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Translocation and Maintenance of Unionid Bivalves to Mitigate Impacts of Infestation Caused by the Zebra Mussel

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Abstract

Unionids were held in cages suspended in nearshore waters of western Lake Erie to determine the potential of *in situ* translocation and maintenance (i.e., periodic cleaning) as a method to increase survival of unionids threatened by zebra mussel infestation. Survival of unionids not cleaned (i.e., uncleaned) of zebra mussels (n=24) and unionids cleaned (n=24) of zebra mussels was determined during eight periods ranging between 21- and 77-day intervals from 5 July 1990 to 3 July 1991. After one year, survival of uncleaned unionids was 0%, whereas survival of cleaned unionids was 42%. Of the 10 species examined, only three (Amblema p. plicata, Fusconaia flava, and Quadrula quadrula) survived translocation one year after collection. These species are the relatively thick, non-~~ornate shelled~~ sculptured species. Maintenance of unionids may be important to survival because a large proportion (98%) of the zebra mussels removed after initial cleaning were young, small mussels (<10 mm long) that could rapidly grow and impact unionids. Survival of translocated, cleaned unionids was comparable to that of earlier published studies. At present, the removal of zebra mussels from unionids is the only technique successfully shown to mitigate impacts of infestation on unionids *in situ*. This and other untested techniques will be needed if mitigation of infested unionid populations is to succeed in North America.

(1)

Introduction

Shortly after the introduction and dramatic increase in densities of zebra mussels (Dreissena polymorpha) in the Laurentian Great Lakes in the mid- to late-1980s, there was major concern about the impacts on native unionids (Bivalvia: Unionidae) (Hebert et al. 1989; Schloesser and Kovalak 1991). Zebra mussels are epizoic on hard-bodied invertebrates including snails, crayfish, and especially unionid bivalves (Figure 1) (Lewandowski 1976; Nalepa and Schloesser 1993). Concerns were warranted because zebra mussel infestation has threatened the existence of unionid populations in the Great Lakes (Gillis and Mackie 1994; Nalepa 1994; Schloesser and Nalepa 1994).

In early 1992, a workshop was held to determine possible ways to mitigate impacts of zebra mussel infestation on unionids in North America (Zebra mussel infestation on unionids in North America; DWS, unpublished minutes). Translocation of unionids to areas where zebra mussels are not found was believed to be one of the most viable and practical methods to mitigate zebra mussel infestation. However, translocation of unionids to areas without zebra mussels is likely to be a temporary mitigation technique because zebra mussels are expected to invade three-quarters of the surface waters in North America (Griffiths et al. 1991; Strayer 1991). Indeed, the most current strategy to mitigate impacts on unionids is to translocate and propagate unionids in artificial habitats, such as fish hatcheries (M. Talbot, unpublished mimeo, Upper Mississippi River Conservation Committee, Rock Island, Illinois; personal communications).

At present, there are no techniques to mitigate impacts of zebra mussel infestation on unionids in areas colonized by zebra mussels. One possible technique to increase unionid survival is periodic removal of zebra mussels from infested populations. This technique would maintain unionid populations in habitats where survival and reproduction has been demonstrated, thereby decreasing the need to maintain artificial habitats aimed at conserving bivalve species whose life history and propagation characteristics are not well known (Winter 1978; Newkirk 1980).

This study was conducted in waters infested by zebra mussels to determine the potential of unionid translocation and maintenance to mitigate the impacts on unionids in areas where zebra mussels are abundant. This procedure potentially will be valuable for management of unionids *in situ* wherever zebra mussels heavily infest unionids in waters throughout North America.

Methods

Unionids, infesting zebra mussels, and associated sediments were collected (ca. 3-m water depth) by SCUBA and suspended in cages (ca. 2.5-m water depth) in the forebay of a power plant intake canal in nearshore waters of western Lake Erie 5 July 1990 (Figures 2 and 3). Unionids were randomly divided into two treatment groups: uncleaned unionids with zebra mussels not removed and cleaned unionids with zebra mussels removed. Two randomly selected unionids of each group (i.e., uncleaned and cleaned) were placed in each of 12 cages. Stratification of impacts on individual unionid species could not be done because massive incrustation of shells prevented species identification. Each cage (22cm by 40cm; 5mm mesh screen) was lined with a plastic bag on the bottom to hold about 25 cm of Lake Erie sediments (primarily sand).

