The status of unionid and dreissenid mussels in northwestern Pennsylvania inland lakes

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ABSTRACT

A survey of the native unionid fauna of the eight natural lakes in the glaciated region of northwestern Pennsylvania suggests that the documented species richness of regional lotic habitats cannot be extended to lentic habitats. Richness ranged from 0 to 5 species per lake, and population densities (<0.03 individuals/m^2) are low. The most frequent and abundant species were *Pyganodon grandis* and *Utterbackia imbecillis*, each occurring in five lakes, and making up 50% and 15% respectively of all unionids collected. Two of the lakes have been successfully colonized by *Driessena polymorpha*, with evidence of an unsuccessful introduction in a third. In Sandy Lake, 78% of the unionids were fouled by *Dreissena*, with an average density of 271 *Dreissena*/unionid. Although none of the seven species of native unionids found in this survey are regionally endangered, the prognosis for lake populations is poor.

Additional Keywords: Unionids, zebra mussels, Pennsylvania lakes, *Corbicula*, *Dreissena*.

INTRODUCTION

With a historical richness of 292 species of Unionidae and five species of Margaritiferidae, North America's freshwater mussel richness (superfamily Unionoidea) is five times greater than that of any of the other continents (Bogan, 1993; Williams et al., 1993; Lydeard et al., 2004). However, as part of a worldwide pattern of decline in many non-marine mollusks, this fauna is declining rapidly and much faster than the continent's mammal or bird fauna (Williams et al., 1993; Lydeard et al., 2004). The National Heritage Network lists 202 species that are presumed extinct, imperiled or vulnerable (Lydeard, 2004), and the Endangered Species Act recognizes that 13 species in the U.S. have gone extinct and that another 70 are threatened or endangered (U.S. Fish and Wildlife Service, 2005).

Potential reasons for these declines include siltation; release of toxic effluents from industrial, municipal, and nonpoint sources; channel modification; damming; heavy metal and pesticide bioaccumulation; anoxia due to anthropogenic eutrophication; a history of commercial exploitation; and the introduction of invasive species, particularly the zebra and quagga mussels (*Dreissena polymorpha* (Pallas, 1771) and *Dreissena bugensis* (Andrusov, 1897) (Nalepa et al., 1991; Bogan, 1993; Goudreau et al., 1993; Gillis and Mackie, 1994; Nalepa, 1994; Schloesser and Nalepa, 1994; Ricciardi et al,. 1996; Schloesser et al., 1998; Poole and Downing, 2004).

It is unclear how this loss of unionid richness and biomass will affect ecosystem function; burrowing bivalves have the potential to play important roles in many benthic and pelagic processes but these roles have gone largely understudied (Vaughn and Hakenkamp, 2001). However, rapid declines have focused recent attention on many facets of mussel biology. Researchers are working to better understand unionid life histories, distribution patterns, and taxonomy so that conservation efforts may be more effective. Part of this work involves taking inventory of current mussel diversity and distribution in various locales and focusing attention on conservation "hotspots"—places that are likely to harbor relatively high diversity.

The Pennsylvania portion of the Ohio River watershed is one of these "hotspots." Before the recent wave of extinctions there was a relatively rich fauna of 53 species in this drainage (Bogan, 1992). Twelve species have been extirpated from the area, but 41 remain, including two federally endangered species *Epioblasma torulosa rangiana* (Lea, 1838) and *Pleurobema clava* (Lamarck, 1819) (Pennsylvania Biological Survey, 2003). Because of this relatively high richness, unionid populations in the lotic waters of Pennsylvania's Ohio River drainage have received considerable attention from such groups as the French Creek Project (Meadville, Pennsylvania), The Nature Conservancy, and the Western Pennsylvania Conservancy (Pittsburgh, Pennsylvania).

