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DISTRIBUTION, ABUNDANCE, AND BIOMASS OF FRESHWATER MUSSELS (BIVALVIA:UNIONIDAE) IN LAKE ST. CLAIR

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ABSTRACT. A mussel population survey was conducted in Lake St. Clair with divers using SCUBA to sample at 29 stations throughout the lake. Mean abundance was 2 m^{-2} and mean biomass was 4.4 g dry wt m^{-2}. Of the 18 species collected, Lampsilis radiata siliquoidea *was by far the most abundant, accounting for 45% of all individuals. The age-frequency distribution of* L. r. siliquoidea *was dominated by individuals between 9 and 12 years old. In contrast, the second most abundant species,* Leptodea fragilis, *showed yearly variation in recruitment with no apparent trends in year class strength. Annual production of* L. r. siliquoidea *was 0.20 g m^{-2} y^{-1} and the turnover ratio was 0.13. The diversity and composition of mussels in Lake St. Clair appear little changed since the turn of the century, but there are indications that population numbers may be declining in the future.*
ADDITIONAL INDEX WORDS: Molluscs, clams, productivity.

INTRODUCTION

The species composition and distribution of unionid bivalves (mussels) in the Great Lakes are well-known (Gooderich and van der Schalie 1932, van der Schalie 1961, Mackie *et. al.* 1980, Clarke 1981), but accurate estimates of mussel abundance, biomass, and production are generally lacking. This can be attributed directly to the difficulty in obtaining quantitative samples of mussels, particularly in offshore waters. Conventional sampling devices such as grab samplers do not adequately sample mussel populations (Haukioja and Hakala 1974, Isom and Gooch 1986), while dredges, although used by some to quantify mussels (Wood 1963), provide uncertain abundance estimates even when calibrated. Sampling with SCUBA is undoubtedly the most accurate technique for obtaining quantitative population estimates (Isom and Gooch 1986), but studies using this approach in the Great Lakes have been either qualitative in nature (van der Schalie 1986), concerned only with growth rates (McCuaig and Green 1983), or have had a limited sampling area (McCall *et. al.* 1979, University of Windsor 1984).

In this paper we give the composition, abundance, and biomass of the mussel population in Lake St. Clair and determine the production and age structure of the most abundant species, *Lampsilis radiata siliquoidea*. All samples were taken using SCUBA.

DESCRIPTION OF STUDY SITE

Lake St. Clair lies at the center of the 125-km-long waterway between Lake Huron and Lake Erie. It has an area of 1,110 km^2, a volume of 3.4 km^3, and a mean depth of 3 m. The main inflow, accounting for about 98% of the total input, is from the St. Clair River, which has a mean flow rate of about 5,100 m^3/s. The theoretical flushing rate of the lake is about 9 days. The waters of Lake St. Clair are usually well-mixed; thermal stratification does not occur and oxygen concentrations remain close to saturation. Other physical and chemical characteristics include: alkalinity, 81.6 mg/L; total calcium, 29.1 mg/L; suspended solids, 12.1 mg/L; secchi depth, 1.5 m; and chlorophyll *a*, 4.7 μg/L (Herdendorf *et al.* 1986).

METHODS

Mussels were collected at 29 stations (Fig. 1) in Lake St. Clair in September, 1986. Station locations were the same as given in Pugsley *et al.* (1985). Divers positioned a 0.5 m^2 frame on the

