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Biomass and Production of the Unionid, *Elliptio complanata* (Lightfoot) in an Old Reservoir in New Brunswick, Canada

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Abstract. In Morice Lake, New Brunswick, *Elliptio complanata* (Lightfoot) has a numerical density of 15.92 ± 1.24/m^2 and an organic matter standing stock of 10.69 g/m^2. Annual production of 2.14 g/m^2/y is divided amongst tissue (69.6%), organic shell material (27.6%) and glochidia (2.8%). The high annual production relative to other populations is thought to be a reflection of the high numerical abundance which results from the high availability of suitable substrates at appropriate depths coupled with adequate fish host populations.

The freshwater unionid bivalve, *Elliptio complanata* (Lightfoot) is common in the northeastern U.S.A. and eastern Canada (Clarke 1981, Matteson 1948a) where it can make a substantial contribution to the benthic biomass (Sephton et al. 1980) of riverine and lentic habitats. Ghent et al. (1978) found that it was essentially restricted to water less than 3 m in depth in Lake Bernard, Ontario. Matteson (1948b) also recorded *E. complanata* as a shallow water species.

Strayer et al. (1981) studied the production of *E. complanata* in an oligotrophic, softwater lake in New Hampshire. The low observed productivity (6.4 mg/m^2/y) reflected a low numerical standing stock (Strayer et al. 1981). The present study was designed to examine the production of *E. complanata* in a softwater lake in New Brunswick, Canada where the population density appeared to be much larger than that observed by Strayer et al. (1981). Other aspects of the biology of this New Brunswick population of *E. complanata* have been dealt with by Cameron et al. (1979); Paterson (1982, 1983, 1984) and Sephton et al. (1980).

STUDY AREA

Morice Lake is an old (ca. 1765), polymictic reservoir located 3 km north of Sackville, New Brunswick, Canada (45° 56′N, 64° 21′W). It has an area of 1.5 km^2 and a maximum depth of 3.5 m. The lake has an average summer conductivity of 52.8 S/cm at 25°C. Calcium ion concentration ranges from 3.0 to 5.0 mg/liter and pH from 5.5 to 7.4. Dissolved organic carbon values in the summer averaged 12.48 ± 1.27 mg C/liter ($\bar{x} \pm s_{\bar{x}}$). Ice cover leaves the lake in late April and reforms in early December. The lake is essentially isothermal during the ice-free period with a maximum temperature of about 22°C reached in August. The unionid populations of the lake consist of *Elliptio complanata* (Lightfoot), *Anodonta cataracta* (Say), *A. implicata* (Say) and *Lampsilis ochracea* (Say).

MATERIALS AND METHODS

This study was restricted to ten sampling stations located in the southwest arm of Morice Lake at a water depth between 0.8 and 3.0 m (Paterson 1982). On five occasions spread over the ice-free period (May 7, July 2, August 4, September 12, November 3), ten standard 9 × 9 inch Ekman grab (522.6 cm^2) samples were obtained at each station. Visual observation of the functioning of the sampler at the shallower stations indicate that this is an efficient method of quantitative collection of bivalves from the substrate encountered

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in Morice Lake. Grab contents were poured into a bucket with a square mesh bottom (0.5 cm) and swirled in lake water. Bivalves were removed, gently scrubbed to remove concretions and maximum length measured to the nearest 0.5 mm with calipers. Each bivalve was opened by severing the adductor muscles and sexed by examining wet mounts of gonadal material or observing eggs and/or glochidia in the marsupia. Tissue was placed in a pre-weighed aluminum drying dish and both shell and tissue oven dried at 60°C for 48 h before weighing. The concentration of organic material in shells was determined after Cameron et al. (1979).

Growth curves were constructed by counting annual rings on all specimens where shell wear had not obscured such rings. Specimens for which an accurate age could not be determined were assigned an age based on shell length. While this undoubtedly introduced errors, it was assumed that the degree of over-estimating and under-estimating age of individuals would balance.

