Reestablishing the Freshwater Unionid Population of Metzger Marsh, Lake Erie

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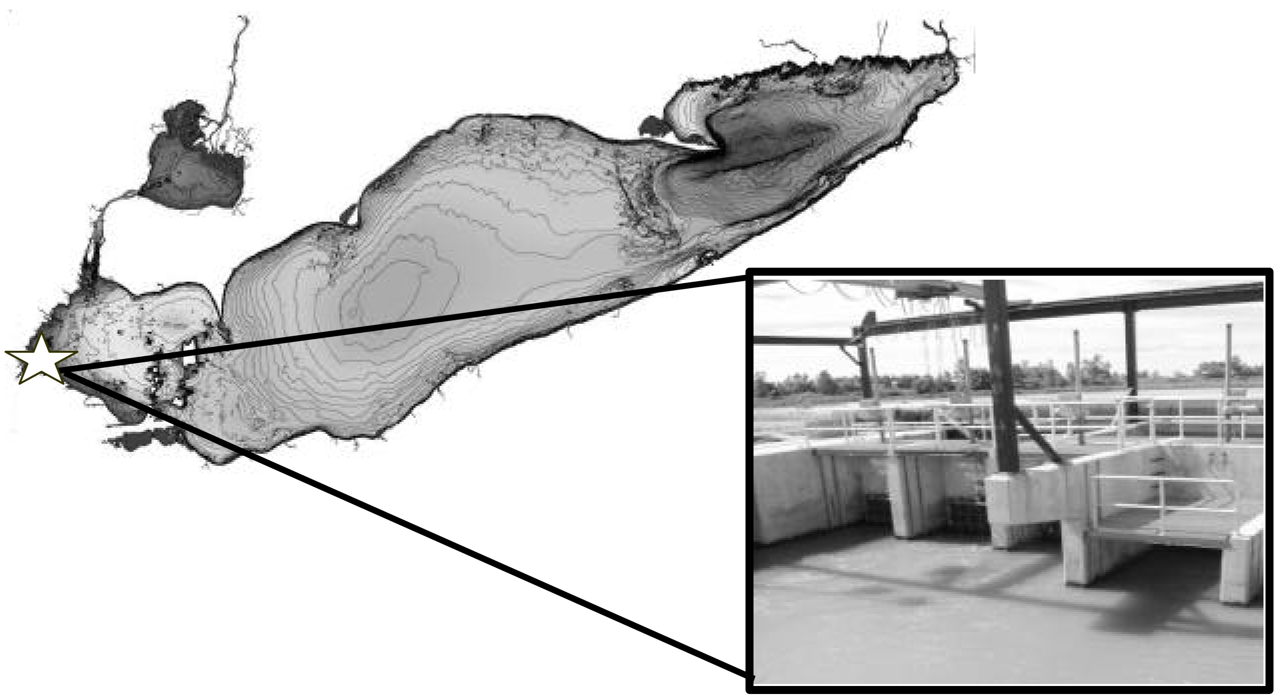


INTRODUCTION

One of the most devastating ecological problems resulting from the recent invasion of North America by zebra mussels *(Dreissena polymorpha)* has been the virtual elimination of native clams or unionids from infested waters. Zebra mussels readily colonize clam shells, disrupting feeding, movement, and reproduction. Clams generally die within 1-2 years after infestation. This die-off has been well-documented in the Great Lakes (Schloesser and Nalepa, 1994; Schloesser et al. 1996), with near total mortality reported throughout most of western Lake Erie. However, in 1996, we discovered a large population of native clams in a western Lake Erie wetland, Metzger Marsh, that showed little sign of infestation despite zebra mussel colonization of the site since about 1990.

Metzger Marsh is a lake-connected wetland located 32 km east of Toledo, Ohio. Prior to 1940, portions of this 367-ha site were diked, actively farmed, and then abandoned and allowed to revert back to wetlands (Figure 1). The wetland embayment was protected from storm activity by a barrier beach, which gradually eroded as sediment supply decreased due to progressive armoring of the shoreline of the lake. By 1990, much of the original wetland had also eroded. In 1994, a consortium of federal, state, and private organizations joined forces to restore the wetland and provide improved habitat for fish and wildlife. A dike was constructed across the opening of the embayment to mimic the protective function of the lost barrier beach, with plans to dewater the wetland to promote seed germination and growth of emergent plants. Following two years of drawdown, a water-control structure was placed in the dike to mimic the natural barrier opening and was opened to restore hydrologic connection with the lake.

Surveys of the biota before construction of the dike identified a large population of zebra mussels in the lakeward half of the site (Figure 2). Two types of zebra mussel colonization occurred: 1) extensive layers, several centimeters thick, totally covering the substrate and 2) individual clusters of mussels limited to hard structures such as logs, rocks, or vegetation. The area totally covered by zebra mussels extended about 150 m by 300 m. Five live unionids, representing two species, *Quadrula quadrula* and *Leptodea fragilis,* were also found in the surveys. Since so few live unionids were collected and the entire area was colonized by zebra mussels, scientists involved in the project hypothesized, based on best available information (Schloesser & Nalepa 1994) that only a small remnant clam population was present. However, the dewatering process later exposed a clam population far more extensive than expected.

About 7000 live unionids representing 20 species, including three State of Ohio threatened species, and multiple year classes were found during the dewatering (Table 1). Once this population was discovered, a conglomerate of state and federal officials met to decide what to do with these animals. To become a functioning wetland, Metzger Marsh had to be dewatered first, a process which would likely result in the destruction of the entire population. On the other hand, the invasion of zebra mussels meant that release of the unionids into Lake Erie proper would also result in their destruction. This population was considered critical to the future restoration of unionids in the western basin of Lake Erie, since it is one of the few Lake Erie genetic stocks to have survived the negative effects of zebra mussels. The Great Lakes Science Center was charged with removing, boarding, and "doing something appropriate" with these animals until they could be returned to Metzger Marsh sometime in the future. In partnership with the EPA, our primary goal was to salvage as much of the unionid fauna as possible, and to use this fauna to ultimately rebuild the population in Metzger Marsh.

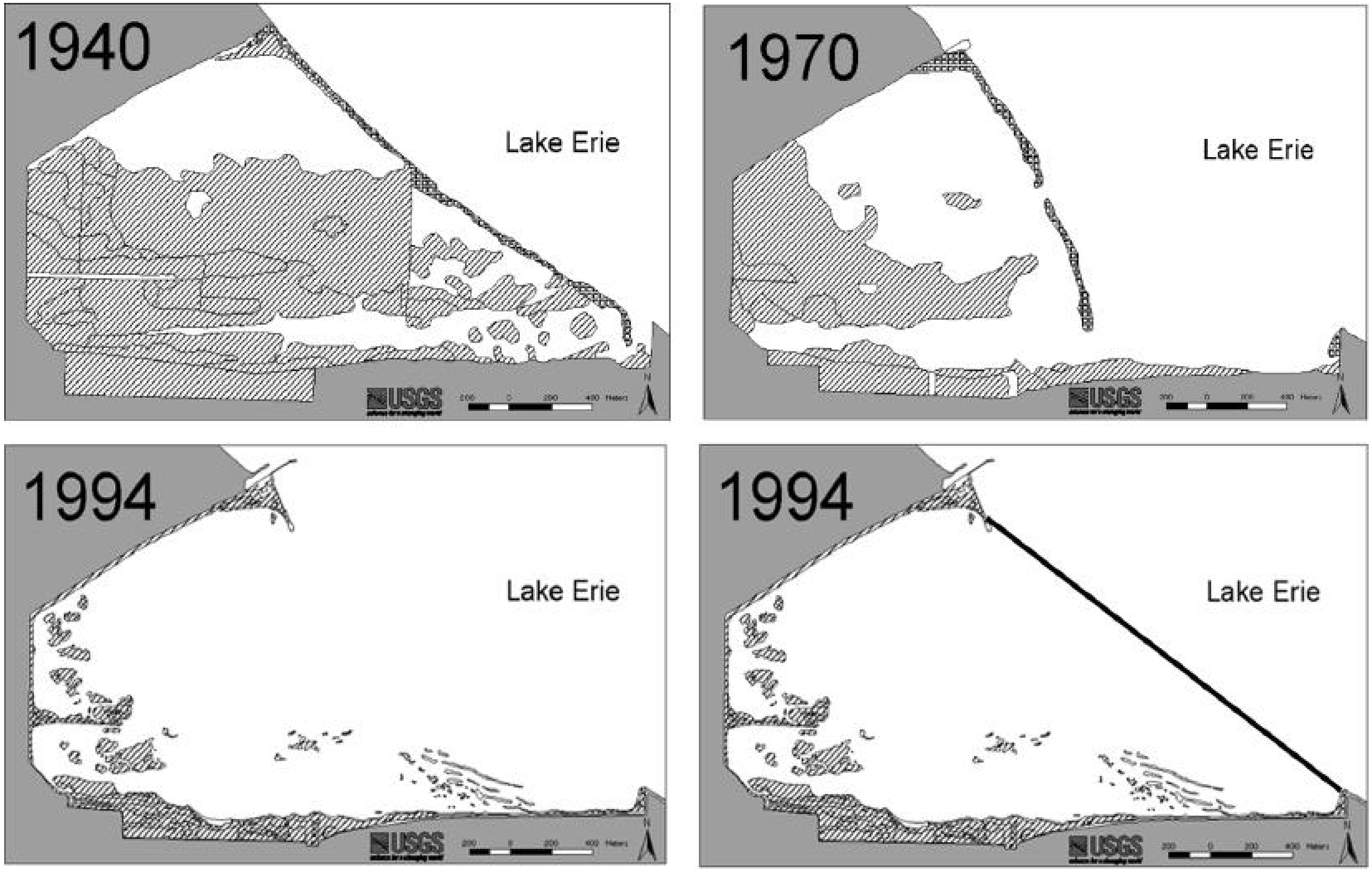
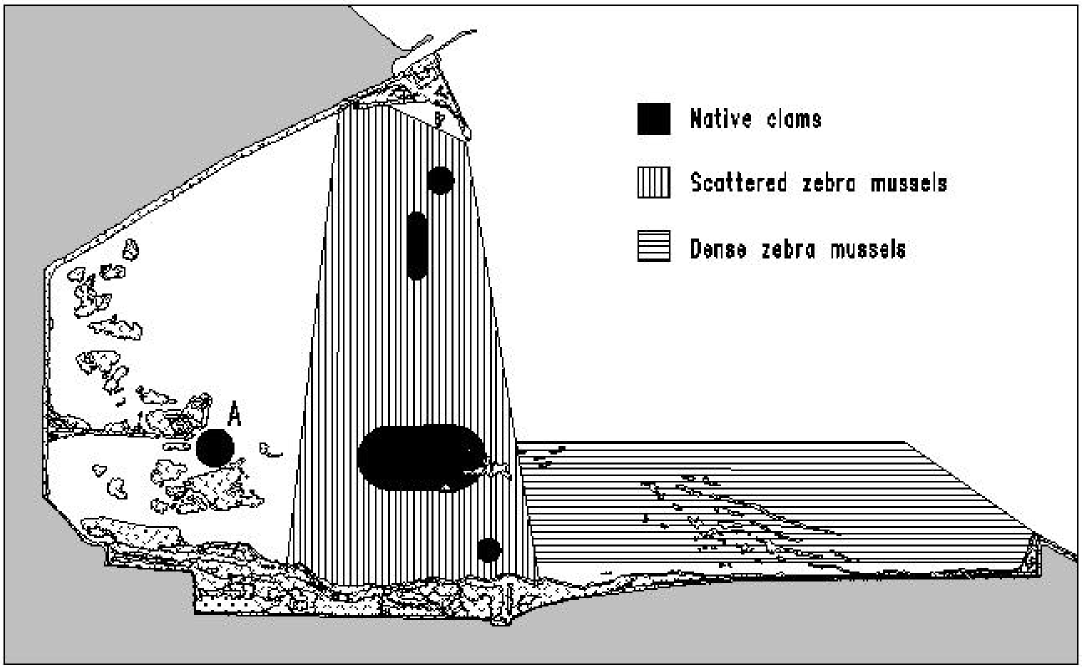


