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SAMPLING FRESHWATER MUSSEL POPULATIONS: THE BIAS OF MUSKRAT MIDDENS

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ABSTRACT – Shells of freshwater mussels collected from middens of muskrats (*Ondatra zibethicus*) often are used in unionid survey work as indicative of the *in situ* population. The relative abundance of mussel species in samples collected from middens was compared with adjacent beds in the lower Muskingum River in Ohio. All samples from middens differed significantly in both mussel diversity and relative abundance from the beds from which they were derived. Samples collected from muskrat middens represent a biased sample that may lead to erroneous conclusions concerning population and community structure of the parent bed.

Key words: Unionidae, predation, Muskingum River, Ohio, muskrat.

INTRODUCTION

Muskrats (*Ondatra zebithicus* (Linnaeus 1758)) are important predators on freshwater mussels (Lee, 1886; Apgar, 1887), including endangered taxa. Muskrats in one lake in Alberta ate an average of 350 mussels a day in the autumn, and over 37,000 a year (Hanson *et al.*, 1989; Convey *et al.*, 1989). Middens often contain hundreds or thousands of shells, usually in good condition. Sampling middens is time and labor efficient when compared to diving, brailing, or other methods that require finding living individuals *in situ*. When available, material from middens often is included in a survey.

There is, however, some evidence to suggest that muskrats are selective in their mussel predation. Bovbjerg (1956), working with a small sample size, found that the relative abundance of mussel species found in muskrat middens differed from that in a nearby stream for several species. Neves & Odom (1989) compared middens during different seasons of the year with quadrat studies of eight species of mussels living in the North Fork Holston River, Virginia. Five species were present in approximately the same relative abundance in both middens and quadrats. Individuals of *Pleurobema oviforme* (Conrad 1834) and the federally endangered *Fusconaia cuneolus* (Lea 1840) were more abundant in middens, however, than in

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the mussel beds. Muskrats avoided the smallest species available, *Medionidus conradicus* (Lea 1834). Elsewhere, Bruenderman & Neves (1993) found juveniles of *Fusconaia cuneolus* to be more common in middens than in collections of live individuals from the Clinch River, Virginia. Conversely, Hanson *et al.*, (1989) found that muskrats primarily ate the largest mussel individuals.

During the fall of 1992, the lower 54 km of the Muskingum River in Ohio were surveyed for mussels by brail, diving, and midden collection (Ecological Specialists, Inc., 1993). This river reach harbors one of the densest and most diverse mussel populations left in North America, with beds having up to 124 individuals per m^2 comprising 34 species. Middens were common, frequently large, and located next to identified beds. The large sample size and high diversity enables one to ascertain the importance of differential muskrat predation on a greater scale than was available to Bovbjerg (1956) and Neves & Odum (1989).

METHODS

The lower Muskingum River is a reach impounded by locks and dams. The average depth is 3-5 m, and the river width is 0.24 km.

The river bank is wooded to the west, with small cottages on the east bank. Middens were found primarily on the west bank. During low water, sand and gravel shoals are emergent below the dams.

The Muskingum River was sampled during 23 September to 30 October 1992 from river mile 34.1 to the mouth. Beds were located by brailing, and sampled quantitatively and qualitatively by divers using a surface air compressor. The quantitative work consisted of forty 0.25 m^2 quadrats placed at random along five 33.3 m, randomly spaced, transect lines within a bed. Each quadrat was excavated to a depth of 15-20 cm. Qualitative work consisted of a diver collecting all specimens found within 1-2 hours. Because the results consisted of all individuals encountered, whether within a quadrat (quantitative) or without (qualitative), these data were combined for this analysis. No evidence was found that individual mussel species were not randomly distributed throughout the mussel bed. The study area was defined as the whole mussel bed, not a quadrat, and only the sum numbers of individuals of each species present in the bed were used, regardless of how obtained. Muskrat middens were found next to these beds and all shells found in middens were identified to species and counted.

Middens were of two types, defined as home base and feeding site middens. Home base middens consisted of large middens associated with the muskrat's burrow, usually among the exposed roots of trees lining the shore. Feeding site middens were found along the shore and on exposed shoals. These were smaller middens that probably represented a single night of predation.

The middens used in this study were chosen by two criteria: size and proximity to a bed. The four largest middens, or series of feeding site middens on a single island, were chosen to obtain sufficient numbers for detailed analysis. These middens clearly were associated with existing beds (Beds 3 and 5 of the survey), being located on the nearest shore or on islands within a bed.

Because the purpose of this study was to compare midden diversity with that of the

parent bed, it was necessary to
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parent bed, it was necessary to reconstruct the diversity of the parent bed. Thus the total for a given bed was the sum of all *in situ* individuals as well as all material collected from the nearby muskrat middens (Table 1). *In situ* material was used from both quantitative and qualitative diving studies. The material collected by brailing is not included, but represents a negligible fraction of the total number found. The number of muskrats responsible for the middens is not known.

