatment. The majority of *A. ligamentina* and *A. marginata* that

Table 1. Occurrence of dead and living mussel species collected from the Knife River, Minnesota, 2000. Numbers in the table are live mussels found. X = found dead only.

		Site Number									
Species	Number of Individuals	1	2	3	4	5	6	7	8	9	Total
Actinonaias ligamentina	Number live						1		11	6	18
Alasmidonta marginata	Number live				1				12		13
Amblema plicata	Number live							43	2	1	46
Anodontoides ferussacianus	Number live	8	38	16		4	11				77
Elliptio dilatata	Number live			61	4						65
Fusconaia flava	Number live			57	16	35	43		1		152
Lampsilis cardium	Number live			6		14	27	X	21	8	76
Lampsilis siliquoidea	Number live		16	82	6	50	90	12	18	10	284
Lasmigona complanata	Number live								1		1
Lasmigona compressa	Number live		3			1					4
Lasmigona costata	Number live			X	4	5	6		1	2	18
Leptodea fragilis	Number live							4	4	2	10
Ligumia recta	Number live								3	4	7
Potamilus alatus	Number live							1	2	1	4
Pyganodon grandis	Number live	1	18	80		4	15	12	2		132
Strophitus undulatus	Number live		2	2	3	39	14	1	X		61
Utterbackia imbecillis	Number live			2			11				13
Total		9	77	306	34	152	218	73	78	34	981

Table 2. Occurrence and age distribution of mussels collected from the Knife River, Minnesota, 2000.

Species	Age Distribution	Number of Individuals	Species	Age Distribution	Number of Individuals
Actinonaias ligamentina	Age <1-5	1	*Lasmigona compressa*	Age <1-5	1
	Age 6-10	2		Age 6-10	3
	Age 11-15	8		Age 11-15	0
	Age >15	7		Age >15	0
	Total	18		Total	4
Alasmidonta marginata	Age <1-5	0	*Lasmigona costata*	Age <1-5	0
	Age 6-10	5		Age 6-10	7
	Age 11-15	8		Age 11-15	9
	Age >15	0		Age >15	2
	Total	13		Total	18
Amblema plicata	Age <1-5	0	*Leptodea fragilis*	Age <1-5	0
	Age 6-10	3		Age 6-10	3
	Age 11-15	15		Age 11-15	4
	Age >15	28		Age >15	3
	Total	46		Total	10
Anodontoides ferussacianus	Age <1-5	42	*Ligumia recta*	Age <1-5	0
	Age 6-10	24		Age 6-10	1
	Age 11-15	0		Age 11-15	6
	Age >15	0		Age >15	0
	Total	77[a]		Total	7
Elliptio dilatata	Age <1-5	8	*Potamilus alatus*	Age <1-5	0
	Age 6-10	33		Age 6-10	0
	Age 11-15	19		Age 11-15	2
	Age >15	5		Age >15	2
	Total	65		Total	4
Fusconaia flava	Age <1-5	19	*Pyganodon grandis*	Age <1-5	61
	Age 6-10	47		Age 6-10	71
	Age 11-15	50		Age 11-15	0
	Age >15	36		Age >15	0
	Total	152		Total	132
Lampsilis cardium	Age <1-5	5	*Strophitus undulatus*	Age <1-5	12
	Age 6-10	18		Age 6-10	48
	Age 11-15	22		Age 11-15	1
	Age >15	32		Age >15	0
	Total	76		Total	61
Lampsilis siliquoidea	Age <1-5	127	*Utterbackia imbecillis*	Age <1-5	10
	Age 6-10	90		Age 6-10	3
	Age 11-15	66		Age 11-15	0
	Age >15	3		Age >15	0
	Total	284		Total	13
Lasmigona complanata	Age <1-5	0			
	Age 6-10	0			
	Age 11-15	1			
	Age >15	0			
	Total	1			

[a] Only 66 of the 77 *Anodontoides ferussacianus* collected were aged due to logistic problems.

were collected were greater than 10 years of age (Table 2). Populations of long-lived mussel species dominated by older individuals have been recorded in other streams in Minnesota (Hart 1999, MNDNR unpublished data), and this is probably a natural phenomenon in these and other long-lived organisms residing in stable habitats (Sibly and Calow 1986).

Five of the seventeen mussel species that we collected from the Knife River were found only inhabiting the river downstream of the dam at sites 7-9 in the reach not treated with rotenone (Table 1). No live or dead specimens of *Amblema plicata*, *Lasmigona complanata*, *Leptodea fragilis*, *Ligumia recta*, or *Potamilus alatus* were collected from any of the sites above the dam (sites 1-6), indicating that they most likely have not inhabited the upstream reaches of the river in recent history. The absence of these species in the upstream reaches of the river is most likely the result of the dam itself (Watters 1996, Parmalee and Bogan 1998), which has been present in some form since the 1800's.