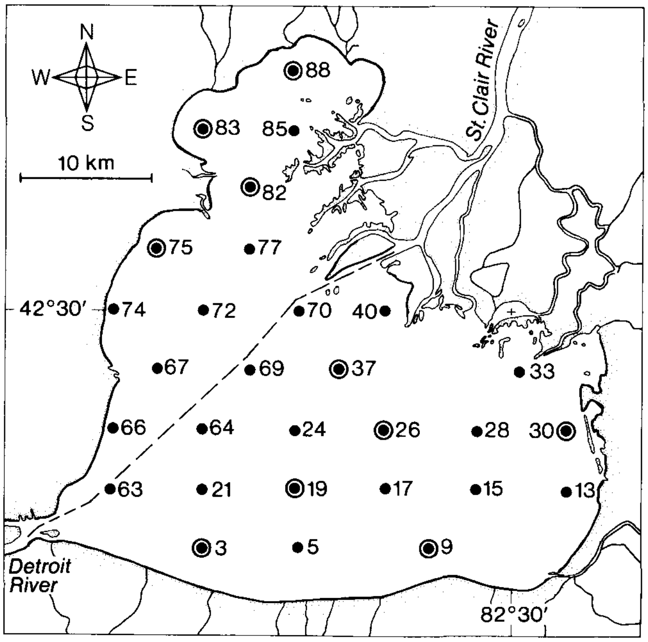

FIG. 1. Location of sampling stations in Lake St. Clair, September 1986. The circled stations were also sampled with a Ponar in October 1986. Station numbers correspond to those used by Pugsley et al. *(1985). Dashed line indicates shipping channel.*

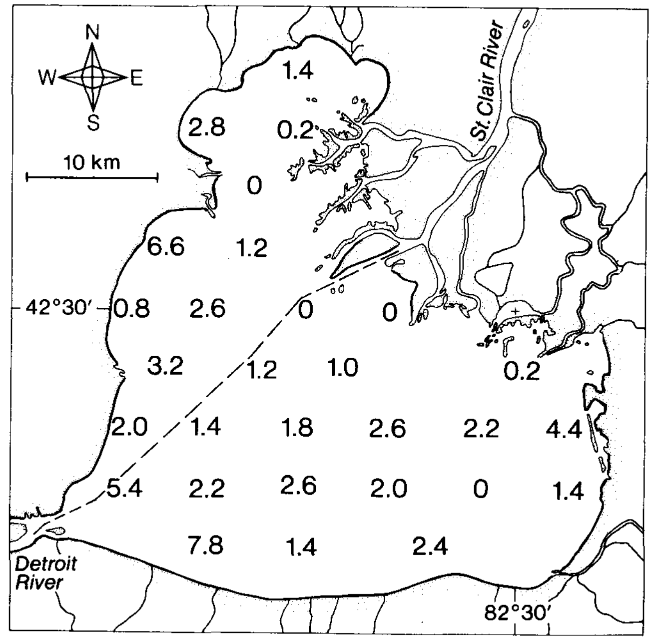

FIG. 2. Mean abundance (number per m²) of mussels at each of the sampling stations in Lake St. Clair.

lake bottom and collected all mussels, including empty shells, within the frame area. Visibility at most stations was poor, so collections were made mostly by touch, with divers probing the upper 5 cm of sediment. Ten replicate samples were taken at each station.

All live mussels were immediately opened and the soft tissue was placed in preweighed aluminum planchets. Dry weights of the tissue and the shell were obtained separately after drying at 60°C for at least 48 h. Total shell lengths were determined to the nearest mm with vernier calipers.

Ages of individuals of the two most abundant species, *Lampsilis radiata siliquoidea* and *Leptodea fragilis*, were determined by counting the number of external growth rings on the shell. The annularity of the growth rings was not verified, but other investigators have confirmed that external growth rings are produced annually in environments at similar or greater latitudes (Isely 1914, Negus 1966, Haukioja and Hakala 1978, Ghent *et al.* 1978). Further, the slow and uniform temperature changes in large water bodies such as Lake St. Clair eliminate the primary cause of false annuli or "disturbance rings" (Grier 1922, Stansbery 1961). True annuli were distinguished from false annuli using the guidelines of Stansbery (1961). When the nature of the ring was ambiguous, it was not counted as a true annulus, thus, age estimates are considered conservative.

Total annual production of *L. r. siliquoidea* was estimated from the sum of the production of each age class (Magnin and Stanczykowska 1971). Since only five individuals older than 13 years were collected and the dry weights of these individuals were not consistent with respect to age, weights used in production estimates for the 13 + ages classes were based on the relationship log (wt) = -1.33651 + 1.57545 log (age). This relationship was derived from a regression using all individuals of this species.