When females carried what appeared to be a full complement of glochidia in the marsupia, samples were obtained and, after measurement of shell length, the marsupia were excised and preserved in 10% formalin. Later the marsupia from each female were placed in 500 ml of water and stirred vigorously until the marsupia were broken and glochidia distributed throughout the volume of water. Five 2 ml aliquotes were removed and the number of glochidia in each counted. The average number of glochidia in the five samples was used to determine the total number in the marsupia. Samples of glochidia from freshly collected material were counted and then oven-dried at 60°C in pre-weighed aluminum dishes which allowed the determination of the average dry weight, including shell, of a glochidium.

Quantitative samples spread over the ice-free period did not reveal detectable seasonal differences in tissue weight-length or shell weight-length relationships. Consequently, observed average length increases from one year class to the next were converted to average increases in tissue weight and shell weight. The average abundance (numbers/m^2) of each year class was then multiplied by the average increase in tissue weight and shell weight over the previous year to determine yearly production. Total yearly production was the sum of the production by each year class. This method of determining yearly production assumes zero mortality, no immigration or emmigration, and zero production during winter months.

RESULTS

The 500 samples of *Elliptio complanata* obtained from Morice Lake revealed an average density of 15.92 ± 1.22 individuals/m^2 ($\bar{x} \pm s_{\bar{x}}$). The frequency of each age class is shown in Figure 1. From ages of 1+ through 10+ there was evidence of variation in abundance of the various age classes. The oldest individuals sampled were 15+ years of age. The low frequency of 0+ individuals may well be an artifact produced by sampling design. Young-of-the-year were not discovered in the sediments until October. Therefore, in the early part of the following summer they would still be small enough to pass through the 0.5 cm mesh sieve.

Increase in shell length as a function of age is shown in Figure 2. The apparent large size of the 0+ clams again reflects the inadequate sampling of these until approaching one year old. Pooling of all results showed that for *E. complanata* the relationship between dry tissue weight (g, W) and length (cm, L) is expressed by the equation: $\log_{10} W = -2.403 \pm 0.071 + 2.770 \pm 0.089 \log_{10} L$ ($n = 281$, $r = 0.97$, $p < 0.001$). Dry shell weight (g, W) as a function of length (cm, L) can be expressed as: $\log_{10} W = -1.936 \pm 0.085 + 3.530 \pm 0.100 \log_{10} L$ ($n = 320$, $r = 0.98$, $p < 0.001$). No statistical differences were observed between the sexes (Cameron et al. 1979). The standing stock of tissue averaged 8.037 g/m^2, while the average weight of shells of living bivalves was 94.66 g/m^2. The shells had an average

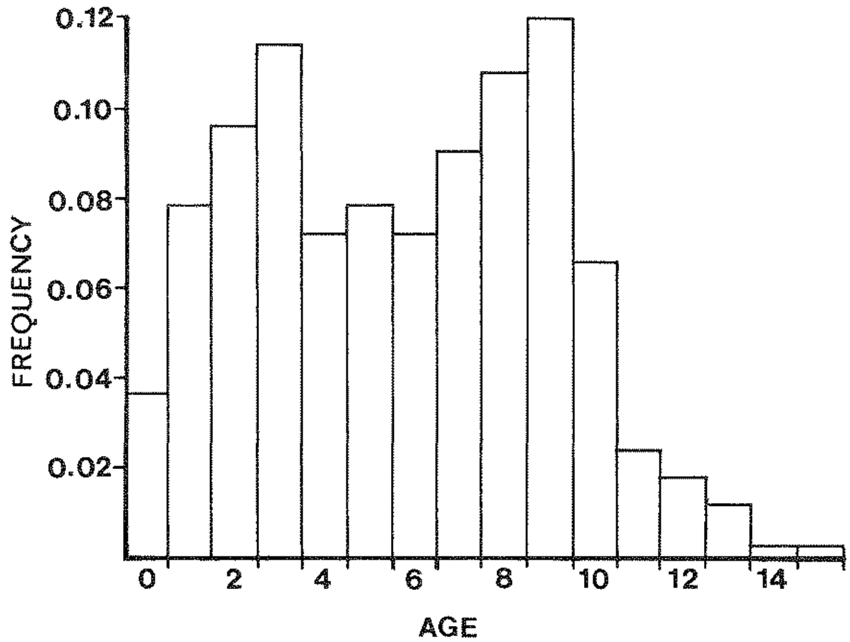

Fig. 1. Age-frequency (years) distribution of *Elliptio complanata* from Morice Lake, N.B. N = 416.