Figure 1. Schematic of aerial photographs of Metzger Marsh, western Lake Erie, showing the destruction of the barrier beach and subsequent erosion of the wetland vegetation between 1940 and 1994. Hatched areas represent patches of wetland vegetation. The bottom drawing shows the location of the artificial barrier beach built at the site.

Figure 2.
Distribution of zebra mussels and thick-shelled unionids collected from Metzger Marsh, western Lake Erie, 1996. "Dense zebra mussels" refers to areas where extensive colony mats covered the substrates and "scattered zebra mussels" to areas where minimal substrate colonization occurred by all other objects (vegetation, rocks, logs, etc.) were colonized with the exception of the unionids. "A" marks the site where the oldest and largest individuals of all species were collected.



PROJECT/TASK DESCRIPTION

Primary Goal: Reestablishing a viable native clam community in Metzger Marsh.

Proposed Time Span: 3-5 years after opening of the water control structure reestablishes access to Lake Erie.

Criteria Used to Measure Success: (1) survival of adult clams, (2) growth of adults, (3) reproductive effort based on presence of glochidia or larvae in the gills of females, and (4) successful recruitment of juveniles into Metzger.

Historical Background

1994. Prior to dike construction, two benthic surveys conducted as required by permitting process. The first survey did not find unionids. The second survey team (GLSC) did find unionids in the fall of 1994, but less than 10 individuals, of two non-listed species. The project managers decided that finding live unionids was a fluke and of minimal importance since published literature stressed that Lake Erie unionids were on the verge of extinction due to zebra mussel-induced mortality.

1995. Dike construction begins. Completed by early 1996.

1996. Dewatering of marsh begins. In May, 1996, during dewatering, large numbers of live unionids were found, including 3 State listed species. (These 3 species have since then been delisted down to Species-of-Concern by Dr. Tom Watters, Ohio State University). The decision was made by the Metzger Marsh management team to remove the unionids from the marsh, board them elsewhere for several years until the marsh was reflooded, and then replace them into the marsh. About 7000 live animals were rescued, representing 20 species. The population structure included many young animals <20 mm in length, indicating that this population was successfully reproducing and recruiting in spite of the zebra mussel presence in the marsh. This is the only known locality in Lake Erie where such successful reproduction of so many species was continuing. All state listed species were sent by the management team to a state approved holding facility at Ohio State University. All other unionids were first sent to the Great Lakes Science Center for temporary holding, and then into the long-term boarding facility at a diked wetland unit, Unit 3, Ottawa Wildlife Refuge, adjacent to Metzger Marsh.

1998. Water control gates remained closed. The marsh was treated with herbicides and there was debate among the management team about further dewatering and treating with rotenone. We made the decision not to replant the unionids in the marsh this year. Surveys of Metzger detected no live unionids, but found one live ~ 10 mm Asian clam (*Corbicula fluminea*). All unionids sent to aquaculture facility at Ohio State University perished.

1999. Marsh gate to Lake Erie opened according to permit requirements. Replanting of unionids from boarding site completed. Monitoring of fish passage in and out of the marsh (EPA grant) begins.

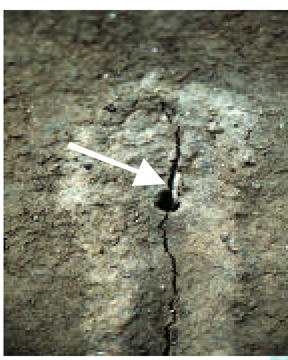
2000-2001. Monitoring of adult unionid growth, reproduction and survival in the marsh. Search for young-of-year unionids initiated, but does not find signs of successful recruitment until late fall 2001. Fish use of Metzger increases.

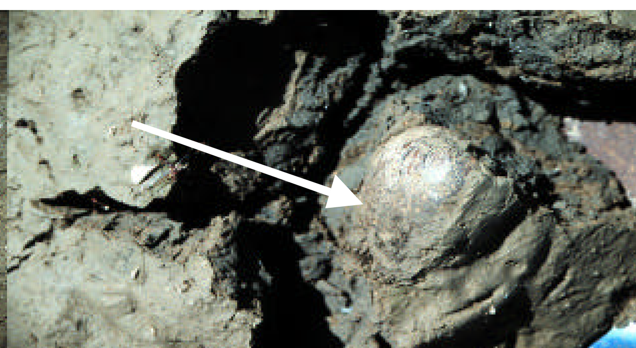
2002. Monitoring of adults continue. No further young unionids found in the marsh.

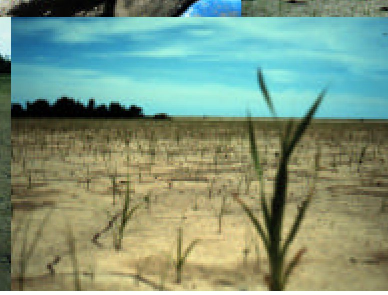
- IN THE BEGINNING, THERE WAS WATER -
Metzger Marsh prior to drawdown, 1996

Hunting unionids during water level drawdown in Metzger Marsh, 1996

Digging live unionids out of dried mud banks in Metzger Marsh, 1996. These animals survived.







Revegetation begins

Boarding unionids at the Great Lakes Science Center and at Ottawa Wildlife Refuge.

METHODS

(1). Initial handling of unionids. As water levels declined in Metzger Marsh, unionids were collected In 1996, from April-September. Biologists walked throughout the 348 hectare site and manually collected animals from the remaining water or dug out those that had burrowed in the mud. Animals were transported to a centralized area where identification, tagging, and measurements were conducted. Most unionids were assigned an identification number, which was etched into both shell valves (duplicate tag) using a battery operated dremel. Each animal was then measured (mm across maximum shell length) and identified by species and sex (if sexually dimorphic). About 75% of these larger individuals had a metal washer glued onto the side of the shell to improve recapture rates through the use of an underwater metal detector. Small unionids (generally under 30 mm in length) were rarely numbered, due to potential shell damage, but were measured and identified to species. After September 1996, the marsh was treated with rotenone to remove carp, and the presence of large numbers of dead and rotting fish prevented further unionid salvage.

(2). Boarding facilities. Once marked and recorded, the unionids were stored in temporary quarters until a suitable long-term boarding facility could be found. About 80% of the unionids were returned to the aquaculture facilities at the Great Lakes Science Center. They were held in a flow through system at about 15 °C. The remaining individuals were placed in shallow embayments of Crane Creek at the Ottawa Wildlife Refuge

(USFWS) near Metzger Marsh. All Ohio State species-of-interest (Table 1), were sent at the request of the Metzger marsh management team to a holding facility at Ohio State University.