In contrast, the lentic waterbodies within Pennsylvania's Ohio River drainage have received much less atten-

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tion. It is possible that these lakes harbor some of the region's mussel diversity since several of them flow into French Creek, a particularly unionid-rich tributary of the Allegheny and Ohio Rivers. French Creek harbors 27 species of unionids, including *Epioblasma torulosa rangiana* and *Pleuroblema clava.*

These lakes are also at risk for dreissenid colonization because of active recreational boat traffic in the area, and close proximity to Lake Erie and to each other. If successfully colonized by dreissenids, these lakes could serve as reservoirs from which dreissenids could then travel to other waterbodies either by going downstream via passive means or by going overland via human transport. Thus, successful dreissenid colonization could negatively affect regional unionid diversity as it did in many other drainages (Gillis and Mackie, 1994; Schloesser and Nalepa, 1994; Ricciardi et al., 1996; Schloesser et al., 1998).

In light of the potential threat of dreissenid colonization of these lakes and the current and historical levels of regional unionid diversity, we sought to accomplish the following goals: 1) Provide a benchmark assessment of unionid richness and density in the natural lakes of northwestern Pennsylvania and 2) Determine the extent of successful dreissenid and any other invasive mollusk colonization.

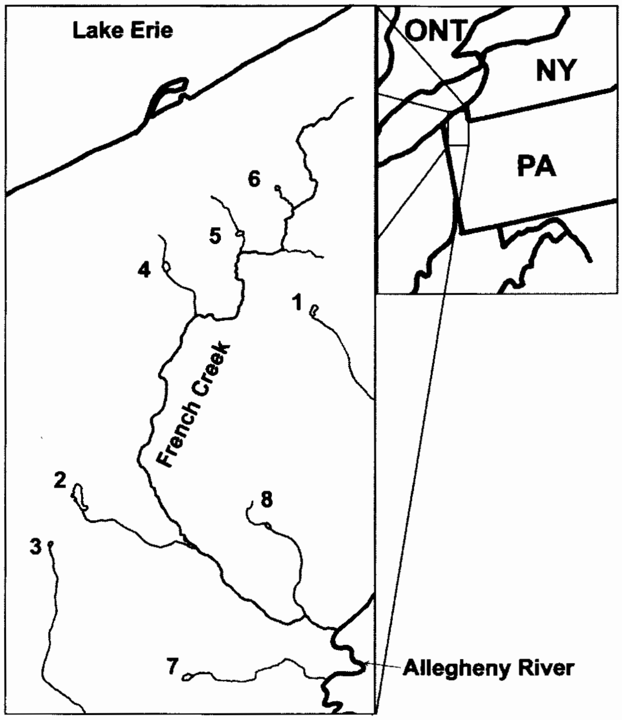

Figure 1. Study area showing the location of lakes and major streams. 1. Canadohta Lake; 2. Conneaut Lake; 3. Crystal Lake; 4. Edinboro Lake; 5. Lake LeBoeuf; 6. Lake Pleasant; 7. Sandy Lake; 8. Sugar Lake.

STUDY AREA

Natural lakes in northwestern Pennsylvania are limited to a relatively small glaciated region (approx. 9200 km^2) that includes all of Erie, Crawford, and Mercer counties, and small portions of adjacent counties. Within this region there exist 8 kettle lakes at elevations between 300 and 400 m above sea level (Figure 1). The lakes range in size from 6 to 378 ha, and are all between 20 and 80 km from the south shoreline of Lake Erie. However, all discharge to the south into the Ohio-Mississippi river drainage. Calcareous glacial deposits dominate the surface geology, and dominant land cover is mixed forest and agriculture. As a consequence, the lakes have moderately hard water, are mesotrophic to eutrophic, and undergo periodic deep-water anoxia during the summer months. All are headwater lakes, and most are drained by permanent streams that allow for easy dispersal of aquatic organisms. The single exception is Edinboro Lake that was enlarged by the construction of a 3 m hydraulic dam in the 19th century. Discharges from Canadohta and Conneaut lakes are also regulated to prevent ice damage to docks, but the outlets are unimpeded between October and May. Physical and chemical characteristics of the lakes are shown in Tables 1 and 2.