organic content of 2.79% (Cameron et al. 1979); thus the standing stock of this material was 2.641 g/m^2 (Table I).

In Morice Lake, *E. complanata* eggs are transferred to the marsupia in late-June and develop into glochidia by mid-July. Glochidia were retained in the female marsupia for approximately one week before release. Glochidia or eggs in the marsupia were not found in any females less than age 4+. For all bivalves of 4+ and older it was found that 40.0% of the individuals were female. The relationship between the number of glochidia (N) in the marsupia and female length (cm, L) was expressed by the equation: $\log_{10} N = 1.101 + 4.088 \log_{10} L$ ($n = 23$, $r = 0.75$, $p < 0.001$).

This relationship held for females from the time of first reproduction until an age of 13+ at which time the average number of glochidia declined from about 50,000 to 40,100. Determination of the average weight of a glochidium produced a value of 5.3×10^{-4} mg.

Values for annual production (Table I) are almost certainly underestimated as mortality rates were not determined. Fluctuations in year class strengths (Fig. 1) prevented estimation of mortality from 'catch curves' while the magnitude of mortality within a year class over the six month sampling period was too small to detect. The production of glochidia was determined from the number of females of each age class 4+ and older. The value for annual production of glochidia (Table I) includes the weight of the glochidial shell. No estimate was obtained of the weight of production of sperm and associated products by the males but this is assumed to be negligible.

Discussion

Although Morice Lake is a softwater system with relatively low productivity, it does support a substantial population of *Elliptio complanata*. The annual production of this population is 2.14 $g/m^2/y$ which is partitioned amongst dry tissue (1.49 $g/m^2/y$; 69.6%), glochidia (0.06 $g/m^2/y$; 2.8%) and organic shell material (0.59 $g/m^2/y$; 27.6%). Strayer et al. (1981) included an estimate of organic shell material in their measurements of

TABLE I

Biomass and production of unionid bivalves in several habitats. Modified from Strayer et al. (1981).

Ecosystem	Biomass (B) g/m^2	Production (P) $g/m^2/y$	P/B	Source
Mirror Lake[1]	0.05	0.006	0.12	Strayer et al. (1981)
Mikolajskie Lake[2]	0.20	0.07	0.35	Lewandowski & Stanczykowska (1975)
Lac Saint-Louis[2]				
E. complanata	0.34	0.02	0.06	Magnin & Stanczykowska (1971)
Total Unionidae	0.71	0.07	0.10	
Crapina Pool (Danube River)[2]	4.8	1.1	0.23	Tudorancea (1972)
Morice Lake[3]				
Tissue	8.04	1.49	0.19	This study
Glochidia		0.06		
Organic shell material	2.64	0.59	0.22	
Total	10.68	2.14	0.20	
Lac des Deux Montagnes[2]				
E. complanata	5.33	0.92	0.17	Magnin & Stanczykowska (1971)
Total Unionidae	8.58	1.66	0.19	
Thames River[2]	12.1	2.1	0.17	Negus (1966)

[1]Includes organic shell material
[2]Wet weight converted to dry weight by a factor of 0.1 except for Mikolajaskie Lake for which a factor of 0.04 was used.
[3]Includes estimates for only *Elliptio complanata*.

production of *Elliptio complanata*, however, most published production values for unionid populations are not corrected for organic shell material and glochidia. This can result in substantial underestimates of annual production. In the Morice Lake population of *E. complanata* only 69.6% of the annual production is accounted for by tissue accumulation.