RESULTS

The mean population abundance of mussels in Lake St. Clair was 2 m^{-2} (range 0 - 8 m^2) and the mean biomass (shell-free dry weight) was 4.4 g m^{-2} (range 0 - 19.4 g m^{-2}). In general, both abundance and biomass increased with increased distance downstream from the mouth of the St. Clair River (Figs. 2 and 3). This distribution was similar to trends in water column productivity and potential sources of food; both nutrients and algal pigments

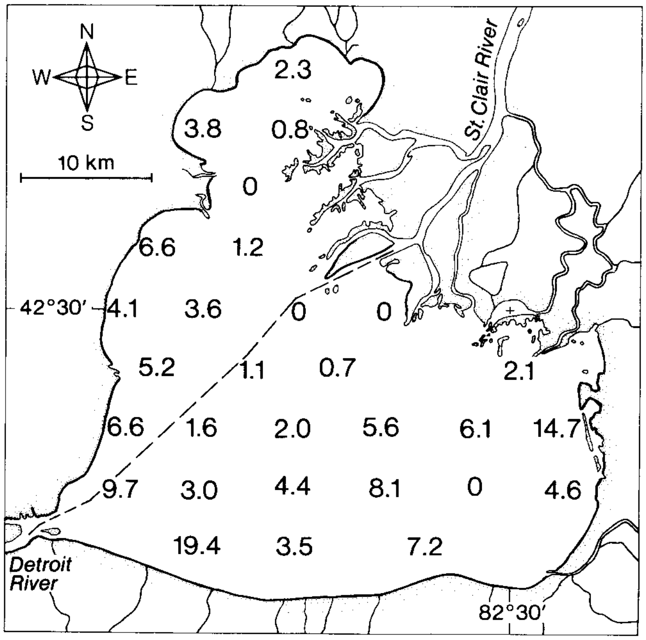

FIG. 3. Mean biomass (g shell-free dry wt per m²) of mussels at each of the sampling stations in Lake St. Clair.

are lower near the mouth of the St. Clair River and increase in areas farther south (Leach 1972). Areas near the St. Clair River mouth are more influenced by the cold, low-nutrient waters from Lake Huron, while areas to the south are more influenced by the stable, enriched waters from Ontario tributaries (Leach 1980).

Substrate type at each of the 29 stations is given in Table 1. Abundances at individual stations were highest in sediments consisting of coarse sand/gravel with some overlying silt (Stations 3, 30, and 63).

Eighteen different species were identified from the 281 individuals collected (Table 2). The three most abundant species, *L. r. siliquoidea, L. fragilis,* and *Proptera alata*, accounted for 45%, 13%, and 10% of all live individuals. The former species was the most widely distributed, being collected at 22 of the 25 stations where mussels were found. Nine species were represented by less than five individuals each.

The age structures of *L. r. siliquoidea* and *L. fragilis* are given in Figure 4. Few individuals younger than 4 years of age or older than 12 years were collected for either species. For *L. fragilis*, the age-frequency distribution of individuals 4–12 years of age was quite similar to that found for mussels in other freshwater lakes (Okland 1963, Strayer *et al.* 1981, Paterson 1985) and reflected yearly variation in recruitment with no apparent trends in year-class strength. However, the age-frequency distribution of *L. r. siliquoidea* was skewed toward the older age classes; individuals 9–12 years old were far more abundant than individuals 4–8 years old.

To determine the age at which mortality was most frequent, age determinations were also made on the empty shells (no soft tissue) of *L. r. siliquoidea*. Unlike the age-frequency distribution of live individuals, the age-frequency distribution of these dead individuals was skewed toward the younger age classes (Fig. 5).