MATERIALS AND METHODS

A census of between 15 and 20 quadrats (7.6×1.5 m) took place in each of the eight lakes between August and October 2002. Three to four locations were chosen in each lake to capture nearshore physical habitat variation. For example, if a lake had sandy, rocky, and weedy areas, all three were sampled. At each location, five quadrats were established—one from each of the following depth intervals: 0–0.6m, 0.7–1.2m, 1.3–1.8m, 1.9–2.4m, and 2.5–3.0m. In most cases, the nearshore substrate conditions gave way to finer substrata as depth increased.

Quadrats were delineated with nylon rope strung between PVC pipe "stakes" that were pushed vertically into the sediments or placed flat on impenetrable substrata such as rock. Using the nylon ropes as visual and tactile guides, a diver manually probed the substrate to a depth of about 5 cm for bivalves. Each quadrat was searched twice.

In quadrats with exceptionally high densities of dreissenids a 1.5×0.6 m sub-quadrat was delineated. For dreissenids, we tallied the number of live individuals. For unionids, we tallied both live and recently dead individuals of all species. Recently dead unionids were those whose valves could be paired and identified to species. Total unionid and dreissenid densities were recorded as individuals/m^2. Where unionids were fouled with dreissenids, the number of dreissenids per unionid was also recorded.

Bivalves were identified to species level using Bogan (1992), Strayer and Jirka (1997), Parmalee and Bogan (1998), and Cummings and Mayer (1992). Nomenclature follows Turgeon et al. (1998).

In addition to quadrats described above, littoral sub-

Table 1. Physical characteristics of northwestern Pennsylvania lakes. (Current bathymetric maps for Lake LeBoeuf and Sandy Lake are unavailable.)

Lake	Location	Area (ha)	Drainage basin area (km^2)	Max depth (m)	Mean depth (m)	Outflow
Canadohta	41°48.91′N 79°50.28′W	68	20.3	13.6	5.5	Oil Creek
Conneaut	41°37.5′N 80°18.3′W	378	72.3	19.8	5.6	Conneaut Outlet to French Creek
Crystal	41°33.21′N 80°22.14′W	6.1	0.28	7.1	3.3	Crooked Creek to Shenango River
Edinboro	41°52.78′N 80°08.22′W	167	65.7	9.1	3.4	Conneauttee Creek to French Creek
LeBoeuf	41°55.61′N 79°58.96′W	32.2	158.6	9.1	—	LeBoeuf Creek to French Creek
Pleasant	42°00.22′N 79°53.85′W	23.7	3.6	13.7	6.8	Lake Pleasant Outlet to French Creek
Sandy	41°20.71′N 80°06.43′W	88.5	7.2	11.4	—	Unnamed stream to Sandy Creek
Sugar	41°33.94′N 79°56.75′W	31	56.4	5.5	3.2	Lake Creek to French Creek

habitats less than 1.8 m in depth were further sampled for benthic macroinvertebrates. This was done to improve the likelihood of finding invasive mollusks at low densities or with small body sizes. We sampled in sandy, rocky, and weedy littoral sub-habitats, although not all of these sub-habitats were present in each lake. Depending on the number of sub-habitats present, the total number of areas sampled per lake ranged from 8–17. We used steel drop boxes (0.125 m^2 and 0.25 m^2, on fine/medium-grained and cobble substrates, respectively) and a corer (0.025 m^2, where the roots of a species of *Nuphar* precluded sampling with the drop boxes). The substrate isolated by drop boxes was swept 6 times with a 900 μm mesh D-net. Catches from replicate sweeps in each drop box sample were washed and pooled. Core samples were taken to a depth of 10 cm and were similarly washed. The material was sorted in the laboratory from white trays. Any invasive mollusks were identified using the sources mentioned above and Jokinen (1992). Densities were expressed as individuals/m^2 substrate.