Cages were suspended for 363 days and lifted on eight sampling dates between 5 July 1990 and 3 July 3 1991 to determine survival of unionids and remove infesting zebra mussels from cleaned unionids (i.e., maintenance). Dead unionids and zebra mussels that colonized cleaned unionids were removed from cages 26 July, 5 September, 4 October, 1 November, and 13 December 1990 and 6 February, 17 April, and 3 July 1991. Number of days between sampling dates varied between 21 and 77. Zebra mussels were removed from 10 cleaned unionids collected 5 July 1990 and from live unionids on the eight sampling dates in 1990 and 1991. Mussels were preserved in 5% buffered ($CaCO_3$) formalin.

In the laboratory, zebra mussels were washed over a U.S. Standard Number 60 sieve (0.25-mm mesh opening), counted, and measured to the nearest millimeter. Zebra mussels smaller than 1-mm long were recorded as 1-mm individuals. Length-frequency distributions of zebra mussels removed from unionids were determined for each sampling date. Distributions were constructed from a randomly selected sub-sample (between 850 and 3,000 individuals) of mussels <6 mm long and all mussels >7 mm long for each sampling date. Distributions of unmeasured mussels <6 mm long were based on proportions of measured mussels <6 mm long in each whole millimeter size group. Total dry weights of mussels infesting cleaned unionids were determined by desiccation at 105 $^{\circ}$C for

48 h. Total lengths of unionids were determined after death of each individual or on termination of sampling when live unionids were sacrificed (i.e., 3 July 1991).

Identification of unionids was performed after zebra mussels were removed from shells at the beginning of maintenance (cleaned unionids, 26 July 1990) and when dead shells were removed from cages or when the study was completed (3 July 1991). Unionid nomenclature follows Turgeon et al. (1988) and Williams et al. (1993), with the exception of combining Lampsilis radiata radiata (Gmelin) and Lampsilis siliquoidea (Barnes) as Lampsilis siliquoidea (Barnes) because the range of these two species overlap and they have been shown to interbreed in the Great Lakes (Clarke 1981).

RESULTS

Survival of uncleaned unionids (0%) was lower than that of cleaned unionids (42%) 5 July 1990 to 3 July 1991 (Table 1; Figure 4). Thirty-three percent of uncleaned unionids died within the first 62 days of translocation and maintenance between 5 July and 5 September 1990. Eighty-three percent died by 4 October. By 13 December, no uncleaned unionids were alive. In contrast, cleaned unionids survived much longer than uncleaned unionids; all 24 (100%) cleaned unionids were live 91 days (until 4 October) after being suspended in cages, 20 (83%) survived 161 days, 17 (71%) survived 216 days, and 10 (42%) survived until the end of sampling (363 days).

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Three species, Amblema p. plicata, Fusconaia flava, and Quadrula quadrula, survived longer than other species (Table 2). Ten of 22 individuals (45%) of these three taxa survived 363 days in cages, whereas none of the 26 individuals of seven other taxa survived. Of the 10 uncleaned species, only A. p. plicata and F. flava were present 91 days after being caged. The last uncleaned specimen that died between 11 November and 13 December was an A. p. plicata. Of the 6 cleaned species, 5 were alive 216 days and 3 (A. p. plicata, F. flava, and Q. quadrula) were alive 363 days after translocation and maintenance was initiated.

In general, numbers and weights of infesting mussels on cleaned unionids fluctuated as a result of small mussels either settling out of the water column as young-of-the-year or movement of small mussels onto unionids (Table 3). Unionids removed from nearshore waters of western Lake Erie were infested by an average of 614 mussels/unionid weighing 17.3 g/unionid 5 July 1990. Numbers of infesting mussels removed from cleaned unionids increased from 0/unionid 5 July 1990 to 25/unionid 26 July. Between 26 July and 5 September 1990, an additional 624/unionid were removed, and between 5 September and 4 October, an additional 827/unionid were removed. Infestation decreased between 4 October 1990 and 6 February 1991 and increased between 6 February and 3 July 1991.