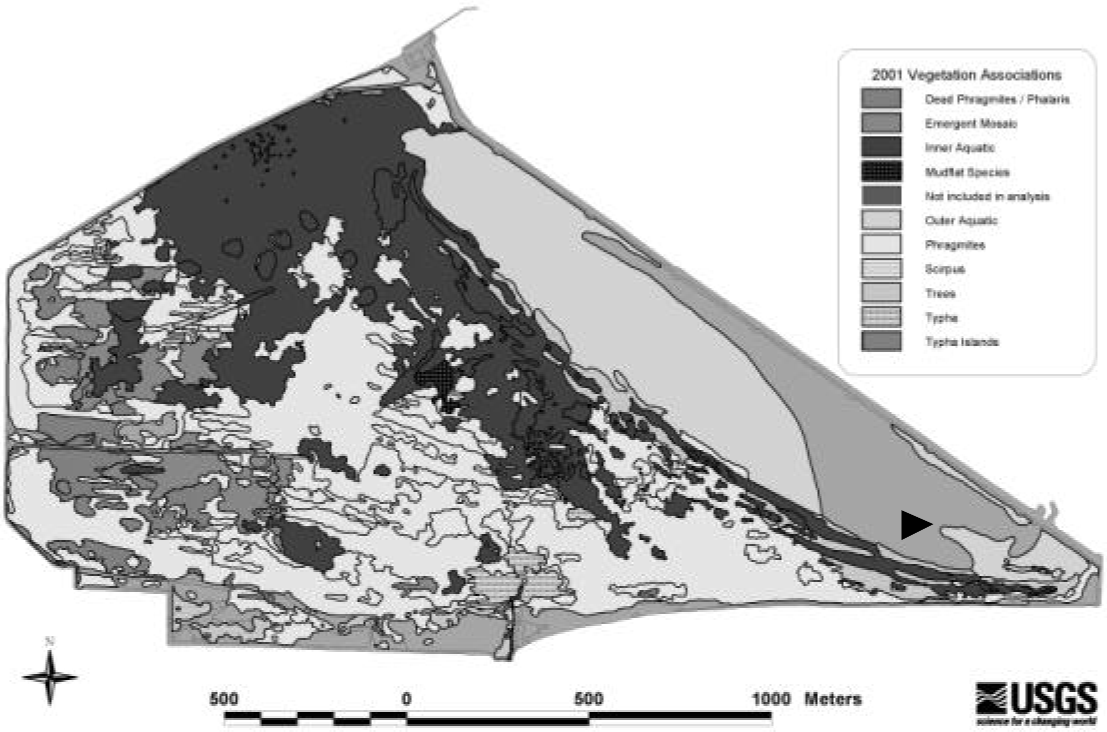
Site selection for a long-term boarding area was based on the following criteria: 1) live unionids had to be present at the site as an indication that unionid habitat was present; 2) some containment capability had to be present so that the animals could be retrieved at a later date; and 3) the site had to be under the jurisdiction of either the USFWS or the Ohio Department of Natural Resources. SCUBA divers were used to survey all waters in the Ottawa Wildlife Refuge and the Crane Creek Wildlife Refuge during August and September of 1996. Based on this above criteria, a diked wetland unit, Unit 3 of the Ottawa Wildlife refuge, adjacent to Metzger Marsh, was selected as a long-term boarding facility. Live giant floaters (*P. grandis*) were present. Water depths were generally less than 1.5 m deep, but water control pumps were available to manipulate water levels as needed. Sediments consisted of soft mud, with some emergent vegetation covering shoreline areas. Waters were very eutrophic and turbid due to sediment type and presence of large numbers of ducks, geese, and eagles. Two muskrat dens were trapped out to prevent predation on unionids. Continuous recording temperature gauges were placed in the unit and oxygen levels monitored weekly during the first year (late 1996-1997). All unionids held at the Great Lakes Science Center and in Crane Creek were moved into this unit by the end of 1996. Marked animals were released in the deepest part of Unit 3, near the water control structure. Unmarked smaller animals were placed in large cages made out of plastic mesh nearby. These unmarked animals were assigned identification numbers when they were removed from Unit 3 in 1999 since they had grown to a larger size by that time.

(3). <u>Returning unionids to Metzger Marsh</u>. Initial plans had been to return the unionids to Meztger Marsh once the gate access to Lake Erie was opened in 1998. However, due to problems with unwanted vegetation, the marsh was treated with herbicides during that year, and further use of rotenone was debated. In consequence, we decided to postpone returning the animals until the following year. In 1999, replanting the unionids became critical because this was a low water year in the western basin of lake Erie. Water levels declined to such an extent that the pump system could not deliver water to Unit 3 and water quality parameters dropped, with oxygen levels declining below 3 ppm. Dead carp were common throughout the unit and unionid mortality increased. Staring in June and continuing until September, unionids were collected from Unit 3 and replanted into Metzger Marsh. Unionids were placed in the deepest part of Metzger, with the highest potential for water flow. This was near the fish gate, on the USFWS side of the marsh (Figure 3). Monitoring the status of the unionid population, and searching for young unionids continued as described below.

(4). Monitoring growth, survival and reproductive effort. Every month from ice-out (April) until duck hunting season (September), SCUBA divers were used to find at least 100 marked unionids in Unit 3, or Metzger Marsh after 1999. The search area was initiated in site of release, and expanded for a total of 30 minutes/diver in a random pattern from that point. Sediments were searched to a depth of about 0.5 m. All unionids found, live or dead, were collected. Species, identification number, and shell length (mm) was recorded. All obvious female unionids (sexually dimorphic species such as *Lampsilis* spp. and *L. fragilis*) were gently pried open and marsupia visually examined for the presence of glochidia. A randomly selected subset of the non-sexually dimorphic species (*A. plicata, P. grandis,* and *Quadrula* spp.) were also pried open and examined. All live animals were then returned to place of collection. All dead shell was taken to the Great Lakes Science Center for further analysis.

(5). Fish community structure and use of Metzger Marsh. The presence of fish is essential for unionid survival as larval unionids require a fish host to complete their development. Fish were eliminated in the marsh during the rotenone treatments and water drawdown in 1996. Fish access to the marsh was controlled through the fish gate structure starting in 1999. A grate prevents ready access by larger fish, except through the use of a fish basket. The fish basket is in use from February through November (see Appendix 1). All fish in the basket were identified to species and measured. Visual examination was done to determine if glochidia were present. All suspect fish were saved for further examination. Glochidial infestation rates were determined in fish as they entered the marsh from Lake Erie to determine if glochidia are being brought into the marsh from some other source unionid population.

Figure 3. 2001 Vegetation Pattern in Metzger Marsh. " ◀Shows Location of Adult Unionids.



RESULTS

<u>1996 Community Structure in Metzger Marsh Before Drawdown.</u>

In 1996, we collected 6708 unionids representing 20 species (Table 1). Two species dominated the community, the fragile papershell (40%) and the giant floater (29%). Three species were at that time Ohio species-of-concern (lilliput, fawnsfoot, and deertoe), but have since been delisted. This type of unionid community is typical of the Great Lakes prior to the zebra mussel invasion. Most species showed signs of multiple size classes, and by inference, multiple year classes (e.g. Tables 2-7). The exceptions were those species with few individuals (fat mucket, plain pocketbook, round pigtoe, Wabash pigtoe).

Table 1. Unionid population structure collected at Metzger Marsh during initial dewatering of site in 1996; returned to the marsh in 1999; found 2000-2002.

Common name	Scientific Name	#live found in 1996	# live returned- 1999	# live found 2000-2002
Fragile papershell	*Leptodea fragilis*	2685	1670 (+562 dead)	555 (+8 dead)
Giant floater	*Pyganodon grandis*	1962	1202 (+325 dead)	439 (+7 dead)
Pink heelsplitter	*Potamilus alatus*	893	597 (+ 55 dead)	195 (+1 dead)
Threeridge	*Amblema plicata*	576	368 (+12 dead)	33 (+0 dead)
Lilliput	*Toxolasma parvus*	271*	25	1 (+0 dead)
Mapleleaf	*Quadrula quadrula*	149	56 (+0 dead)	14 (+0 dead)
Fawnsfoot	*Truncilla donaciformis*	28*	0* 6 replaced from Maumee River, Ohio	2
Three horn wartyback	*Obliquaria reflexa*	26*	0	
Pimpleback	*Quadrula pustulosa*	24	22 (+1 dead)	2
Heelsplitter	*Lasmigona complanata*	23	19 (+3 dead)	6
Pondhorn	*Uniomerus tetralasmus*	20	22	6
Paper pondshell	*Utterbackia imbecillis*	15	13	5
Fatmucket	*Lampsilis siliquoidea*	13	10 (+2 dead)	3
Plain pocketbook	*Lampsilis cardium*	8	8 (+0 dead)	4
Deertoe	*Truncilla truncata*	6*	0* 3 replaced from Maumee River	1
Round pigtoe	*Pleurobema sintoxia*	2	2 (+0 dead)	1
Wabash pigtoe	*Fusconaia flava*	2	2 (+0 dead)	0
Hickorynut	*Obovaria olivaria*	2	2 (+0 dead)	1
Strange floater	*Strophitus undulata*	3	3 (+0 dead)	0
Spike	*Elliptio dilatata*	1	1 (+0 dead)	0
TOTAL		6708	4022 (960 confirmed dead)	

** State-listed species and species-of-concern sent to Ohio State University aquaculture facilities at request of Metzger Marsh management team. Facility failure in 1998 resulted in death of all animals held on site*

Table 2. Fragile papershell (*Leptodea fragilis*) length frequency (mm) and number collected from Metzger Marsh, Lake Erie, Ohio, and marked in 1996; length frequency of the same group of animals as removed from a managed wetland unit in 1999; and subsequent length frequency of the same group of animals after return to Metzger Marsh (1999-2002).

	Length Frequency				
Length range (mm)	1996	1999	2000	2001	2002
10s	115	0	0	0	0
20s	356	0	0	0	0
30s	131	0	0	0	0
40s	113	1	0	0	0
50s	437	3	0	0	0
60s	665	3	0	0	0
70s	478	18	0	0	0
80s	172	50	1	0	0
90s	91	188	22	2	0
100s	51	320	66	15	0
110s	34	404	85	38	14
120s	18	382	91	45	17
130s	9	196	45	41	23
140s	15	74	13	16	11
150s	0	30	3	5	2

Table 3. Giant floater (*Pyganodon grandis*) length frequency (mm) and number collected from Metzger Marsh, Lake Erie, Ohio, and marked in 1996; length frequency of the same group of animals as removed from a managed wetland unit in 1999; and subsequent length frequency of the same group of animals after return to Metzger Marsh (1999-2002).

	Length Frequency				
Length range (mm)	1996	1999	2000	2001	2002
10s	45	0	0	0	0
20s	72	0	0	0	0
30s	226	0	0	0	0
40s	64	0	0	0	0
50s	95	0	0	0	0
60s	187	1	0	0	0
70s	437	6	2	0	0
80s	440	16	1	0	0
90s	298	91	2	0	0
100s	64	188	16	1	0
110s	19	420	69	4	0
120s	3	337	75	24	0
130s	9	101	48	75	5
140s	3	29	11	33	23
150s	0	10	5	15	15
160s	0	1	0	3	6
170s	0	2	0	0	5
180s	0	0	0	0	1

Table 4. Three ridge (*Amblema plicata*) length frequency (mm) and number collected from Metzger Marsh, Lake Erie, Ohio, and marked in 1996; length frequency of the same group of animals as removed from a managed wetland unit in 1999; and subsequent length frequency of the same group of animals after return to Metzger Marsh (1999-2002).

	Length Frequency				
Length range (mm)	1996	1999	2000	2001	2002
10s	56	0	0	0	0
20s	45	0	0	0	0
30s	53	0	0	0	0
40s	32	1	0	0	0
50s	17	0	0	0	0
60s	72	16	0	0	0
70s	97	78	1	0	0
80s	110	109	5	2	0
90s	69	97	9	6	1
100s	21	54	4	2	2
110s	4	10	4	3	5
120s	0	3	0	0	1

Table 5. Heelsplitter (*Potamilus alatus*) length frequency (mm) and number collected from Metzger Marsh, Lake Erie, Ohio, and marked in 1996; length frequency of the same group of animals as removed from a managed wetland unit in 1999; and subsequent length frequency of the same group of animals after return to Metzger Marsh (1999-2002).