Because the relative abundances of species between a midden and the total for the bed are assumed to be covariant, data were compared with a pairing design test, a type of t-test. The more typically used group comparison test increases the likelihood of accepting a false null hypothesis in this case (Woolf, 1968). The data for each species were expressed as a percentage of the total untransformed numbers and arcsin transformed.

RESULTS

A total of 11,139 individuals of 34 unionid species were found in the survey, including living specimens of the U. S. federally endangered *Cyprogenia stegaria* (Rafinesque, 1820), and ten species listed as endangered by the State of Ohio. The data set used here represents 7,581 individuals of 32 species.

The most abundant mussel species were *Quadrula pustulosa* (Lea 1831) *Obliquaria reflexa* Rafinesque 1820, *Quadrula quadrula* (Rafinesque 1820), *Pleurobema cordatum* (Rafinesque 1820), and *Amblema plicata* (Say 1817) (Table 1). The hypothesis that the mussel species relative abundance from middens was the same as the parent bed was rejected in all cases ($P < 0.05$). Muskrats did not remove mussels at random from the mussel beds. In every case, the relative abundances of the dominant mussel species collected from middens differed from those of their parent beds.

Two of the dominant species were found to be underrepresented in middens: *Amblema plicata* and *Pleurobema cordatum*. *Amblema* is a heavy species when adult that may be too heavy for a muskrat to handle, and was underrepresented by at least a factor of ten in three of the middens. However, it was accurately represented in one midden, mostly as juveniles. There was no indication that this species was more common near that midden than any other. The reasons why *Pleurobema cordatum* was not selected are unknown. The most massive North American species, *Megalonaias nervosa* (Rafinesque 1820), also may be underrepresented, but was too rare in the study for this conclusion to be drawn.

Three taxa were over represented: *Leptodea fragilis* (Rafinesque 1820), *Obliquaria reflexa* and *Quadrula pustulosa*. *Leptodea* was over represented by a factor of two in three of the middens, but underrepresented by a factor of four in the fourth midden. These species

TABLE 1. Mussel species and numbers found in each midden and in parent bed. * = species not found in bed.

Taxa	Bed 3				Bed 5							
	Midden 1		Total		Midden 1		Midden 2		Midden 3		Total	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Actinonaias ligamentina	1	0.09	4	0.14	0	0.00	0	0.00	0	0.00	3	0.06
Alasmidonta marginata				*	0	0.00	0	0.00	0	0.00	1	0.02
Amblema plicata	9	0.79	353	12.38	2	0.27	4	0.81	155	11.23	504	10.66
Anodonta grandis	1	0.09	4	0.14	1	0.13	1	0.20	3	0.22	5	0.11
Anodonta imbecillis	1	0.09	1	0.04	0	0.00	0	0.00	1	0.07	1	0.02
Cyprogenia stegaria	*	*	*	*	2	0.27	0	0.00	0	0.00	6	0.13
Ellipsaria lineolata	5	0.44	16	0.56	53	7.07	19	3.84	42	3.04	150	3.17
Fusconaia flava	*	*	*	*	0	0.00	1	0.20	0	0.00	1	0.02
Fusconaia maculata	1	0.09	7	0.25	0	0.00	0	0.00	0	0.00	2	0.04
Lampsilis radiata luteola	*	*	*	*	0	0.00	1	0.20	0	0.00	1	0.02
Lampsilis ventricosa	0	0.00	3	0.11	0	0.00	0	0.00	2	0.14	8	0.17
Lasmigona complanata	0	0.00	2	0.07	0	0.00	0	0.00	5	0.36	18	0.38
Lasmigona costata	0	0.00	2	0.07	0	0.00	0	0.00	0	0.00	1	0.02
Leptodea fragilis	29	2.56	46	1.61	2	0.27	14	2.83	36	2.61	51	1.08
Megalonaias nervosa	0	0.00	1	0.04	2	0.27	0	0.00	2	0.14	19	0.40
Obliquaria reflexa	430	37.89	856	30.01	306	40.80	250	50.51	568	41.16	1610	34.05
Obovaria subrotunda	3	0.26	8	0.28	19	2.53	4	0.81	1	0.07	25	0.53
Plethobasus cyphyus	*	*	*	*	1	0.13	0	0.00	0	0.00	2	0.04
Pleurobema cordatum	42	3.70	202	7.08	3	0.40	35	7.07	127	9.20	781	16.52
Pleurobema rubrum	*	*	*	*	0	0.00	0	0.00	0	0.00	1	0.02
Pleurobema sintoxia	1	0.09	5	0.18	2	0.27	0	0.00	0	0.00	6	0.13