Weights of colonizing mussels between 26 July 1990 and 3 July 1991 were low compared to the initial infestation rate (17.3 g/unionid) 5 July 1990 (Table 3). About 98% of the total mussels (4706) removed from cleaned unionids between 26 July 1990 and 3 July 1991 were less than 10 mm long; 1% were 11 to 15 mm long, and only 17 (< 1%) were greater than

15 mm. Large numbers of small mussels were found in September, October, and November 1990 and July 1991.

Discussion

Results indicate that the removal of zebra mussels from infested unionids increases the survival of unionids *in situ* in waters infested with zebra mussels. No uncleaned unionids survived. In addition, near total mortality of unionids occurred throughout most of western Lake Erie and in the area where unionids were collected during the time this study was conducted (Schloesser and Nalepa 1994; DWS, unpublished data). All studies conducted to date indicate that unionids exposed to zebra mussel infestation for a period of two to four years show near total mortality (Gillis and Mackie 1994; Nalepa 1994; Schloesser et al. In review). However, this study indicates that translocated and maintained/cleaned unionids had a survival of 42%.

This study and others have shown that individual unionid species have varying susceptibility to impacts of zebra mussel infestation (Hunter and Bailey 1992; Haag et al. 1993;Gillis and Mackie 1994; Tucker 1994). Data suggest that species with heavy, non-ornate shells that are short-duration brooders are more resistant to impacts of mussel infestation than species that have thin, ornate shells and are long-term brooders (Haag et al. 1993). Unfortunately, there are data from only a few species and sites that support generalities of different susceptibility of species to infestation. Haag et al. (1993) showed that energy reserves of the infested long-term brooder *Lampsilis radiata* (*L.*

siliquoidea) were lower in females than males. In addition, energy reserves in the short-term brooder Amblema p. plicata were relatively high compared to L. siliquoidea. Other studies attribute faster mortality of thin, ornate shelled species (e.g., L. siliquoidea) as compared to thick, non-ornate shelled species (e.g., A. p. plicata) to species stability in sediments and ability to burrow (Gillis and Mackie 1994; Tucker 1994). In general, data support conclusions that subfamilies of Lampsilinae and Anodontinae are more susceptible and the subfamily Ambleminae is less susceptible to infestations.

Periodic removal of zebra mussels in the present study is believed to have contributed substantially to the survival of cleaned unionids. Between sampling periods, cleaned unionids became infested by large numbers of mussels on four of eight sampling dates. However, a large proportion of mussels were relatively small, and weights of mussels were consistently lower than initial weights (i.e., 5 July 1990) by a factor greater than 4. If mussels were not periodically removed, infesting mussels could grow and become a larger proportion of the unionid's weight and filter a larger proportion of food otherwise available to unionids. The extent to which newly settled mussels contribute to unionid mortality was not determined in this study. In the Great Lakes, unionid mortality does not occur in the first year of heavy infestation (e.g., > 5,000 mussels/m^2 of substrate: Ricciardi et al. In press; Schloesser et al. In review; unpublished data) when most zebra mussels are small (e.g., < 8mm long) (Hebert et al. 1989, 1991; Schloesser and Kovalak 1991; Masteller et al. 1993).

Survival of translocated and maintained unionids (42%) is within the range of survival rates reported for other translocation studies where zebra mussels were not present (Sheehan et al. 1989; Cope and Waller 1993; Havlik 1994). However, survival rates in earlier studies are difficult to assess because they have been inadequately assessed and generally documentation occurred only for successful programs (Ahlstedt 1979; Sheenhan et al. 1989; Cope and Waller 1993). For example, in most translocation studies, unionids were not confined, and the fate of unfound specimens during assessments of survival often was not documented, leading to inaccurate survival and mortality estimates (Sheehan et al. 1989).

Translocation, maintenance, and artificial propagation of unionids *in situ* was first initiated in North America in response to unionid depletion as a result of the commercial pearl button industry started in the late 1800s (Lefevre and Curtis 1910; Coker et al. 1922; Howard 1923). These early programs were phased out by the mid-1930s, and few studies were conducted until the mid-1970s when translocation programs were initiated to save unionid beds from pollution and construction projects. At present, translocation of unionids is rarely attempted and is primarily used to mitigate construction projects and pollution abatement, culture for commercial and exhibit industries, and re-establish species under state and federal endangered species programs (e.g., Ahlstedt 1979; Sheehan et al. 1989; Havlik 1994). The present study indicates that the translocation of unionids to mitigate impacts of zebra mussel infestation is likely to become another reason for translocation programs.