Since young mussels are easily missed when samples are collected by hand, an additional ten replicate samples were taken with a Ponar grab at each of ten stations the following month (see Fig. 1 for the location of these stations). The samples were immediately washed through a screen with 500-μm openings. Five mussels were collected in the 100 samples, and all were juveniles (either 1 or 2 years old). This compares to just three juveniles collected in the SCUBA survey. The average mussel density in the Ponar samples was 1 m^{-2}, compared to 2.7 m^{-2} at the same 10 stations in the SCUBA survey.

Both shell length and dry weight of *L. r. siliquoidea* increased at a constant rate after age 4 (Fig. 6). The growth rate (expressed as increase in shell length with age) was lower than found at several sandy, shallow sites in western Lake Erie (Brown *et. al.* 1938), but similar to growth rates at a deep, silty site (10 m) in western Lake Erie (Roth and Mozley, unpublished) and at several sites in Long Point Bay, Lake Erie (McCuaig and Green 1983). Absolute growth rate in mussels is related to substrate type, with most rapid growth occurring in coarse sediment and slower growth occurring in fine sediments (Stansbery 1970, Hinch *et. al.* 1986). This is more related to a morphological adaptation to the environment than to differences in food or feeding efficiency; mussels with large and long shells are more suited to maintaining position in sandy sediments, while mussels with smaller, more obese shells are less likely to sink in soft sediments (Tevesz and McCall 1979, Hinch *et. al.* 1986). Consistent with these results, length at a given age in this survey was generally greater for individuals collected from stations with coarse sediments than from stations with fine sediments (Table 3).

TABLE 1. Water depth and substrate type of sampling stations in Lake St. Clair, September 1986.

Station	Depth (m)	Substrate	Station	Depth (m)	Substrate
85	3.3	silty clay	28	6.1	silty clay
74	3.0	silty sand	63	6.1	silt over gravel
83	3.6	silt, macrophytes	70	6.1	sand
33	3.6	sand	21	6.4	silt
82	4.2	sand	72	6.4	silt
40	4.5	sand	17	6.7	silt
66	4.5	silty sand	64	6.7	silt
88	4.5	silt, macrophytes	67	6.7	silt
13	4.8	silt	69	6.7	silt
30	4.8	silt over coarse sand	15	7.0	silt
75	4.8	silt	37	7.0	silty clay
3	5.2	silt over gravel	19	7.3	silt
77	5.2	sand	24	7.3	silt
9	5.5	coarse sand, gravel	26	7.3	silt
5	6.1	silt			

TABLE 2. List and frequency (total collected) of unionid species in Lake St. Clair, September 1986.

Species	Total Collected
Amblema plicata Say	6
Anodonta grandis grandis Say	14
Elliptio dilatata (Rafinesque)	20
Fusconaia flava (Rafinesque)	10
Lampsilis fasciola Rafinesque	1
Lampsilis ventricosa (Barnes)	16
Lampsilis radiata siliquoidea (Barnes)	127
Lasmigona complanata (Barnes)	1
Leptodea fragilis (Rafinesque)	37
Ligumia nasuta (Say)	8
Ligumia recta (Lamarck)	3
Obvaria subrotunda (Rafinesque)	1
Pleurobema cordatum f. coccineum (Rafinesque)	1
Proptera alata (Say)	29
Quadrula quadrula (Rafinesque)	2
Strophitus undulatus (Say)	1
Truncilla donaciformis (Lea)	1
Truncilla truncata Rafinesque	3

Annual production of *L. r. siliquoidea* over all stations was 0.20 g DW m^{-2} y^{-1} and the turnover ratio (P/B) was 0.13.

DISCUSSION

Mussel abundances in this survey were generally lower than abundances reported in other surveys in the Great Lakes. For instance, mean abundances of 5 m^{-2} (Carr and Hiltunen 1965; Peterson grab), 7 m^{-2} (Wood 1963; drag dredge) and 10 m^{-2} (McCall *et al.* 1979; SCUBA) have been reported from western Lake Erie, while a mean abundance of 7 m^{-2} was reported from seven stations in southwestern Lake St. Clair (University of Windsor 1984; SCUBA). Our results can be directly compared to the latter survey (conducted in 1983) since three sampling stations overlapped and collection techniques were similar (SCUBA). Abundances in our survey were significantly ($P < 0.05$) lower at two of the three stations (Table 4). Since only three stations were compared, it is not clear whether our lower abundances reflected an actual decline in the population, or were simply a result of horizontal patchiness. Yet reports of a large die-off of mussels in Lake St. Clair in the summer of 1985 (Neves 1987; David Kenaga, Michigan Department of Natural Resources, personal communication 1988) may indicate that a large decline in populations in the time period between the two surveys did indeed occur.