The results obtained for dry tissue weight biomass and production are similar to those reported by Magnin and Stanczykowska (1971) for *E. complanata* in Lac des Deux Montagnes, Quebec (Table I). Morice Lake has a higher numerical density (15.92 vs. $12.81/m^2$); dry tissue weight biomass (8.04 vs. 5.33 g/m^2) and production (1.49 vs. 0.916 $g/m^2/y$) but production/biomass ratios (P/B) are similar (Morice Lake 0.185; Lac des Deux Montagnes 0.172). These P/B ratios are within the range of values (0.06 to 0.35) for other populations of *E. complanata* (Magnin & Stanczykowska 1971; Strayer et al. 1981) and associations of unionid species (Lewandowski & Stanczykowska 1975; Magnin & Stanczykowska 1971; Negus 1966; Tudorancea 1972). The dry tissue weight standing stock of *E. complanata* in Morice Lake is larger than the total standing stock of unionids found in most habitats, with the exceptions of Lac des Deux Montagnes (Magnin & Stanczykowska 1971) and the Thames River (Negus 1966). However, these are riverine or semi-riverine habitats that could support higher biomasses of unionids. As predicted from the similar P/B ratios, the softwater nature and the relatively low productivity of Morice Lake does not appear to influence the growth of individuals. As noted in Figure 2, the increase in shell length with age is similar in four rather different habitats. This is also the case with increases in tissue weight with increasing age (Fig. 3). The high production of *E. complanata* in Morice Lake therefore is a reflection of the high numerical standing stock ($15.92 \pm 1.22/m^2$). Thus, it would appear that possible explanations for the observed differences in the productivity of *E. complanata* and other unionid bivalves among lakes are more dependent on factors that control abundance than on factors that influence the growth of individuals.

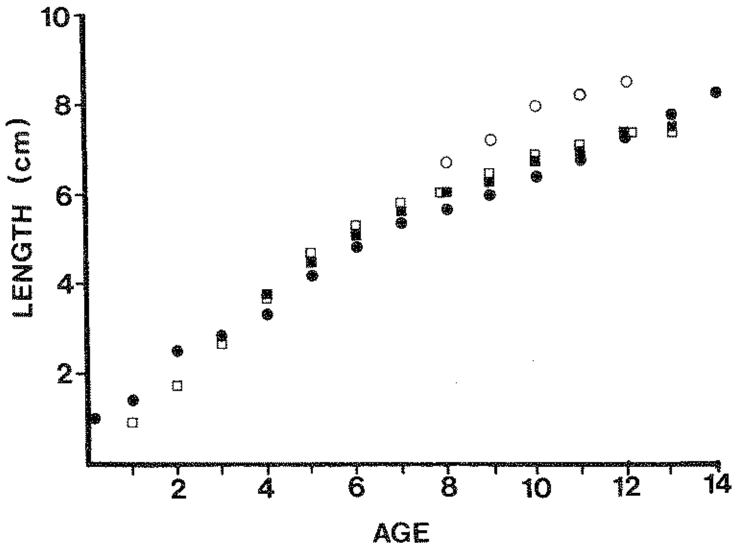

Fig. 2. Increase in shell length with age (years) in *Elliptio complanata* from (■) Lac des Deux Montagnes (Magnin & Stanczykowska 1975); (○) Lac Saint-Louis (Magnin & Stanczykowska 1975); (□) Mirror Lake (Strayer et al. 1981) and (●) Morice Lake.