Survival of cleaned unionids in this study (42%) is probably underestimated because of substantial differences between habitats in which unionids were collected and to which they were translocated and maintained for one year. Unionids were translocated from a high energy wave habitat in western Lake Erie and maintained in a uniform unidirectional flowing (i.e., 1 m/second) habitat. This was done because waves in western Lake Erie would have destroyed cages used to hold unionids. Unpublished data suggest that careful selection of donor and recipient translocation habitats can minimize translocation mortality to <10% (Havlik 1994; personal communication, D. Neves, Virginia Polytechnic Institute, Blacksburg, Virginia). To date, few data exist on survival of unionids that are removed and replaced in the same habitat, but since habitat appears to be critical for survival of translocated unionids, the technique of maintaining unionids in the presence of zebra mussel may increase survival of unionids more than translocating them to habitats where no zebra mussels occur.

In addition to habitat differences, the use of heavily infested unionids in the present study may have contributed to mortality of cleaned unionids. Unionids were exposed to heavy infestation for three years (1989-1991) before collection and translocation (Schloesser and Kovalak 1991). Heavy infestations have been shown to reduce fitness (i.e., energy reserves) and increase stress (i.e., cellulase enzyme activity) of host unionids in as little as 120 days (Haag et al. 1993).

The unionid population in the vicinity where unionids were collected showed some mortality in 1990, and by 1993, they were nearly extirpated (DWS, unpublished data). Therefore, survival rates of artificially maintained and possibly wild populations of unionids may be greater than the 42% in the present study if unionids are cleaned of zebra mussels before heavy infestations and resulting impacts begin to occur.

To date, the best indicator that removal of zebra mussels is needed to mitigate impacts of infestation on unionids is the number of infesting zebra mussels after mussel spawning and the visual observation that the entire posterior portions of unionids exposed to the water column are covered by zebra mussels (Figure 1 ; reviewed in Schloesser et al. In review). Massive numbers of young zebra mussels covering exposed unionids were observed in Lake Balaton in the 1930s immediately before unionid mortality (Sebestyen 1938). In the Great Lakes, heavy infestations after mussel spawning (>1,000/unionid) have been observed in Lake St. Clair, the Detroit River, and western and eastern Lake Erie about one to three years before near complete mortality of unionids occurred (Gillis and Mackie 1994; Nalepa 1994; Schloesser and Nalepa 1994; unpublished data). Similar infestations are beginning to be observed in major rivers of North America (Tucker et al. 1993; Blodgett et al. 1994; Schloesser et al. In review).

The zebra mussel, which poses a threat to unionid survival in North America, has renewed interest in the overall conservation of unionids and in the techniques of translocation, maintenance, and artificial propagation of unionids to mitigate impacts of zebra mussels

(DWS, 1992 workshop minutes; M. Talbot, unpublished mimeo, Upper Mississippi River Conservation Committee, Rock Island, Illinois; Stolzenburg 1992). Results of the present study indicate that translocation and maintenance of unionids *in situ* is a viable technique to mitigate impacts of infestation, especially since increased survival has been shown in the most heavily colonized zebra mussel waters ever recorded (Schloesser and Kovalak 1991; Nalepa and Schloesser 1993). Therefore, the translocation and maintenance of unionids *in situ* will be important to the conservation of unionids wherever high infestation of unionids by zebra mussels occures in North America.

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FIGURES

Figure 1. Relatively low (top photo; <50/unionid) and heavy (bottom photo; >1,000/unionid) infestation intensity of a unionid mollusk (Pyganodon grandis) by zebra mussels. Heavy infestation intensity has been shown to result in mortality of unionids. (Schloesser and Kovalak 1991).

Figure 2. Locations where unionids, infesting zebra mussels, and sediments were collected in western Lake Erie (i.e., XXX), and where caged unionids were placed in the forebay of a power plant intake canal (i.e., shaded area) in nearshore waters of western Lake Erie 5 July 1990.