In western Lake Erie, mussel abundance and

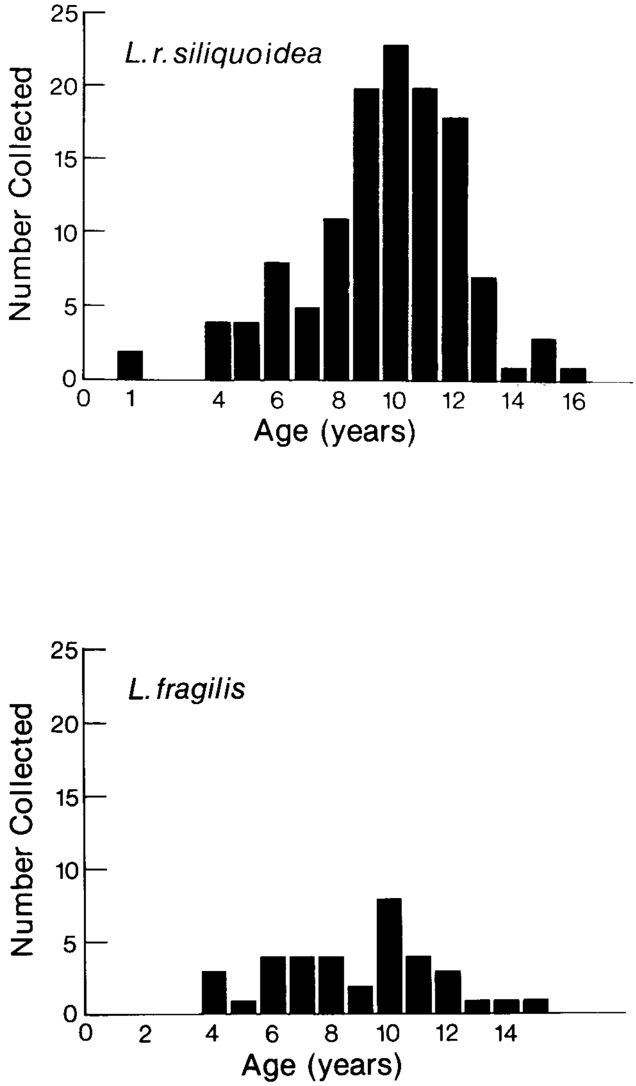

FIG. 4. Age-frequency distribution of the two most abundant species, **L. r. siliquoidea** *and* **L. fragilis.**

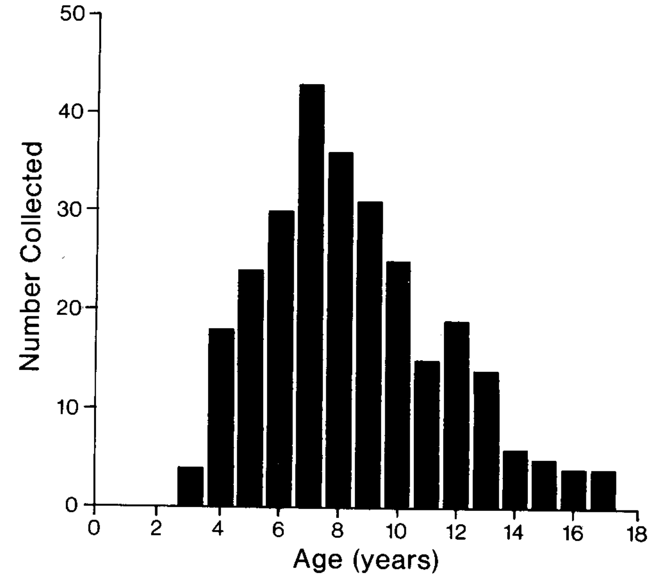

FIG. 5. Age-frequency distribution of empty shells (no soft tissue) of **L. r. siliquoidea.**