TABLE 1 (continued)

Taxa	Bed 3		Bed 5			
	Midden 1	Total	Midden 1	Midden 2	Midden 3	Total

Lasmigona complanata	0	0.00	2	0.07	0	0.00	0	0.00	5	0.36	18	0.38
Lasmigona costata	0	0.00	2	0.07	0	0.00	0	0.00	0	0.00	1	0.02
Leptodea fragilis	29	2.56	46	1.61	2	0.27	14	2.83	36	2.61	51	1.08
Megalonaias nervosa	0	0.00	1	0.04	2	0.27	0	0.00	2	0.14	19	0.40
Obliquaria reflexa	430	37.89	856	30.01	306	40.80	250	50.51	568	41.16	1610	34.05
Obovaria subrotunda	3	0.26	8	0.28	19	2.53	4	0.81	1	0.07	25	0.53
Plethobasus cyphyus	*	*	*	*	1	0.13	0	0.00	0	0.00	2	0.04
Pleurobema cordatum	42	3.70	202	7.08	3	0.40	35	7.07	127	9.20	781	16.52
Pleurobema rubrum	*	*	*	*	0	0.00	0	0.00	0	0.00	1	0.02
Pleurobema sintoxia	1	0.09	5	0.18	2	0.27	0	0.00	0	0.00	6	0.13

TABLE 1 (continued)

Taxa	Bed 3				Bed 5							
	Midden 1		Total		Midden 1		Midden 2		Midden 3		Total	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Potamilus alatus	5	0.44	16	0.56	2	0.27	13	2.63	26	1.88	51	1.08
Potamilus ohiensis	0	0.00	2	0.07	0	0.00	0	0.00	5	0.36	7	0.15
Quadrula metanevra	0	0.00	1	0.04	43	5.73	0	0.00	2	0.14	61	1.29
Quadrula pustulosa	576	50.75	1222	42.85	199	26.53	99	20.00	209	15.14	695	14.70
Quadrula quadrula	15	1.32	52	1.82	111	14.80	41	8.28	166	12.03	638	13.49
Strophitus undulatus	0	0.00	2	0.07	*	*	*	*	*	*	*	*
Truncilla donaciformis	16	1.41	47	1.65	0	0.00	13	2.63	25	1.81	71	1.50
Truncilla truncata	*	*	*	*	2	0.27	0	0.00	5	0.00	10	0.21
Totals	1135		2852		750		495		1380		4729	

* = species not found in bed.

represent both thin and thick shelled species, as well as sculptured and unsculptured, and are of medium size when adults (70-120 mm). With the possible exception of their taste to the muskrat, these species have little in common that would suggest a cause for their over representation.

DISCUSSION

Marinelli & Messier (1993) summarized the data on the home range size of muskrats in their study and others. Home range size varied between 0.03 and 4.24 ha. This is substantially smaller than the mussel beds on which the Muskingum River muskrats fed. It is unlikely that the muskrats responsible for the middens bypassed the adjacent bed to travel to a farther one and then transport the shells back. There seems little question that the shells in a midden came from the adjacent bed.

It also is unlikely that the shells within a midden were not gathered the same year that the survey was conducted. Winter and spring high water wash away middens made the previous summer and autumn and new middens are constructed each year (personal observations). The shells within the middens are, therefore, concurrent to those collected in the diving survey.

Muskrats appear to sample mussel beds in a non-random manner. Middens on the Muskingum River often contain many juvenile mussels (< 40 mm). Heavy, older individuals presumably are too cumbersome to carry and were passed over. It did not matter if the shells were thin or thick, or sculptured or smooth. Species seemed to be favored or avoided for reasons not yet known. Taste may be a factor.

Although Hanson *et al.* (1989) and Convey *et al.* (1989) found that muskrats selected the largest mussels, their study area did not have the massive species of the Muskingum River, such as *Megalonaias nervosa*. Indeed, Narrow Lake supports only the thin-shelled *Anodonta grandis simpsoniana*. That species is much lighter than most unionids of the same size, and apparently was manageable at large sizes (up to 90 mm long) by muskrats.

The results support the conclusion of Bovbjerg (1965) and Neves & Odum (1989) that muskrats selectively prey on certain unionid species in a mussel bed. This study addresses a widespread and common practice among field malacologists interested in unionid diversity: the use of muskrat middens as estimates of mussel populations. The results indicate that muskrats are biased collectors and that

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their middens do not represent the actual diversity or relative abundance *in situ*. Results of other studies suggest that there is a further bias in the sizes of individuals of a species found in middens (Hanson *et al.*, 1989; Bruenderman & Neves, 1993). Interpretations and generalizations about a unionid population based on midden material are apt to be incorrect.

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