	Length Frequency				
Length range (mm)	1996	1999	2000	2001	2002
10s	42	0	0	0	0
20s	53	0	0	0	0
30s	96	0	0	0	0
40s	95	0	0	0	0
50s	112	1	0	0	0
60s	127	7	0	0	0
70s	119	6	2	0	0
80s	32	29	4	2	0
90s	41	76	20	2	2
100s	28	140	22	5	2
110s	33	107	28	15	3
120s	33	58	17	11	9
130s	53	51	11	6	6
140s	25	38	4	2	4
150s	3	37	4	1	0
160s	0	33	4	0	2
170s	0	14	1	1	2
180s	0	0	0	3	0

Table 6. Lilliput (*Toxolamsma parvus*) length frequency (mm) collected from Metzger Marsh, Lake Erie, Ohio, and marked in 1996; length frequency of the same group of animals as removed from a managed wetland unit in 1999; and subsequent length frequency of the same group of animals after return to Metzger Marsh (1999-2002).

	Length Frequency				
Length range (mm)	1996	1999	2000	2001	2002
1s	20	0	0	0	0
10s	84	0	0	0	0
20s	22	0	0	0	1
30s	97	0	0	0	2
40s	48	0	0	0	0

Table 7. Pimpleback (*Quadrula quadrula*) length frequency (mm) collected from Metzger Marsh, Lake Erie, Ohio, and marked in 1996; length frequency of the same group of animals as removed from a managed wetland unit in 1999; and subsequent length frequency of the same group of animals after return to Metzger Marsh (1999-2002).

	Length Frequency				
Length range (mm)	1996	1999	2000	2001	2002
10s	15	0	0	0	0
20s	21	0	0	0	0
30s	21	0	0	0	0
40s	37	2	0	0	0
50s	7	6	0	0	0
60s	30	16	2	1	0
70s	8	17	3	3	0
80s	8	9	1	1	1
90s	1	5	1	0	0
100s	1	1	1	0	0

1999 Unionid Community Replanted in Metzger Marsh.

In 1996, 6399 unionids representing 17 species were moved into Unit 3, Ottawa Wildlife Refuge. The listed species, (deertoe, fawnsfoot, lilliput, and threehorn wartyback) had been sent to Columbus Ohio, with the exception of 25 lilliput that were accidentally placed in Unit 3. Starting in May 1999 and continuing until November, we removed animals from Unit 3 for replanting in Metzger Marsh. We recovered 4022 live individuals, representing all seventeen species, and a further 960 dead shell (Table 1). We had a 78% recovery rate overall, with 100% recapture of some species, particularly the thick-shelled species such as the hickorynut, pigtoes, plain pocketbook, and spike. Thin-shelled, highly mobile species such as the fragile papershell and the giant floater had the lowest recapture rates. We found more of one species, the pondhorn, that we had recorded as being placed in Unit 3. All the pondhorn were marked, including the extra two animals, but two had been misrecorded as paper pondshells in 1996. A total of 1421 animals, both marked and unmarked, could not be found either live or as dead shell. Three species originally in Mezger Marsh (deer toe, fawnsfoot, and threehorn wartyback) were no longer available for replanting. We consulted with the Ohio State malacologist (Dr. T. Watters) and with consent of the management team, obtained representatives of two of these species, deer toe (n=6; 64,59,63,63,60,54 mm) and fawnsfoot (n=3; 59, 63, 54 mm), from the nearby Maumee River drainage. These animals were placed in Metzger Marsh in September 1999. No threehorn wartyback were returned to the marsh.

While in Unit 3 the size composition of the population changed, with large animals dominating the community in 1999. Growth rates during the 2.5 years these animals were in Unit 3 were exuberant with some individuals growing 45 mm a year (Tables 8-12; Figures 4-8). Growth rates were fastest for the thin-shelled species such as fragile papershell and giant floater, averaging 10 mm/year, and slowest for the thick-shelled species such as three ridge averaging 3mm/year. The maximum growth rate was found in a fragile papershell (#754) which was 48 mm in length when placed in Unit 3 in October 1996 and measured 152 mm (+104 mm) in May 1999. Increases in shell length of >90 mm were common for both the fragile papershell and the giant floater.

Table 8. Summary statistics for the giant floater (*Pyganodon grandis*) collected from Metzger Marsh in 1996, moved into Unit 3 till 1999, and then returned to Meztger Marsh. *For those animals that were marked in 1996.

1996	2001
range = 22-146 mm*	range = 101-169 mm
average = 82 mm*	average = 137 mm
N = 1962 (1497 marked)	N = 155 (0 dead)
	10.4% recaptured
1999	**2002**
range = 69-173 mm	range = 130-180 mm
average = 117 mm	average = 152 mm
N = 1202 (325 [27.0%] dead)	N = 55 (0 dead)
80.3% recaptured	3.7% recaptured
growth: min = -6 mm, max = 84 mm avg. growth 1996-1999 = 35 mm	
2000	**Small size classes not marked in 1996**
range = 74-156 mm	A total of 465 mussels not marked in 1996.
average = 123 mm	154 unmarked mussels collected in 1999.
N = 229 (7 [3.1%] dead)	
15.3% recaptured	

Table 9. Summary statistics for fragile papershell (*Leptodea fragilis*) collected from Metzger Marsh in 1996, moved into Unit 3 till 1999, and then returned to Meztger Marsh. *For those animals that were marked in 1996.

1996	2001
range = 34-149 mm*	range = 95-159 mm
average = 70 mm*	average = 126 mm
N = 2685 (2086 marked)	N = 162 (2 [1.2%] dead)
	7.8% recaptured
1999	**2002**
range = 44-156 mm	range = 111-152 mm
average = 116 mm	average = 130 mm
N = 1670 (562 [33.7%] dead)	N = 67 (0 dead)
80.1% recaptured	3.2% recaptured
growth: min = -6 mm, max= 104 mm	
Avg. 1996-1999 = 46 mm	
2000	**Small size classes not marked in 1996**
range = 89-154 mm	A total of 599 mussels not marked in 1996.
average = 118 mm	105 unmarked mussels collected in 1999.
N = 326 (6 [1.8%] dead)	
15.6 % recaptured	

Table 10. Summary statistics for three ridge (*Amblema plicata*) collected from Metzger Marsh in 1996, moved into Unit 3 till 1999, and then returned to Meztger Marsh. *For those animals that were marked in 1996.

1996	2001
range = 47-115 mm*	range = 84-116 mm
average = 80 mm*	average = 99 mm
N = 576 (391 marked)	N = 13 (0 dead)
	3.3% recaptured
1999	**2002**
range = 42-122 mm	range = 97-124 mm
average = 88 mm	average = 112 mm
N = 368 (12 [3.3%] dead)	N = 9 (0 dead)
94.1% recaptured	2.3% recaptured
growth: min = -6 mm, max = 20 mm, avg. 1996-1999= 9 mm	
2000	**Small size classes not marked in 1996**
range = 76-115 mm	A total of 185 mussels not marked in 1996.
average = 97 mm	24 unmarked mussels collected in 1999.
N = 23 (0 dead)	
5.9 % recaptured	

Table 11. Summary statistics for the heelsplitter (*Potamilus alatus*) collected from Metzger Marsh in 1996, moved into Unit 3 till 1999, and then returned to Meztger Marsh. *For those animals that were marked in 1996.

1996	2001
range = 24-159 mm*	range = 86-182 mm
average = 84 mm*	average = 124 mm
N = 893 (636 marked)	N = 48 (1 [2.1%] dead)
	7.5% recaptured
1999	**2002**
range = 54-177 mm	range = 90-177 mm
average = 119 mm	average = 130 mm
N = 597 (55 [9.2%] dead)	N = 30 (0 dead)
93.9% recaptured	4.7% recaptured
growth: min = -3 mm, max = 67 mm avg. 1996-1999 = 36 mm	
2000	**Small size classes not marked in 1996**
range = 74-170 mm	A total of 257 mussels not marked in 1996.
average = 115 mm	45 unmarked mussels collected in 1999.
N = 117 (0 dead)	
18.4 % recaptured	

Table 12. Summary statistics for the pimpleback (*Quadrula quadrula*) collected from Metzger Marsh in 1996, moved into Unit 3 until 1999, and then returned to Meztger Marsh. *For those animals that were marked in 1996.

1996	2001
range = 38-101 mm*	range = 63-86 mm
average = 67 mm*	average = 76 mm
N = 149 (58 marked)	N = 5 (0 dead)
	8.6% recaptured
1999	**2002**
range = 44-104 mm	only 1 marked animal recaptured
average = 73 mm	length = 80 mm
N = 56 (0 dead)	
96.6% recaptured	
growth: min = 3 mm, max = 8 mm avg. 1996-1999 = 5 mm	
2000	**Small size classes not marked in 1996**
range = 60-107 mm	A total of 91 mussels not marked in 1996.
average = 79 mm	18 unmarked mussels collected in 1999.
N = 8 (0 dead)	
13.8 % recaptured	

Figure 4. Changes in length frequency of the fragile papershell (*Leptodea fragilis*) collected from Metzger Marsh in 1996 and removed from Unit 3 in 1999. Marked individuals only.