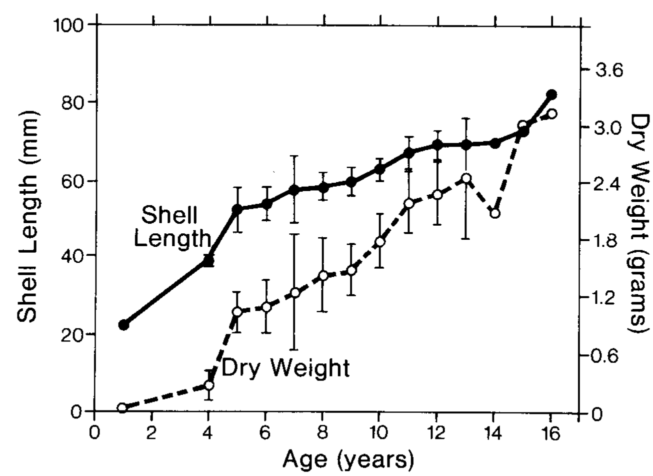

FIG. 6. Mean shell length vs. age (±95% confidence level) and mean dry weight vs. age (±95% confidence level) of **L. r. siliquoidea** *in Lake St. Clair, September 1986.*

diversity have apparently declined over the past few decades (Mackie *et al.* 1980). Unfortunately, historical records of mussel abundance in Lake St. Clair are lacking. Almost a century ago, Reighard (1894) reported finding 20 species in the lake, with *L. r. siliquoidea* being very "widespread and abundant" and *Proptera alata, Ligumia nasuta*, and *Anodonta grandis* being found "frequently." Thus, mussel diversity and composition appear to have changed little since the turn of the century. The only notable difference between our survey and Reighard's was in the relative abundance of *L. fragilis*; Reighard reported this species as "scarce," whereas it was the second most abundant species in our survey.

The scarcity of individuals younger than 4 years is a common finding in population surveys of mussels (Lewandowski and Stanczykowska 1975, Negus 1966, Green 1980, Strayer *et al.* 1981, Samad and Stanley 1986). Because of their small size, juvenile mussels are easily missed when sam-

TABLE 3. Mean shell length (mm) of **L. r. siliquoidea** *at a given age at stations with sand/gravel sediments (total of 11 stations) and at stations with silt sediments (total of 18 stations) in Lake St. Clair. SD = standard deviation, n = number of individuals.*

	Sand/Gravel			Silt		
Age	x	SD	n	x	SD	n
5	51.8	6.2	2	51.9	1.8	2
6	56.5	5.1	3	52.0	4.4	5
7	59.5	0.7	2	56.4	10.2	3
8	60.2	4.2	2	58.4	5.3	9
9	65.4	6.1	7	56.1	5.8	13
10	69.7	4.8	2	62.8	6.0	21
11	67.3	5.5	6	67.9	9.6	14
12	73.6	8.1	5	68.0	7.0	13
13	73.2	14.1	2	69.3	4.7	5

*TABLE 4. Comparison of mean mussel abundances (per m^{-2}) at three stations in Lake St. Clair in 1983 (University of Windsor 1984) and in 1986 (this study). Standard error in parentheses. * = Abundances significantly different at the 0.05 level (t-test).*

Station	1983	1986
3	13.8 (1.7)	7.8 (1.5)*
21	9.8 (2.1)	2.2 (0.9)*
66	2.4 (0.6)	2.0 (0.7)

ples are collected by hand, and they apparently burrow deeper into the sediments than do adults (Coker *et al.* 1921), further confounding the sampling problem. Using a grab sampler might provide a better representative number of juveniles in the population (Paterson 1985), but total numbers are likely to be underestimated (Haukioja and Hakala 1974). Our study showed, as is typical, that more juveniles are collected when using a grab sampler, but total abundance is better estimated using SCUBA.