The immediate and short term impacts of the rotenone treatment on the mussel fauna were not measurable; furthermore, there is no known data that document the pre-rotenone treatment mussel fauna of the Knife River, MN. However, the lack of extirpated species, along with the fact that many mussels older than 15 years of age were collected, indicate that the mussel fauna present before the rotenone treatment is most likely still intact.

ACKNOWLEDGEMENTS

We thank the landowners adjacent to the Knife River who graciously allowed us access to survey sites. We also thank Stephanie Sherraden and Stan Triebenbach for field assistance in the collection of mussels. We thank the editor and two anonymous reviewers for their helpful comments on an earlier draft of this manuscript. Funding for this research was approved and supported in part by the Minnesota Legislature, 1999 Minnesota Laws, Ch. 23, Sec. 16, Subd15(a), as recommended by the Legislative Commission on Minnesota Resources from the Minnesota Environment and Natural Resources Trust Fund.

LITERATURE CITED

Baker, F. C. 1928. The freshwater Mollusca of Wisconsin, Part II Pelecypoda. Madison, Wisconsin.

Calhoun, A., editor. 1966. Inland fisheries management. California Department of Game and Fish.

Courtenay, W. R., Jr. and C. R. Robbins. 1989. Fish introductions: good management, mismanagement, or no management? Chemical Rubber Critical Reviews in Aquatic Sciences1:159-170.

Downing, W. L., J. Shostell, and J. A. Downing. 1992. Non-annual external annuli in the freshwater mussels *Anodonta grandis grandis* and *Lampsilis radiata siliquoidea*. Freshwater Biology 28:309-317.

Eschmeyer, P. H., editor. 1975. Rehabilitation of fish populations with toxicants: a symposium. American Fisheries Society, North Central Division, Special Publication 4, Bethesda, Maryland.

Hart, R. A. 1999. Population dynamics of unionid mussels in Lake Pepin, Upper Mississippi River, Minnesota and Wisconsin. Ph.D. thesis. North Dakota State University, Fargo, North Dakota.

Kohler, C. C. and W. A. Hubert, editors. 1999. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Lennon, R. E., J. B. Hunn, R. A. Schnick, and R. M. Burress. 1970. Reclamation of

ponds, lakes, and streams with fish toxicants: a review. FAO (Food and Agriculture Organization of the United Nations) Fisheries Technical Paper 100.

Magnuson, J. J. 1976. Managing with exotics-a game of chance. Transactions of the American Fisheries Society 105:1-9.

MNDNR. 1996. Minnesota's list of endangered, threatened, and special concern species. Minnesota Department of Natural Resources. Division of Ecological Services.

Moyle, P. B. 1986. Fish introductions in North America: patterns and ecological impact. Pages 22-43 in H. A. Mooney and J. A. Drake, editors. Ecology of biological invasions of North America and Hawaii. Springer-Verlag, New York.

Neves, R. J. and S. N. Moyer. 1988. Evaluation of techniques for age determination of freshwater mussels (Unionidae). American Malacological Bulletin 6:179-188.

Obermeyer, B. K. 1998. A comparison of quadrats versus timed snorkel searches for assessing freshwater mussels. American Midland Naturalist 139:331-339.

Parmalee, P. W. and A. E. Bogan. 1998. The freshwater mussels of Tennessee. The University of Tennessee Press, Knoxville, Tennessee.

Schnick, R. A. 1974. A review of the literature on use of rotenone in fisheries. United States Fish and Wildlife Service Literature Review 74-15. NTIS (National Technical Information Service) PB-235/AS, Springfield Virginia, USA.

Schnick, R. A., F. P. Meyer, and D. L. Gray. 1986. A guide to approved chemicals in fish production and fishery resource management. University of Arkansas, Cooperative Extension Service Bulletin MP-241, Little Rock.

Sibly, R. M. and P. Calow. 1986. Physiological ecology of animals: an evolutionary approach. Blackwell, London.

Sousa, R. J., F. P. Meyer, and R. A. Schnick. 1985. Better fishing through management. How rotenone is used to help manage our fishery resources more effectively. USDI, Fish and Wildlife Service.

Turgeon, D. D., J. F. Quinn, Jr., A. E. Bogan, E. V. Coan, F. G. Hochberg, W. G. Lyons, P. M. Mikkelsen, R. J. Neves, C. F. E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F. G. Thompson, M. Vecchione, and J. D. Williams. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks, 2nd edition. American Fisheries Society, Special Publication 26, Bethesda, MD.

Watters, G. T. 1994. An annotated bibliography of the reproduction and propagation of the Unionoidea (primarily of North America). Ohio Biological Survey Miscellaneous Contributions. 1:1-158.

Watters, G. T. 1996. Small dams as barriers to freshwater mussels (Bivalvia, Unionidae) and their hosts. Biological Conservation 75:79-85.

Received: 15 January 2001

Accepted: 13 May 2001