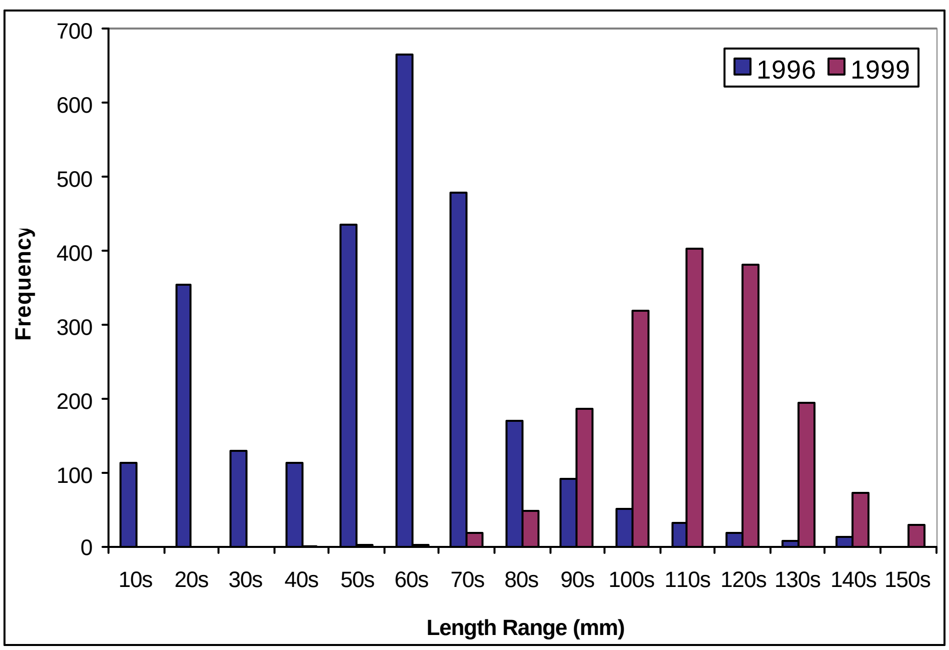


Figure 5. Changes in length frequency of the giant floater (*Pyganodon grandis)* collected from Metzger Marsh in 1996 and removed from Unit 3 in 1999. Marked individuals only.

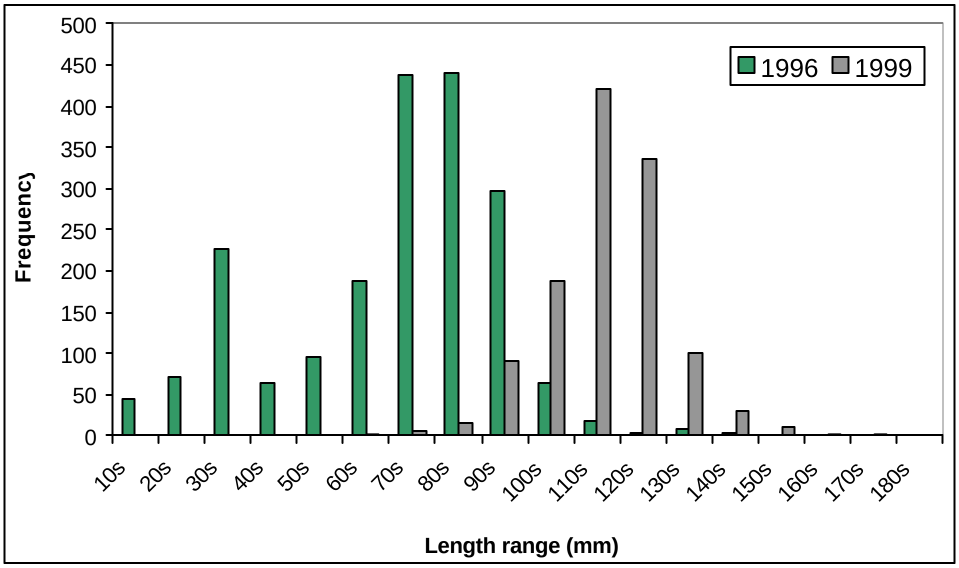


Figure 6. Changes in length frequency of the heelsplitter (*Potamilus alatus)* collected from Metzger Marsh in 1996 and removed from Unit 3 in 1999. Marked individuals only.

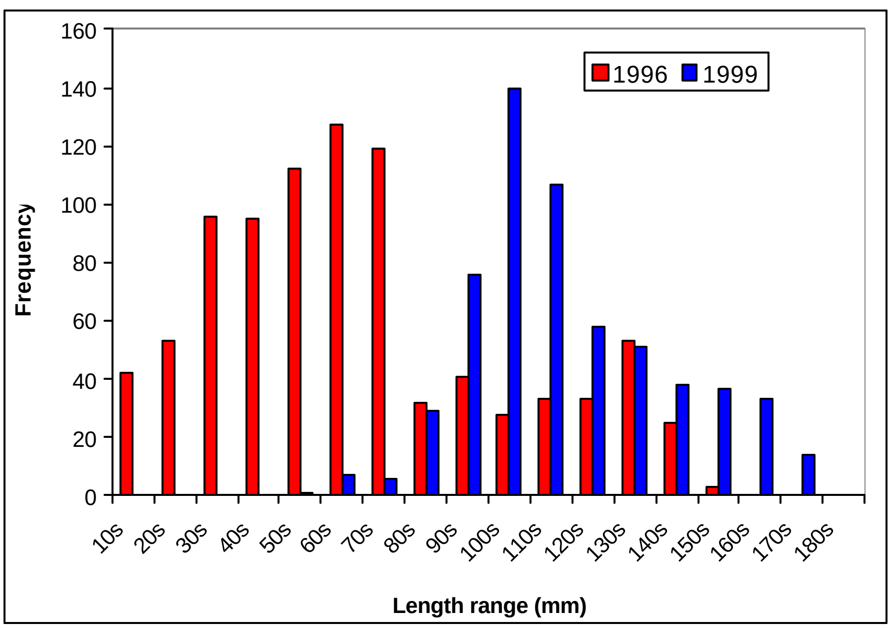


Figure 7. Changes in length frequency of three ridge (*Amblema plicata*) collected from Metzger Marsh in 1996 and removed from Unit 3 in 1999. Marked individuals only.

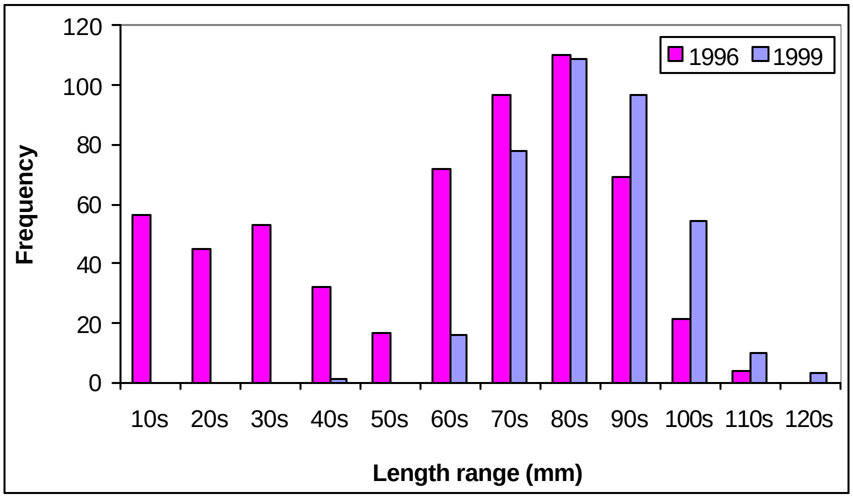
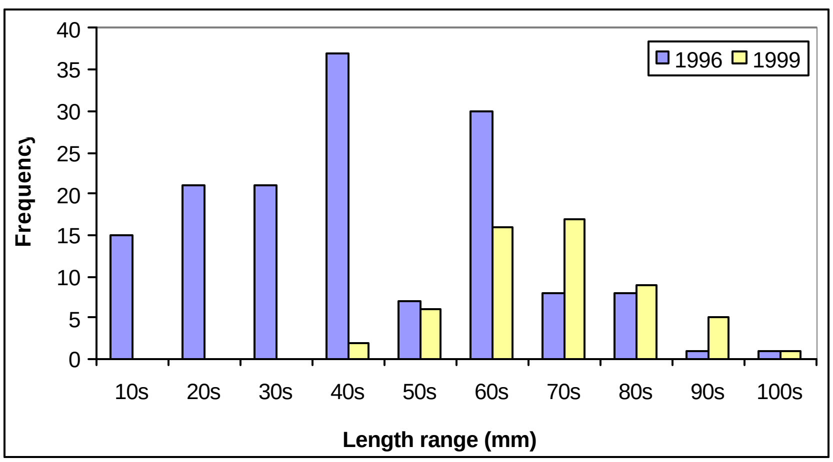


Figure 8. Changes in length frequency of the pimpleback (*Quadrula quadrula*) collected from Metzger Marsh in 1996 and removed from Unit 3 in 1999. Marked individuals only.



In 1999, a number of unmarked unionids were recovered and assumed to be the animals considered too small for marking in 1996 and placed in the unit in cages. These cages broke apart during the winter of 1998, but most of the unionids were still in the immediate area. Summary statistics for these animals are presented in Tables 13-17. There is a possibility that some of the unmarked fragile papershell and giant floater recovered in 1999, were not from Metzger Marsh but endemic to Unit 3. Most of the time these endemic animals were readily distinguishable from Metzger Marsh animals by shell coloration. Metzger Marsh animals showed a distinct change in shell coloration when moved into Unit 3. Endemic animals did not have such distinct banding.

Table 13. Length frequency for unmarked fragile papershell (*Leptodea fragilis*) collected from Unit 3, Ottawa Wildlife Refuge, and marked in 1999 prior to replacement in Metzger Marsh. Length frequencies for years 2000-2002 are for Metzger Marsh.

	Frequency			
Length range (mm)	1999	2000	2001	2002
50s	1	0	0	0
60s	1	0	0	0
70s	1	0	0	0
80s	7	0	0	0
90s	18	1	0	0
100s	14	2	0	0
110s	15	3	2	0
120s	20	3	0	4
130s	18	2	2	1
140s	9	3	1	0
150s	1	1	0	0

Table 14. Length frequency for unmarked giant floaters (*Pyganodon grandis*) collected from Unit 3, Ottawa Wildlife Refuge, and marked in 1999 prior to replacement in Metzger Marsh. Length frequencies for years 2000-2002 are for Metzger Marsh.

	Frequency			
Length range (mm)	1999	2000	2001	2002
90s	1	0	0	0
100s	16	0	0	0
110s	36	5	0	0
120s	57	14	2	0
130s	27	11	9	0
140s	12	11	8	0
150s	3	1	2	1
160s	1	0	2	1
170s	1	1	0	4
180s	0	0	0	1

<u>Table 15</u>. Length frequency for unmarked giant floaters (*Potamilus alatus*) collected from Unit 3, Ottawa Wildlife Refuge, and marked in 1999 prior to replacement in Metzger Marsh. Length frequencies for years 2000-2002 are for Metzger Marsh.