Figure 3. Two uncleaned (i.e., with zebra mussels attached) and two cleaned (i.e., without zebra mussels attached) unionids in a cage suspended in near shore waters of western Lake Erie.

Figure 4. Numbers of live uncleaned (i.e., with attached zebra mussels) and cleaned (i.e., without attached zebra mussels) unionids in cages suspended in near shore waters of western Lake Erie 5 July 1990 to 3 July 1991.

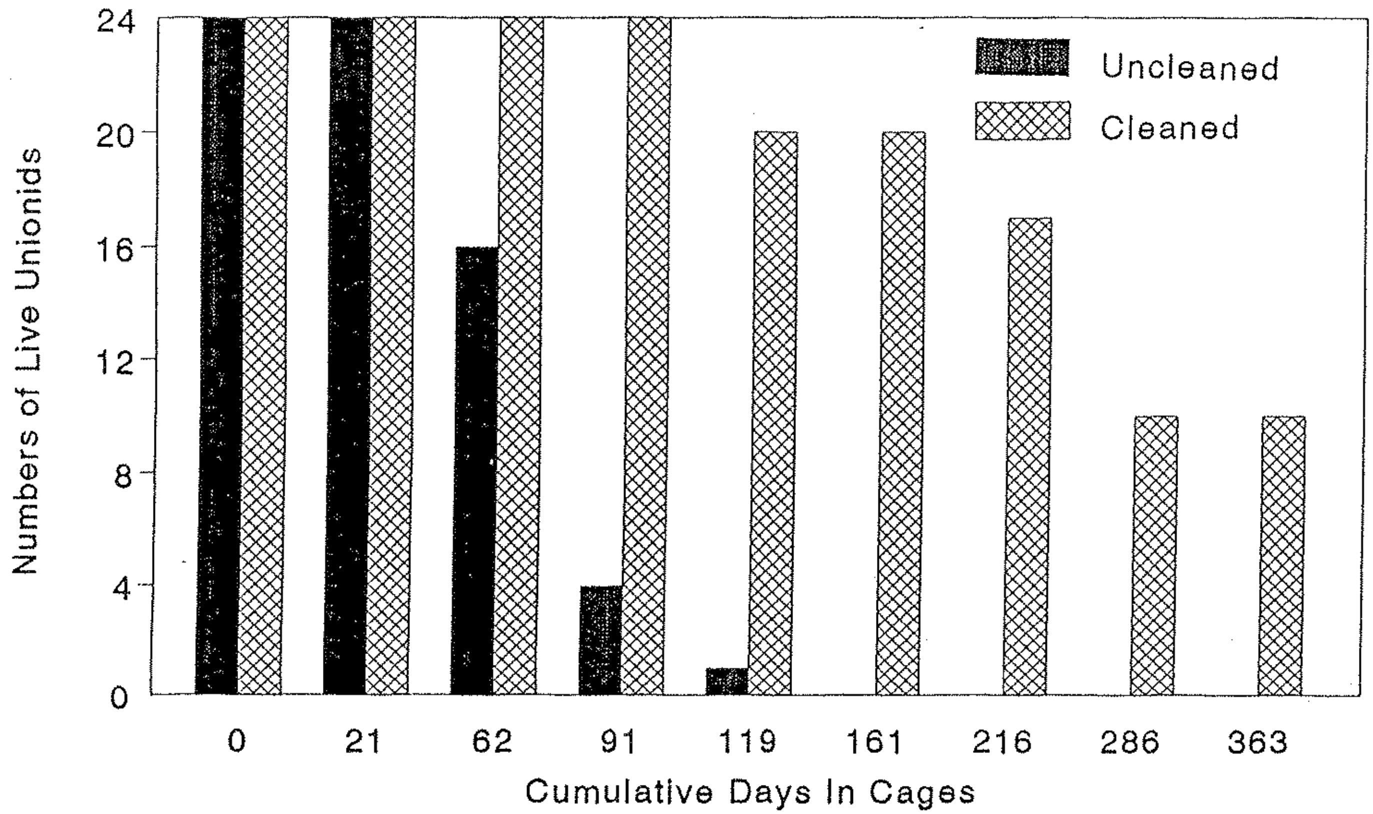
Uncleaned
Cleaned
Numbers of Live Unionids
24
20
16
12
8
4
0
0
21
62
91
119
161
216
286
363
Cumulative Days In Cages

Figure 4

Table 1. Numbers and (±S.E) length mean of live uncleaned and cleaned unionids suspended in nearshore waters of western Lake Erie 5 July 1990 to 3 July 1991.