Voucher specimens of the species examined in this study are deposited in the Section of Mollusks at the Carnegie Museum of Natural History, Pittsburgh, as follows:

Actinonaias ligamentina: CMNH 74451; *Lampsilis siliquoidea:* CMNH 74452; *Utterbackia imbecilis:* CMNH 74453; *Pyganodon grandis:* CMNH 74454; *Lasmigona complanata:* CMNH 74455; *Ligumia recta:* CMNH 74456.

RESULTS

Native Unionids

A survey of the eight natural lakes resulted in a list of seven species of native unionids (Table 3). *Pyganodon grandis* (Say, 1829) was both the most broadly distributed, occurring in 5 of the lakes, and the most abundant, making up half of the individuals collected in all lakes. In New York State, there has been difficulty surrounding the taxonomy and identification of the closely related species *Pyganodon cataracta*, *P. grandis*, and *P. lacustris* (Strayer and Jirka 1997). However, according to Strayer and Jirka (1997) and Strayer (Institute of Ecosystem Studies, personal communication, 2003), *P. grandis* is the only one of these three species to occur in the Ohio basin. Therefore, all *Pyganodon* collected in this study were identified as *P. grandis* even if the beak sculpture was obliterated or damaged and could not be used as a definitive identifying character. *Utterbackia imbecillis* (Say, 1829) was found in five of the lakes, but it made up less than 15% of all individuals collected. *Lampsilis siliquoidea* (Barnes, 1823) was found in two lakes, and *Ligumia recta* (Lamarck, 1819), *Lasmigona complanata* (Barnes, 1823), *Actinonaias ligamentina* (Lamarck, 1819), and *Amblema plicata* (Say, 1817) were each found in only one lake. Lake LeBoeuf had the highest species richness with five species. No mussels were found in Crystal Lake.

In the 5 lakes where live unionids were present, they were found in low densities ranging from 0.01 individuals/m^2 in Conneaut Lake to only 0.03 individuals/m^2 in Canadohta Lake. In Pleasant and Sugar Lakes only valves were found. Unionid distributions and densities are shown for each lake in Tables 3 and 4.

Dreissenids and Other Invasive Mollusks

All dreissenids in this study were identified as *Dreissena polymorpha* based on morphological characteristics outlined by Pathy and Mackie (1993) and confirmed by Mackie (University of Guelph, personal communication, 2003).

Living zebra mussels (*D. polymorpha*) were found only in Edinboro Lake and in Sandy Lake. In Edinboro

Table 2. Chemical characteristics of northwestern Pennsylvania lakes. P = phosphorus.

Lake	Spring total P (μg/L)	Carlson's trophic state index	Total alkalinity (mg/L)	Total dissolved solids (ppm)
Canadohta	26.9	52	39.0	80
Conneaut	18.6	46	73.0	120
Crystal	22.8	49	61.5	130
Edinboro	30.1	53	67.0	150
LeBoeuf	47.5	60	73.5	110
Pleasant	35.8	56	95.5	140
Sandy	13.6	42	66.5	140
Sugar	41.2	58	37.0	70

Lake, the mean density of *D. polymorpha* was 52 individuals/m^2 (s.e.=48) and the mean density in Sandy Lake was 442 individuals/m^2 (s.e.=137). *Dreissena polymorpha* was densely aggregated on scattered submersed wood, rocks, and on the shells of native unionids. In Edinboro Lake, approximately 21% of the live unionids and paired valves were fouled with *D. polymorpha* and an additional 42% had been recently fouled as evidenced by attached byssal threads. The average density of fouling *D. polymorpha* in Edinboro Lake was 1.4/unionid (s.e.=1.1). In Sandy Lake, 78% of the live unionids and paired valves were fouled with *D. polymorpha*, and an additional 22% had byssal threads only. The average density of fouling *D. polymorpha* here was 271/unionid (s.e.=87).

The drop boxes yielded *D. polymorpha* valves in two other lakes. In Lake LeBoeuf shells were found in an artificially sandy area along the northwestern shore and probably were transported to the lake in beach sand dredged and imported from Lake Erie. In Canadohta Lake, a few valves were found near the Pennsylvania Fish and Boat Commission access point. Prior to this study, several live *D. polymorpha* were found at this same location in 2001. These individuals probably represent a failed introduction inadvertently brought in by recreational boaters.