	Frequency			
Length range (mm)	1999	2000	2001	2002
40s	2	0	0	0
50s	8	0	0	0
60s	12	6	0	0
70s	3	4	1	0
80s	5	1	2	1
90s	2	1	2	1
100s	3	0	1	1
110s	2	1	1	0
120s	2	1	0	0
130s	3	1	0	1
140s	2	2	0	0
150s	1	0	1	1

<u>Table 16</u>. Length frequency for unmarked three ridge (*Amblema plicata*) collected from Unit 3, Ottawa Wildlife Refuge, and marked in 1999 prior to replacement in Metzger Marsh. Length frequencies for years 2000-2002 are for Metzger Marsh.

	Frequency			
Length range (mm)	1999	2000	2001	2002
50s	2	0	0	0
60s	1	0	0	0
70s	10	0	0	0
80s	2	1	0	0
90s	7	2	1	2
100s	2	3	0	0
110s	0	1	0	0

<u>Table 17</u>. Length frequency for unmarked pimpleback (*Quadrula quadrula*) collected from Unit 3, Ottawa Wildlife Refuge, and marked in 1999 prior to replacement in Metzger Marsh. Length frequencies for years 2000-2002 are for Metzger Marsh.

	Frequency			
Length range (mm)	1999	2000	2001	2002
50s	2	1	0	0
60s	5	4	0	0
70s	5	2	0	0
80s	2	1	1	1
90s	3	1	0	0

Highest mortality rates from 1996-1999 were seen for those species that were growing the fastest, e.g., the fragile papershell and giant floater. However, very little of this mortality could be attributed to handling stress suffered during the removal from Metzger Marsh in 1996. Handling mortality was estimated based on measurement of growth increments in all dead shell collected. Most of the live animals collected showed an average growth rate of at least 10 mm per year. Growth rates of < 5 mm in dead shell in these two species was assumed to indicate death occurred soon after initial 1996 measurement occurred. The thicker shelled species showed lower growth rates overall per year, and growth rates of <3mm were considered indicative of early mortality in these species. As shown in Figures 9-12, most animals of all species had grown substantially before death, indicating that handling mortality in 1996 was not a major factor.

Figure 9. Estimate of handling mortality based on growth frequency of fragile papershell (*Leptodea fragilis*) between 1996 collection from Metzger Marsh and death, sometime prior to 1999 from Unit 3. Growth rates of <5mm as indicated by the dotted line, shows those animals that died right after being placed in Unit 3 and is the estimate of handling mortality.

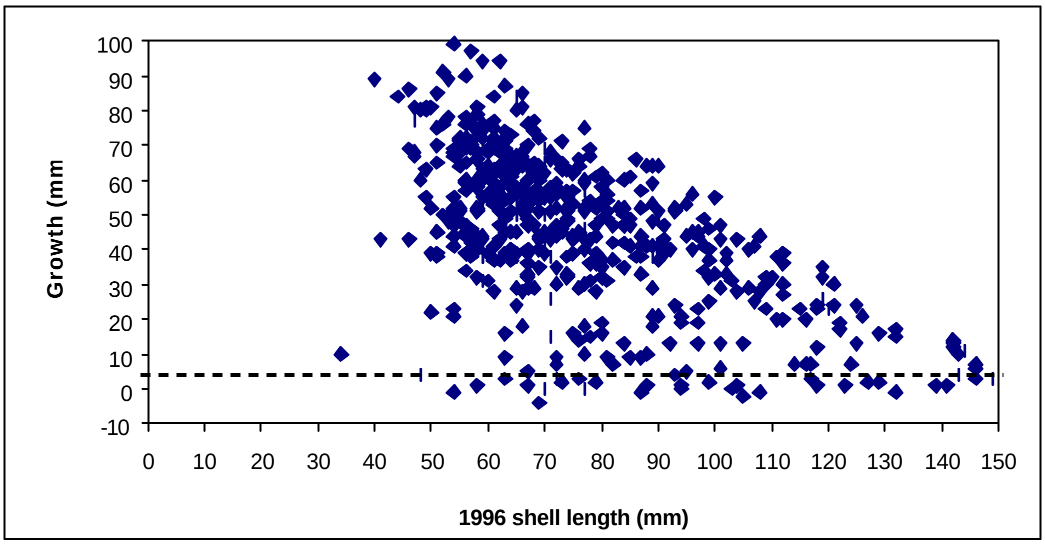


Figure 10. Estimate of handling mortality based on growth frequency of the giant floater (*Pyganodon grandis*) between 1996 collection from Metzger Marsh and death, sometime prior to 1999 from Unit 3. Growth rates of <5mm as indicated by the dotted line, shows those animals that died right after being placed in Unit 3 and is the estimate of handling mortality.

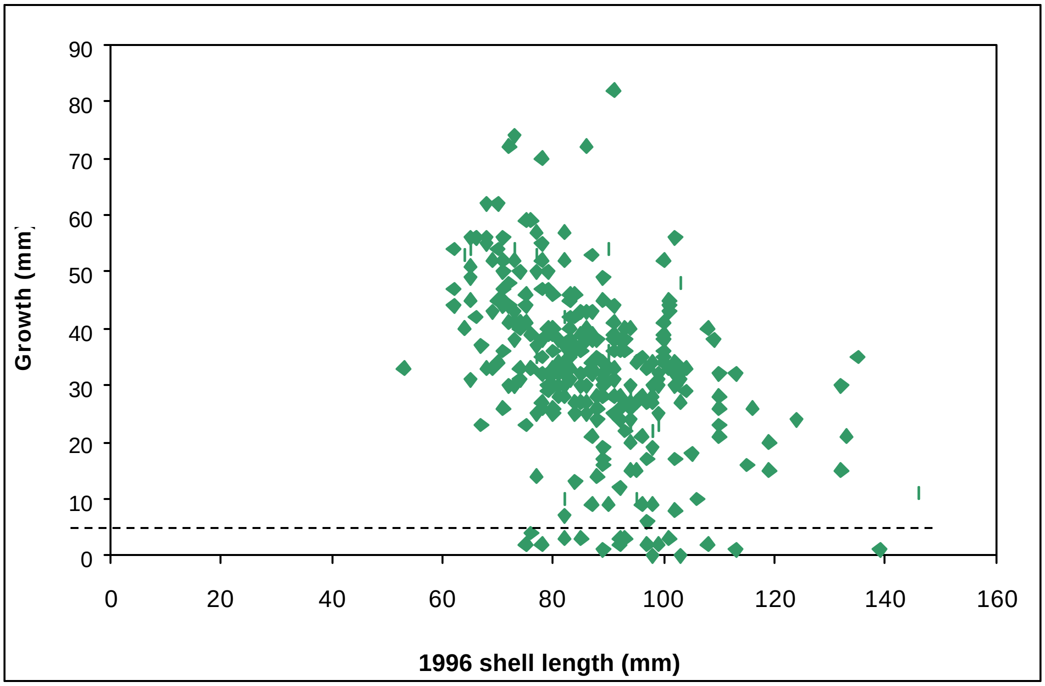


Figure 11. Estimate of handling mortality based on growth frequency of the heelsplitter (*Potamilus alatus*) between 1996 collection from Metzger Marsh and death, sometime prior to 1999 from Unit 3. Growth rates of <3mm as indicated by the dotted line, shows those animals that died right after being placed in Unit 3 and is the estimate of handling mortality.

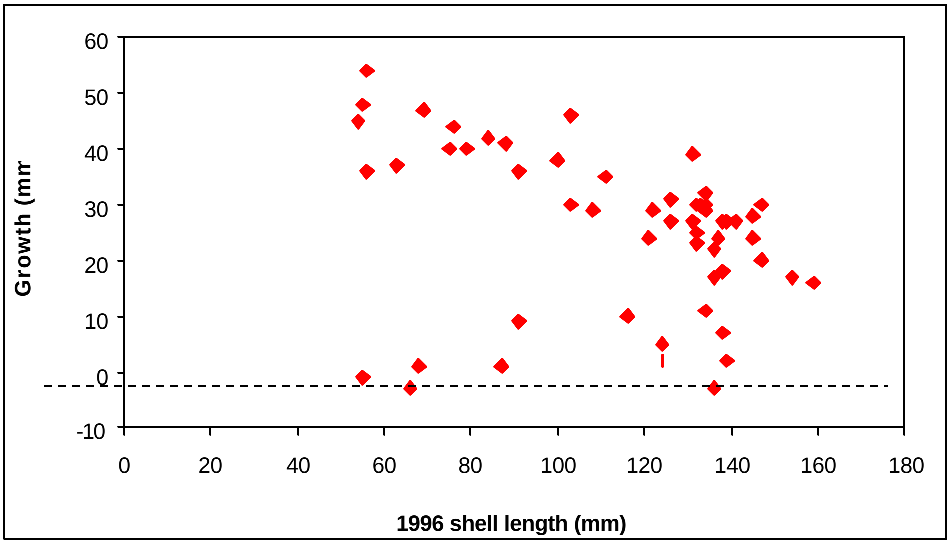
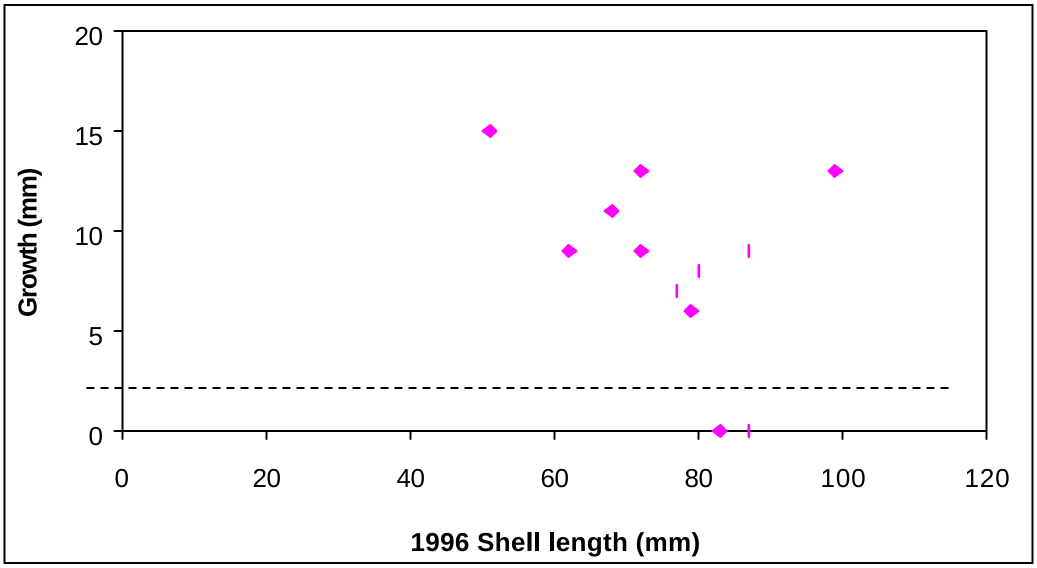


Figure 12. Estimate of handling mortality based on growth frequency of the three ridge (*Amblema plicata*) between 1996 collection from Metzger Marsh and death, sometime prior to 1999 from Unit 3. Growth rates of <5mm as indicated by the dotted line, shows those animals that died right after being placed in Unit 3 and is the estimate of handling mortality.