	Cumulative Days Between Sampling	Live Unionids Uncleaned	Live Unionids Cleaned
1990			
5 July	-	24	24
26 July	21	24	24
5 September	62	16	24
4 October	91	4	24
1 November	119	1	20
13 December	161	0	20
1991			
6 February	216	0	17
17 April	286	0	10
3 July	363	0	10
Mean (±S.E.) length (mm)		70 ± 3.0	71 ± 3.1

Table 2. Numbers of live uncleaned and cleaned unionid species suspended in nearshore waters of western Lake Erie 5 July 1990 to 3 July 1991. Number of cumulative days between dates in parentheses.

	1990						1991		
	5 July (0)	26 July (21)	5 Sept (62)	4 Oct (91)	11 Nov (119)	13 Dec (161)	6 Feb (216)	17 April (286)	3 July (363)
Uncleaned									
Amblema p. plicata	3	3	2	2	1	0	0	0	0
Fusconaia flava	4	4	2	1	0	0	0	0	0
Lampsilis siliquoidea	8	8	6	0	0	0	0	0	0
Quadrula quadrula	1	1	1	0	0	0	0	0	0
Quadrula p. pustulosa	1	1	0	0	0	0	0	0	0
Elliptio complanata	2	2	1	0	0	0	0	0	0
Potamilus alatus	1	1	1	0	0	0	0	0	0
Leptodea fragilis	2	2	2	0	0	0	0	0	0
Obovaria olivaria	1	1	1	1	0	0	0	0	0
Pyganodon grandis	1	1	0	0	0	0	0	0	0
Total	24	24	16	4	1	0	0	0	0
Cleaned									
Amblema p. plicata	7	7	7	7	7	7	7	5	5
Fusconaia flava	5	5	5	5	5	5	5	3	3
Lampsilis siliquoidea	6	6	6	6	4	4	1	0	0
Quadrula quadrula	2	2	2	2	2	2	2	2	2
Quadrula p. pustulosa	3	3	3	3	2	2	2	0	0
Elliptio complanata	1	1	1	1	0	0	0	0	0
Total	24	24	24	24	20	20	17	10	10

Table 3. Length-frequency distributions (number/unionid) and mean number and dry weight (g) of zebra mussels per unionid removed from cleaned unionids suspended in nearshore waters of western Lake Erie 5 July 1990 to 3 July 1991. Number of cumulative days in parentheses.

	1990						1991		
Length (mm)	5 July (0)	26 July (21)	5 Sept (62)	4 Oct (91)	1 Nov (119)	13 Dec (161)	6 Feb (216)	17 April (286)	3 July (363)
1	<1	<1	228	262	250	42	<1	2	2400
2	5	<1	151	165	43	18	<1	1	5
3	24	<1	56	150	47	34	<1	2	6
4	42	<1	59	108	89	31	<1	2	6
5	62	<1	44	78	56	31		3	7
6	86	2	39	24	33	15		3	5
7	85	3	5	18	8	6		3	4
8	83	5	5	11	7	8		2	3
9	78	5	6	5	6	3		1	5
10	56	3	7	1	2	1		<1	7
11	38	2	5	1	<1	<1		<1	4
12	23	1	5	<1	<1	<1		<1	6
13	13	1	5	<1				<1	4
14	9	<1	5	<1					4
15	4		6	<1	<1	<1			4
16	2	<1	1	<1	<1			<1	2
17	<1		<1	<1				<1	1
18	<1		<1	<1					1
19	<1		<1		<1			<1	
20			<1		<1				<1
21	<1								
22				<1	<1				
23									
24	<1								
25									
26									
27	<1								
28	<1								
x Number/ unionid	614	25	624	827	544	190	1	22	2473
x Weight/ unionid	17.3	0.6	1.7	2.4	2.2	1.3	<0.1	0.4	3.7