The drop box samples also revealed the invasive Asiatic clam, *Corbicula fluminea* (Müller, 1774), in Conneaut and Sandy Lakes. Like *Dreissena polymorpha*, the distributions were highly aggregated with mean densities in the two lakes of 454 (s.e.=251) and 216 (s.e=87) individuals/m^2, respectively. In addition, the invasive snail *Cipangopaludina chinensis* (Reeve, 1863) was found in drop box samples from Canadohta Lake and Lake Pleasant.

DISCUSSION

The unionid assemblages in northwestern Pennsylvania's natural lakes are species-poor and low in density when compared to the unionid assemblages in the region's rivers and streams. This stream fauna is also unique in that it contains endangered species such as *Pleuroblema clava* and *Epioblasma torulosa rangiana*. In contrast, all of the taxa in our study lakes are ranked globally as "secure, common" by the Heritage ranking system and none have been granted special status under federal law or Pennsylvania code (NatureServe, 2005). In terms of within-state rankings by non-legislative groups, *P. grandis*, *U. imbecillis*, *L. siliquoidea*, *A. ligamentina* and *L. recta* all have Heritage state ranks of "secure" or "secure/vulnerable" (NatureServe, 2005) and have no status according to the Pennsylvania Biological Survey (2003). However, *L. complanata* has a Heritage state rank of "critically imperiled" (NatureServe, 2005) and is considered endangered in the state by the Pennsylvania Biological Survey (2003). Similarly, *A. plicata* has a Heritage state rank "imperiled" (NatureServe, 2005) and is considered threatened in PA by the Pennsylvania Biological Survey (2003).

It is difficult to determine if these two taxa of local concern (*L. complanata* and *A. plicata*) or any of the other taxa we found represent self-sustaining populations within our study lakes. Downing et al. (1993) found that in Lac de L'Achigan, Québec, complete fertilization failure occurs when *Elliptio complanata* (Lightfoot, 1786) is found at densities less than 10/m^2. In our study area, the density of all living unionids is less than 0.03/m^2 and much lower for a given species, thus, successful sexual reproduction is unlikely. On the other hand, Strayer et al. (1981) found similar low densities of *Elliptio complanata* (0.032 individuals/m^2) in oligotrophic Mirror Lake, and the size distribution of individuals there suggest regular recruitment. Frequent hermaphrodism may facilitate species survival in such low-density populations.

Past and present human impacts on unionid fauna of these lakes are possible since these waterbodies have

Table 3. Native Unionid species recorded from northwest Pennsylvania lakes.

	Canadohta	Conneaut	Crystal	Edinboro	LeBoeuf	Pleasant	Sandy	Sugar
Pyganodon grandis	+	+	–	+	+	–	+	–
Utterbackia imbecillis	+	–	–	–	+	+	+	+
Lampsilis siliquoidea	–	–	–	–	+	–	+	–
Lasmigona complanata	–	–	–	–	+	–	–	–
Actinonaias ligamentina	–	–	–	+	–	–	–	–
Ligumia recta	–	–	–	+	–	–	–	–
Amblema plicata	–	–	–	–	+	–	–	–
Total number of species	2	1	0	3	5	1	3	1

Table 4. Densities of live unionids and paired valves. All densities are individual per m^2. Values in parentheses are standard errors.