There is some indication that at least one species, the fragile papershell, successfully recruited juveniles while in Unit 3. This hypothesis is based on the length frequency of the unmarked animals removed from Unit 3 in 1999 (Figures 13 & 14). Several 50-mm individuals were collected. While it is possible that these individuals were small in 1996 upon entry into Unit 3, and grew slowly, the average growth rate seen for marked individuals of this species would suggest that these are young animals. No such small individuals of other fast growing unionids, such as the giant floater, or for any other species were found. Lack of fish hosts was not a factor for most species. While no official fish survey was done on this unit, fish of various species were present, including various minnows, bluegill, and largemouth bass, all acceptable fish host species for many of the unionid species present. However, the only known fish host for the fragile papershell is the freshwater drum, and it was not seen in Unit 3, though no accurate fish sampling was done.

Figure 13. Length frequency for unmarked fragile papershell (*Leptodea fragilis*) collected from Unit 3, Ottawa Wildlife Refuge, and marked in 1999 prior to replacement in Metzger Marsh.

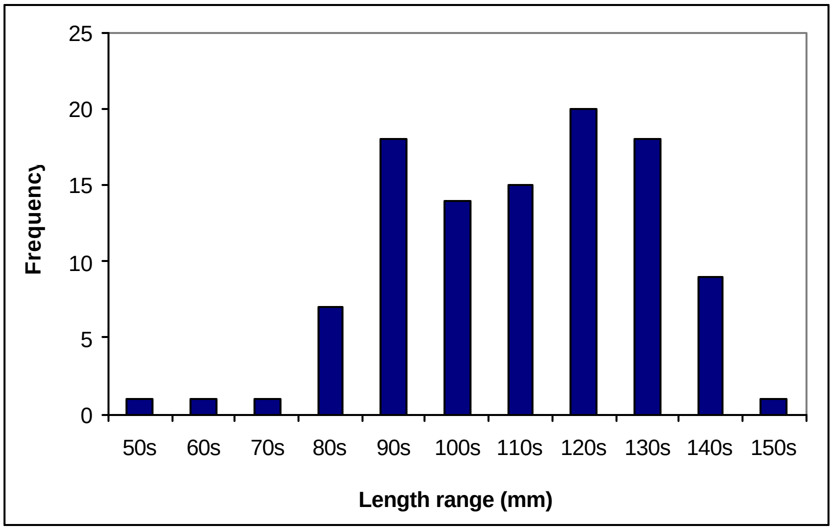
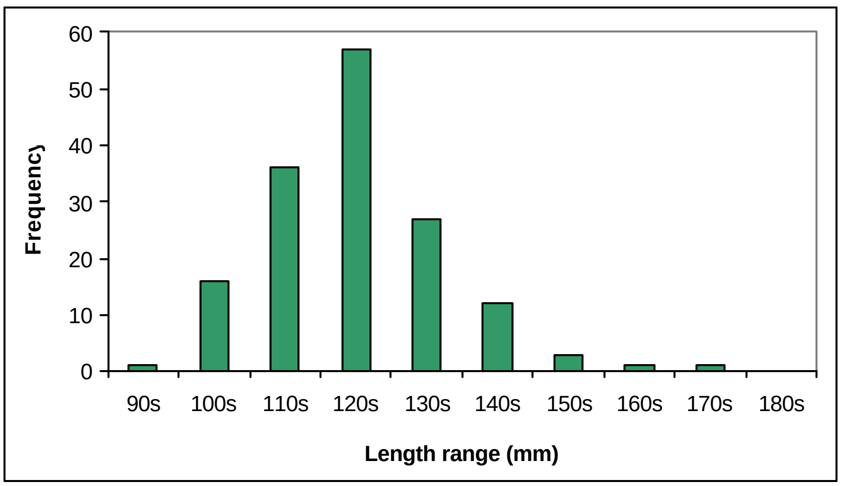


Figure 14. Length frequency for unmarked giant floaters (*Pyganodon grandis*) collected from Unit 3, Ottawa Wildlife Refuge, and marked in 1999 prior to replacement in Metzger Marsh.



Metzger Marsh: Late 1999-2002.

About 4022 live individuals were removed from Unit 3 and in addition to 9 deertoes and fawnsfoot brought in from the Maumee River were replanted into Metzger by October 1999 and monitored from 2000-2002. Mortality rates remained low, but recapture rates decreased steadily with every year (Tables 2-7). Growth rates slightly declined for most species as compared to what had been seen in Unit 3, but as the population has aged, we could not determine if this growth slowdown was age-dependent or site-dependent (Tables 2-7). Gravid females were commonly found indicating conditions were appropriate for the formation of glochidia (Table 18). No juvenile mussels were found in 2000 or in 2002. However, in the late fall of 2001, some young unionids representing 3 species were found in the marsh. They were identified, measured, and replaced where captured (Table 19). These young animals were not found near the area where the adults were, but over 1/8-km away, closer to the vegetation.

Table 18. Number of gravid females, as indicated by swollen marsupium, found in Metzger Marsh, 2000-2002.

SPECIES	2000	2001	2002
Leptodea fragilis	51	45	25
Pyganodon grandis	61	58	20
Amblema plicata	5	2	0
Potamilus alatus	20	10	2
Lampsilis siliquoidea	1	2	0
Lampsilis cardium	1	0	0

Table 19. Juvenile unionids (shell length **in cm**) found in September and October 2001, in Metzger Marsh. Data provided by Dr. Ferenc de Szalay, Kent State University.

SPECIES	2002
Giant floater (*Pyganodon grandis*)	N=11: 5.1, 5.1, 5.5, 5.5, 5.8, 5.0, 5.4, 5.6, 6.0, 10.2, 13.1 N=9 between 5 and 13 cm.
Lillliput (*Toxolasmus parvus*)	N=3 2.6, 3.0, 3.4
Pond sandshell (*Utterbackia imbecillis*)	N=2 4.1, 5.0

Fish Community in Metzger Marsh 1999-2002

A total of 45 species of fish were identified at the Metzger Marsh fish passage structure (Table 20; Appendix 1). No glochidia were ever found on fish entering or leaving Metzger Marsh, nor during electroshocking sampling within the marsh proper. The fish community present in the marsh between 1999-2002 contain most of the fish host species required by the unionid species present (Table 21). One exception is the flathead catfish, which is the only known host fish for the mapleleaf and the shovelnose sturgeon used by the hickory nut. Sauger was not found in the marsh, and is used as a host by several of the unionids, but is not the sole host fish.

Table 20. Combined total catch of fish sampled at the Metzger Marsh fish passage structure from 1999 -2002. CPUE= catch per unit effort. From Wells et al. 2002. Appendix 1.

Common Name	Scientific Name	Total Catch From 1999 - 2002	
		number	*CPUE*
Emerald Shiner	*Notropis atherinoides*[L]	37735	92
Spottail Shiner	*Notropis hudsonius*[L]	4286	10
White Perch	*Morone americana*[L]	2630	6
Alewife	*Alosa pseudoharengus*[L]	2258	6
White Bass	*Morone chrysops*[L]	1238	3
Freshwater Drum	*Aplodinotus grunniens*[L]	286	< 1
Mimic Shiner	*Notropis volucellus*[L]	1	< 1
Quillback	*Carpiodes cyprinus*[L]	252	< 1
Rainbow Trout	*Oncorhynchus mykiss*[L]	10	< 1
Smallmouth Bass	*Micropterus dolomieu*[L]	33	< 1
Rainbow Smelt	*Osmerus mordax*[L]	8	< 1
Troutperch	*Percopsis omiscomaycus*[L]	26	< 1
Walleye	*Stizostedion vitreum*[L]	133	< 1
Yellow Perch	*Perca flavescens*[L]	78	< 1
Gizzard Shad	*Dorosoma cepedianum*[T]	59270	145
Goldfish	*Carassius auratus*[T]	1395	3
Carp	*Cyprinus carpio*[T]	627	2
Bigmouth Buffalo	*Ictiobus cyprinellus*[T]	21	< 1
Bluntnose Minnow	*Pimephales notatus*[T]	134	< 1
Channel Catfish	*Ictalurus punctatus*[T]	42	< 1
Green Sunfish	*Lepomis cynanellus*[T]	3	< 1
Orangespotted Sunfish	*Lepomis humilis*[T]	51	< 1
Spotfin Shiner	*Cyprinella spiloptera*[T]	87	< 1
White Crappie	*Pomoxis annularis*[T]	97	< 1
White Sucker	*Catostomus commersoni*[T]	70	< 1
Largemouth Bass	*Micropterus salmoides*[P]	2803	7
Sand Shiner	*Notropis stramineus*[P]	986	2
Bowfin	*Amia calva*[P]	909	2
Pumpkinseed	*Lepomis gibbosus*[P]	434	1
Black Crappie	*Pomoxis nigromaculatus*[P]	52	< 1
Bluegill	*Lepomis macrochirus*[P]	372	< 1
Brown Bullhead	*Ameiurus nebulosus*[P]	15	< 1
Golden Shiner	*Notemigonus crysoleucas*[P]	68	< 1
Longnose Gar	*Lepisosteus osseus*[P]	18	< 1
Northern Logperch	*Percina caprodes semifascita*[P]	53	< 1
Northern Pike	*Esox lucius*[P]	14	< 1
Rockbass	*Amploplites rupestris*[P]	72	< 1
Tadpole Madtom	*Noturus gyrinus*[P]	11	< 1
Yellow Bullhead	*Ameiurus natalis*[P]	35	< 1
Round Goby	*Neogobius melanostomus*	2108	5
Creek Chub	*Semotilus artomaculatus*	1	< 1
Silver Redhorse	*Moxostoma anisurum*	1	< 1
Silver Chub	*Macrohybosis storeriana*	1	< 1
Sea Lamprey	*Petromyzon marinus*	3	< 1
Shorthead Redhorse	*Moxostoma macrolepidotum*	2	< 1

Table 21. Known required fish hosts of the unionid species returned to Metzger Marsh in 1999. Host data from Watters 1994. Fish names highlighted were not found in Metzger Marsh between 1999-2002.