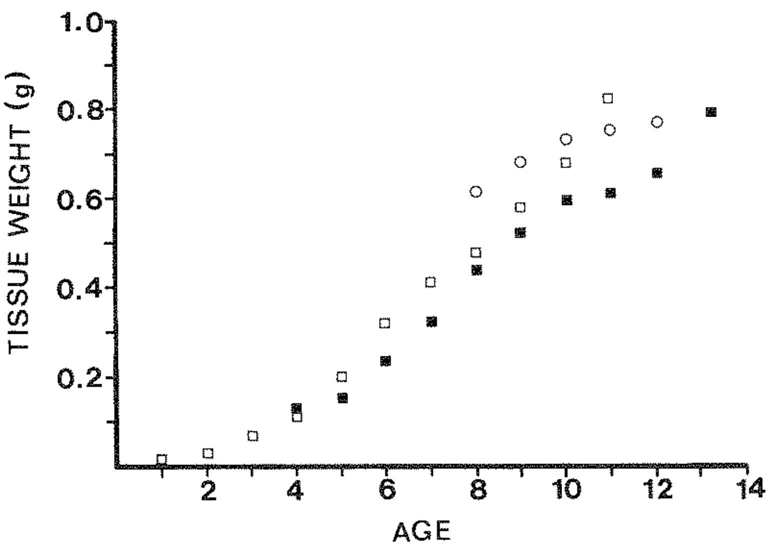

Fig. 3. Increase in dry tissue weight with age (years) in (■) Lac des Deux Montagnes (Magnin & Stanczykowska 1975); (○) Lac Saint-Louis (Magnin & Stanczykowski 1975) and (□) Morice Lake.

The abundance of each age class in Morice Lake remained relatively constant from ages 1+ to 10+. While it is obvious from the collection of empty, intact shells that there is some degree of mortality in these age groups, there does not appear to be any obvious age specific mortality until an age of about 11+. Excluding older bivalves, and those which are not sampled adequately because of young age, the average density of each year class is $1.37/m^2$ while variation in the abundance of ages 1+ through 10+ are in the range of 0.58 to $2.88/m^2$.

The abundance of female *Elliptio complanata* of ages 4+ and older indicate that the total release of glochidia should amount to 109.9×10^3 glochidia/m^2/y. To maintain an average year class abundance of 1.37 bivalves/m^2 would require the survival of only 0.00124% of the glochidia through to age 4+. Therefore, a very minor change in survival rate resulting from a combination of such factors as larger extents of suitable substrate, greater availability of fish hosts or a minor reduction in predation, could result in the establishment of a substantially denser population. Although the yellow perch (*Perca flavescens* (Mitchill)) is listed as the host for the glochidia of *Elliptio complanata* (Clarke 1981; Matteson 1948b), repeated sampling of Morice Lake over a period of years by gill nets and beach seines has failed to reveal the presence of this species. Extensive collections of fish from Morice Lake during the time of glochidia release showed that only banded killifish (*Fundulus diaphanus* (Lesuer)) were infected. This species is particularly abundant in Morice Lake. The combination of water depth and suitable substrate may also be a major contributing factor to the maintenance of the high numerical abundance of *Elliptio complanata* in Morice Lake. *Elliptio complanata* has an aggregated distribution over small areas in the study arm but the average abundance does not differ significantly at the various stations (Paterson 1983). Further unpublished studies (Blair & Paterson, 1974) have also revealed that the abundance of this species remains relatively uniform throughout all of Morice Lake. *Elliptio complanata* and other unionid bivalves have been found in the greatest numbers at depths of less than 3 m and are rare in deeper water (Ghent et al. 1978; Matteson 1948b; Okland 1963; Strayer et al. 1981). The maximum water depth in Morice Lake is 3.5 m. It is speculated that in Morice Lake, glochidia released from females would have a reasonable possibility of finding and attaching to a suitable fish host. Release from the fish host after metamorphosis would place a young bivalve on a substrate and at a water depth suitable for development. In many lakes, such as Mirror Lake (Strayer et al. 1981), the release of the young individual from a fish host could frequently occur in a region where the water depth and/or substrate were unsuitable for survival. As a result, the mortality of the young age classes would be relatively high and this would then be reflected in the low average numerical standing stock of older individuals. In spite of the ability of these older individuals to maintain an individual production similar to that found in Morice Lake, the overall production would be greatly diminished because of decreased population density.

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