The age-frequency distribution of *L. r. siliquoidea* indicated a population dominated by individuals 9–12 years old. The decline in the number of individuals 12+ years old and the near absence of individuals < 4 years old was likely related to age-specific natural mortality, and biased sampling techniques, respectively. However, the relatively low number of 4- to 8-year-old individuals is not easily explained. Reasons may include the following: (1) a decline in recruitment success of *L. r. siliquoidea* since 1978 (year class of 8-year-olds); (2) an increase in mortality of young individuals since 1978; (3) recruitment since 1978 was typical, while recruitment between 1974 and 1977 (year classes of 9–12 year olds) was exceptionally high.

Annual recruitment success of mussels is highly variable and depends on environmental conditions during the breeding period (Tudorancea 1972) and on the availability of fish hosts for the glochidia. In large water bodies like Lake St. Clair, conditions are relatively stable on an annual basis and, although events affecting recruitment (high or low water levels, high spring runoff, fish distributions, etc.) can vary from year to year, environmental conditions that could have consistently impaired recruitment in Lake St. Clair since 1978 are not immediately apparent. Populations of fish species which serve as hosts for the glochidia of *L. r. siliquoidea* (e.g., yellow perch, smallmouth bass, largemouth bass, bluegill, and crappie among others; Clarke 1981) have remained stable or increased over the past decade (Robert Haas, Michigan Department of Natural Resources, personal communication, 1987). An increase in mortality of individuals 8 years of age or less in recent years could account for the low abundances. The die-off of mussels noted in 1985 may have consisted mostly of individuals in this age category. This seems plausible particularly since these younger age classes were more frequent in the age-frequency distributions of dead individuals (empty shells) than of live individuals (compare Fig. 4 to Fig. 5). Under normal population demographic patterns, older individuals should constitute the majority of dead specimens. Unfortunately, aging empty shells only identifies the age at which death occurred and not the year of death. The condition of the empty shells, in terms of deterioration state, was not recorded.

The biomass of mussels in Lake St. Clair was generally similar to biomass estimates from other freshwater lakes (Table 5). However, because of the dominance of older individuals in the population, the annual turnover ratio of *L. r. siliquoidea* was only 0.13, which is lower than found in these other areas. The mean biomass of 4.4 g m^{-2} was about four times greater than the mean biomass of all other benthic macroinvertebrates occurring in the lake (Hudson *et al.* 1986).

Since few young individuals of the dominant species, *L. r. siliquoidea*, are now present in the population, mussel numbers may decrease dramatically in the next 5 years when the current large

TABLE 5. Biomass (g shell-free dry wt m^{-2}) and turnover ratio (production/biomass) of Unionidae from various lentic environments. Modified from Strayer et al. (1981) and Paterson (1985).

Water Body	Biomass	P/B	Reference
Lake Zbechy			
Total Unionidae	3.17	0.45	Kasprzak (1986)
Mikolajskie Lake			Lewandowski and
Total Unionidae	0.26	0.34	Stanczykowska (1975)
Lac des Deux Montagnes			
Total Unionidae	8.60	0.20	Magnin and
Lampsilis radiata	0.13	0.32	Stanczykowska (1971)
Lac Saint Louis			
Total Unionidae	0.71	0.10	Magnin and
Lampsilis radiata	0.10	0.19	Stanczykowska (1971)
Morice Lake			
Elliptio complanata	8.04	0.19	Paterson (1985)
Lake St. Clair			
Total Unionidae	4.40		This Study
Lampsilis r. siliquoidea	1.54	0.13	
Mirror Lake			
Total Unionidae	0.05	0.006	Strayer *et al.* (1981)

number of 9–12 year olds declines as a result of natural age-specific mortality. Future surveys of mussel abundances, along with an examination of the age frequency distribution of *L. r. silquoidea*, should provide some valuable insights into the changing nature of the mussel population in Lake St. Clair.

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