Common name	Scientific name	Known fish host
Fragile papershell	*Leptodea fragilis*	Freshwater drum
Giant floater	*Pyganodon grandis*	Black crappie, bluegill, creek chub, freshwater drum, gizzard shad, golden shiner, green sunfish, largemouth bass, longnose gar, orangespotted sunfish, pumpkin-seed, white bass, white crappie, yellow bullhead, yellow perch +others
Pink heelsplitter	*Potamilus alatus*	Freshwater drum
Threeridge	*Amblema plicata*	Black crappie, bluegill, green sunfish, largemouth bass, northern pike, pumpkinseed, rock bass, white bass, white crappie, yellow perch
Lilliput	*Toxolasma parvus*	Bluegill, green sunfish, orangespotted sunfish
Mapleleaf	*Quadrula quadrula*	**Flathead catfish**
Fawnsfoot	*Truncilla donaciformis*	Freshwater drum, **sauger**
Pimpleback	*Quadrula pustulosa*	Brown bullhead, white crappie, channel catfish, **flathead catfish**
Heelsplitter	*Lasmigona complanata*	Carp, green sunfish, largemouth bass, orangespotted sunfish, white crappie
Pondhorn	*Uniomerus tetralasmus*	Golden shiner
Paper pondshell	*Utterbackia imbecillis*	No host required, but can use bluegill, creek chub, green sunfish, largemouth bass, pumpkinseed, rock bass, yellow perch
Fatmucket	*Lampsilis siliquoidea*	Black crappie, bluegill, largemouth bass, orangespotted sunfish, pumpkinseed, rock bass, **sauger**, smallmouth bass, walleye white bass, white crappie, white sucker, yellow perch
Plain pocketbook	*Lampsilis cardium*	**Black bass**, bluegill, largemouth bass, **sauger**, smallmouth bass, walleye, white crappie, yellow perch
Deertoe	*Truncilla truncata*	Freshwater drum, **sauger**
Round pigtoe	*Pleurobema sintoxia*	Bluegill
Wabash pigtoe	*Fusconaia flava*	Black crappie, bluegill, white crappie
Hickorynut	*Obovaria olivaria*	**Shovelnose sturgeon**
Strange floater	*Strophitus undulata*	None needed, but can use creek chub, largemouth bass
Spike	*Elliptio dilatata*	Black crappie, gizzard shad, white crappie, yellow perch

DISCUSSION

To some degree, the unionid population has been restored in Metzger Marsh, but its future success is not assured either at the biological or political level. The initial portion of this project, removing the unionids in 1996, boarding them elsewhere for 3 years and then returning them to Metzger Marsh in 1999, was very successful. This salvage operation was conducted under very harsh collection conditions (see photos pg. 8), with animals literally being dug out of dried mud banks during the heat of the summer. Yet in spite of this, there was very little handling mortality. In some cases over 90% of the collected individuals survived this handling, plus the entire three-year boarding experience. This is one of the few salvage projects known where long-term off-site boarding of an entire population was successful and is in direct contrast to the high mortality rates usually seen (e.g. Cope and Waller 1995). The low mortality rate enabled us to preserve much of the original species diversity. But species diversity is not always enough to ensure long-term species survival.

The species composition of Metzger Marsh has been changed and will continue to change. In 1996, Metzger contained at least 20 species, but only 17 were returned to the marsh in 1999 due to loss of the species-of-interest. While we did replace two of the three species, (deer toe and fawnsfoot), we obtained only a few individuals of each and do not know if these individuals removed from the Maumee River will survive the very different habitat provided by Metzger. One of the main problems for maintaining original species diversity was low collection numbers for several species. Only single individuals represent many of the species collected in 1996, such as the hickory nut and strange floater. Obviously, their population numbers were low in Metzger Marsh to begin with. Even though these animals survived the boarding experience and were replaced into Metzger in 1999, their ability to successfully reproduce is limited. Hermaphrodism is known to occur in unionids, but self-fertilization is rare. In all probability, these species with low population numbers are functionally extinct even though extant individuals may continue to live for many years. Thus, we hypothesize that without influx of individuals of some of these low-density species from populations outside Metzger Marsh, population diversity will continue to decline over the next few decades, even if conditions for successful recruitment for other species are present. Exactly which species will disappear cannot be completely predicted, as the minimum population size required to ensure population survival is not known. One study by Downing (2001) indicates that population densities of < 10/square meter are too isolated to successfully reproduce. However, populations in Metzger prior to 1996 did not appear to meet this minimum population level and recruitment was occurring. A key factor will be whether the fish host/gravid unionid connection occurs and if so, where in the marsh the larval unionids are released.

The future survival of this population depends on the occurrence of successful recruitment. Our hypothesis is that successful recruitment has occurred for at least a few species, based on the smaller animals collected in the fall of 2001 (Table 19). Based on the growth rates seen for the giant floater and the paper pondshell in Unit 3, the animals 40-60 mm in length collected in Metzger in 2001 are likely recent recruits, produced within the last 3 years. The case could be made that these were animals overlooked during the 1996 removal, and are thus residuals and not recent recruits. However, given the growth rates documented for one of these species in Unit 3, a six+-year-old giant floater growing in a wetland habitat should be much larger than 60 mm in length. The giant floaters >10 cm and the larger lilliput present more of an enigma, and may be either recent recruits exhibiting fast growth rate, or survivors of the 1996 marsh restoration process. It is certainly possible for a giant floater to reach 100 mm in length at the end of 2.5 years in a wetland habitat as shown in Unit 3. Unfortunately, we lack data on lilliput growth as we only have group measurements and do not know which animals were actually placed in Unit 3 in 1996. It is within the realm of possibility that a few unionids survived the restoration process. Although no live residual fauna were found during our searches for survivors in the marsh in 1997, the fact that one small live Asian clam was found does indicate that survival was possible, even if limited in extent.

While the source of the larger unmarked unionids found in the marsh in 2001 might be questioned, the presence of smaller individuals certainly does indicate that conditions in Metzger are suitable for successful recruitment to occur. The low abundance of young unionids found is likely a reflection of timing and the traditional difficulties in locating unionids <3 years of age. Young unionids are often buried deep in the substrate and are frequently difficult to sample accurately (McMahon 1991). If recruitment is truly occurring in the marsh on a regular basis, then the number of young unionids found should increase exponentially during surveys over the next few years. Since unionid replanting in the marsh only started in May 1999, successful recruitment the first year was probably limited even though gravid females were present and fish were entering the marsh. Until more young animals representing more species are found, the case for successful population restoration cannot be made.

One problem that may severely impact the future of this unionid population is where the young unionids have been found to date. The young animals were not found near the adults, but instead were found farther into the vegetated areas of the marsh. This distribution pattern most likely results from fish movement in the marsh and would be of only esoteric interest except for the future management plans for the marsh. The Metzger Marsh management team is struggling to maintain specific plant community structure and to exclude certain plant species from the upper parts of the marsh. Future management actions may lead to partial dewatering of the marsh and further treatment with herbicides. The adult unionids should only be minimally impacted by such wetland management practices, unless extremely toxic chemicals such as copper sulfate are used. The adult unionids were purposely located in the deepest part of the marsh, where the exchange of water with Lake Erie was highest, in order to protect them from future landscape manipulations, as well as to maximize contact with fish entering the marsh. However, the young unionids found only higher in the marsh could be completely exposed to any wide-scale landscape alteration plans. Additional surveys in 2003 are critical to further delineate the distribution and presence of young unionids in the marsh. Wide scale loss of young unionids at this stage of the restoration process would destroy the future of this population. The population structure has shifted toward an unnatural dominance of aging adults with many year classes of juveniles not present since no effective recruitment occurred in Unit 3. Maximizing successful recruitment over the next few years is critical to stabilizing this population. Of further concern are the current discussions among the Metzger Marsh management team regarding the closing of the fish access gate (see Appendix 1). Traditionally, periodic draw-downs of impounded wetland units are done to encourage growth of desirable vegetation while inhibiting exotic and invasive vegetation. The dewatering, which exposes mudflats. usually occurs in the spring with reflooding in early fall. If this is done in Metzger Marsh, it could have a deleterious impact on fish communities in the marsh, and break the critical unionid/fish host linkage. The key will be periodicity. Dewatering on a yearly basis will prevent unionid recruitment from occurring, thus basically destroying this population. Dewatering every once every three to four years would be less damaging. Recruitment would likely be interrupted, but production in other years would sustain this population.

This population is still one of the few remaining unionid populations known to exist in the zebra mussel infested areas of the Great Lakes. The unionid work at Meztger Marsh (see Nichols and Wilcox 1997: Nichols and Amberg 1999) has had a tremendous impact on unionid research throughout the Great Lakes. Not only was this one of the few unionid communities to survive in a zebra mussel area it was also one of the first to document the acceptability of wetland habitats to thick-shelled species. The finding that soft marsh sediments and warm water temperatures stimulate unionid burrowing and provide separation and cleansing of zebra mussels caused a flurry of surveys of similar habitats around the Great Lakes. As a result, a few other remnant populations of unionids have been found in lake-associated wetlands in areas such as Lake St. Clair and Lake Erie (see Appendix 2), including the nearby Crane Creek estuary. This does not diminish the importance of the population at Metzger. These additional populations are few in number, widely separated, usually low in density (< 2000 individuals), and are vulnerable to water level fluctuations. When low water levels occur, unionids move out into deeper water. As research described in Appendix 2 shows, if these unionids reach coarse sand, they are at risk to zebra mussel colonization and eventual mortality.

RECOMENDATIONS

1. Maintain an open and free flowing system as much as possible and encourage maximum use of the marsh by Lake Erie fish populations. This would not negate occasional closure of the marsh for vegetation manipulation.

2. Further surveys for young unionids need to be done yearly for at least the next three years to determine if recruitment is occurring consistently in a majority of species.

3. Continue to monitor the status of the adult unionids.

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