	Canadohta	Conneaut	Crystal	Edinboro	LeBoeuf	Pleasant	Sandy	Sugar
Live unionids	0.030	0.011	0	0.029	0.023	0	0.023	0
	(0.011)	(0.008)		(0.014)	(0.018)		(0.010)	
Paired empty valves	0.017	0	0	0.080	0.052	0.011	0.020	0.011
	(0.012)			(0.039)	(0.030)	(0.008)	(0.009)	(0.011)
Combined	0.047	0.011	0	0.109	0.075	0.011	0.040	0.011
	(0.019)	(0.008)		(0.039)	(0.028)	(0.008)	(0.014)	(0.011)

been subject to a variety of alterations such as cultural eutrophication, lakeshore development, fish stocking, water level modification, etc. However, it is difficult to ascertain whether the current density, richness, and taxonomic composition are typical for small, nutrient-rich lakes or if they represent the types of declines in richness/abundance and the alterations in taxonomic composition that have occurred in many unionid assemblages across the continent (e.g., Nalepa et al., 1991 on pre-*Dreissena* unionid declines in Lake Erie). Unionid densities in other small lakes (e.g., small Adirondack lakes, personal observation) can be much higher than found in our study area, but richness may naturally be low. For example, Strayer and Jirka (1997) found that small lakes in New York State usually contain five species or fewer. While we have some anecdotal basis for comparison, we lack models that predict unionid species' richness or abundance for lentic systems. Predictors of lentic unionid richness that are potentially worth exploring include fish species' richness and the area of oxygenated lake bottom (see Watters (1992) for an exploration of similar predictors in lotic systems).

Another way to assess the current status of unionidae in PA's lakes would be to draw comparisons between past and present. We searched for historical records of the freshwater mussel fauna in these lakes from the Cleveland Museum of Natural History (Cleveland, Ohio), the Carnegie Museum of Natural History (Pittsburgh, PA), and from documents by key mussel collectors, primarily A.E. Ortmann, who surveyed for the Carnegie Museum in the early 20th century. Specific documents searched included Ortmann (unpublished, 1909, 1911, 1919). These efforts yielded only species lists in Ortmann (unpublished), a few specimens in the physical collections at the Carnegie Museum, and a few records in the Carnegie's electronic database. These bits of information summed to an early 20th century, anecdotal account for Conneaut Lake and Edinboro Lake (then called "Conneauttee" Lake in Ortmann, unpublished). Thus, overall, the dearth of quantitative and taxonomically clear information on the past mussel fauna of our study area makes inferences regarding human impacts speculative at best.

In any case, whether due to natural factors or human impacts, unionid assemblages in the glacial lakes of northwestern, PA are currently low in density and low in species richness and the establishment of zebra mussels is likely to cause density and species richness to become even lower. The average number of fouling zebra mussels/unionid specimen in Sandy Lake is well over 100 and models by Ricciardi et al. (1995) predict that this degree of fouling will result in greater than 90% unionid mortality. Whereas the average number of fouling *Dreissena polymorpha*/unionid specimen was only 1.4 in Edinboro Lake, this number is probably not an accurate indicator of the overall degree of fouling. Winter drawdown has been used at Edinboro Lake to manage dreissenid populations (Grazio and Montz, 2002) and the lake was drawn down approximately 1.5 m during the winter prior to this study. Thus many of the zebra mussels that were fouling unionids in depths shallower than 1.5 m were killed due to exposure, leaving only byssal threads on 42% of our specimens (22% of the specimens were fouled by byssal threads only in Sandy Lake). However, below the drawdown level, zebra mussels persist in field densities up to 727 individuals/m^2 and thus are likely to keep fouling unionids even if periodic drawdown is successful in reducing *D. polymorpha* in shallow depths.

Because the unionids in these lakes possibly do not represent self-sustaining populations, it is unlikely that *D. polymorpha*-induced losses within these waterbodies will contribute to any further decrease in richness or abundance on a regional scale. However, the potential spread of *D. polymorpha* from the lentic waterbodies of northwestern PA to nearby unionid-rich lotic systems is a potential threat to regional diversity. In addition, while not necessarily a threat to unionid populations, the presence of *Corbicula fluminea* in Conneaut Lake and Sandy Lake (Strayer, 1999) and the invasive snail *Cipangopaludina chinensis* in Lake Pleasant and Canadohta Lake highlights the need for continued public education as to the causes and potential impacts of the spread of invasive species.

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