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Loss of Freshwater Shellfish After Water Drawdown in Lake Sebasticook, Maine

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ABSTRACT

Water drawdown to improve water quality of Lake Sebasticook, Maine, exposed virtually all mussel habitat and stranded freshwater mussels. Populations of adult (6- to 18-year-old) eastern elliptio (Elliptio complanata) and eastern lamp mussel (Lampsilis radiata), which had a combined density of 1.4 ± 0.4 m^{-2} in water 2 to 4 m deep, largely disappeared after drawdown. They survived only near the lake's inlet, and here the population declined from 1.9 m^{-2} to 0.14 m^{-2} in the following year. The movement rate of 1 to 16 mm min^{-1} of the elliptio would have allowed escape to open water as the water receded; however the movement was random.

INTRODUCTION

Lake drawdown is a well-established procedure for improving water quality and increasing productivity (Dubravius 1547). However, if large numbers of freshwater mussels are stranded and die during drawdown, water quality might be reduced by the loss of these filter-feeding organisms, thus counteracting the goal of the drawdown. Freshwater mussels living in the littoral zone are vulnerable to fluctuations in water levels (Cooper 1984). Because mussels reproduce seasonally, they must survive the dry conditions if they are to maintain their populations.

We report loss of most individuals of two freshwater mussels populations after lake drawdown of a north temperate eutrophic lake.

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METHODS

Study Area

Lake Sebasticook is a 1,800-ha eutrophic lake on the East Branch of the Sebasticook River, Maine; normally the mean and maximum depths are 6.2 and 18.2 m, the volume is 10^8 m^3, and the hydraulic retention time is 0.6 year (Rock et al. 1984). Beginning in 1982, in an attempt to reduce internal phosphorus, about half the volume of water was withdrawn from the lake in late summer (when nutrients were concentrated in the epilimnion). The 4-m drawdown removed all epilimnetic water; water remained only over bottoms composed of organic mud that were anoxic before drawdown. In the epilimnetic water in summer in 1979-1982, total phosphorus was 46 - 64 $\mu g\ l^{-1}$, chlorophyll 20 - 30 $\mu g\ l^{-1}$, and Secchi disk transparency 1.4 to 1.9 m (Maine Department of Environmental Protection, unpublished data).

Our study was conducted in 1982 and 1983 shortly after the first and second drawdowns. The lake was refilled each year by spring snowmelt and precipitation.

Population Estimates

Immediately after drawdowns in 1982 and 1983, we estimated population density of the eastern elliptio (*Elliptio complanata*) and the eastern lamp mussel (*Lampsilis radiata*) for two areas of exposed shore. Every individual was collected in five randomly selected zones in each area. Each zone was 5 m wide and extended 30 to 90 m from the original shoreline. Mussels were absent beyond 90 m, e.g. in what had been 4 m deep water. Mussels were easily located by the depressions they made in the substrate surface and all were collected for measurements and age determination. Population densities were estimated only for the area where mussels were present.

Age and size-at-age were determined from winter annuli (Strayer et al. 1981). The length at each annulus was measured with a vernier caliper for 107 specimens of the elliptio and 98 of the lamp mussel. In Lake Sebasticook, the annuli of both species were regular and consistent from individual to individual and we had no difficulty in interpreting these annuli.

Survival and Movement

Three field measurements were made to determine survivorship of stranded elliptios after drawdown in 1982. Population estimates were made on stranded live mussels on 8 November and again on 22 November. Percent mortality was calculated from the decrease in the mean number of live mussels.

Survival of stranded elliptios also was determined by noting the death rate of 40 tagged mussels. Stranded elliptios, marked with a diamond pencil by scraping the periostracum, were returned to their original position in the substrate. Each mussel was recaptured at 8, 11 and 25 days after marking. In a third test, 52 mussels captured in shallow water were marked, and returned to the water to determine whether they were able to keep pace with the receding water. After the water receded, we attempted to locate the marked mussels and recorded their location relative to substrate and water.

Movement was estimated for elliptios in the water and for those stranded on the exposed shore. We marked the initial position of individually labeled mussels with a stake and measured the actual distance moved along the path left in the substrate during a given time interval.

RESULTS

Population Densities

The most abundant species of mussel in Lake Sebasticook was the eastern elliptio which composed almost 75% of the mussel population. The distribution of the eastern lamp mussel, which ranked second, was more limited than that of the elliptio. The elliptio occurred in a band around the entire lake in what had been shallow water (2 to 4 m deep) between 30 and 90 m from the shoreline. We estimated that Lake Sebasticook had 165 ha of mussel habitat. The substrate was mainly organic mud, littered with decaying wood. Both species occurred near the lake's inlet where the substrate was clay and sand. In the zone in which the mussels occurred, the population density was 1.4 ± 0.4 m^{-1} (range 0.44 - 2.35 m^{-2}).

Nearly all mussels were longer than 50 mm and most were 70 to 80 mm long. Populations were dominated by older age groups; no mussels less than 6 years old were found. The most abundant age group of the elliptio was 12 years old, with a density of 0.17 m^{-2}. Age groups 7 through 11 were all about the same density (0.11 to 0.14 m^{-2}). Those in age group 13 had a density of 0.09 m^{-2}. Biomass was about 23 g m^2 of wet tissue weight and about 18.5 g m^{-2} of shell weight. Among lamp mussels, 8-year-olds were the most abundant, and 13-year-olds were the oldest.

Survivorship

Population estimates in a test area were 0.82 m^{-2} on the first day and 0.54 m^{-2} after 2 weeks; hence the population was reduced by 34% in two weeks.

Survival of tagged elliptios was 100% for the first 11 days after the mussels were marked, or 2 weeks after they were stranded. At 25 days after tagging 80% were dead.

Of 52 mussels marked and returned to the water, 21 (40%) were recovered alive after the water receded: 7% in the water and 33% on land. Some of the marked mussels probably escaped with the receding water, and others may have buried outside the area of search.

Field measurements in 1983, after the second drawdown, indicated that the only area where live mussels remained was near the lake's inlet. Even in this region, population density of live mussels was low (about 0.14 m^{-2}); this was less than 7% of the original population density of 1.9 m^{-2}. We estimate that more than 98% of the total mussel population died after the first drawdown.

Movement

Mussels moved actively along the substrate surface. Elliptios in the water moved randomly at rates of 1 to 16 mm min^{-1}. Most mussels moved in circles, with no specific orientation. Consequently they did not move with the receding water. After the water receded, the mussels immediately burrowed; thereafter the maximum lateral movement we observed was 4 cm day^{-1}.

DISCUSSION

The near absence of juvenile mussels in Lake Sebasticook was probably caused by the unsuitability of the habitat. The lake bottom was composed mainly of organic mud and clay, except for the area of fine sand and clay where the East Branch of the Sebasticook River enters the lake. Possibly we failed to detect smaller mussels. Coker et al. (1921) observed that collectors generally consider juvenile mussels difficult to find. Juvenile mussels bury themselves deeper into the bottom than do adults (Coker et al. 1921). Juveniles of some mussel species have byssal glands and inhabit loose gravel, whereas the adults live in deep mud or sand. Negus (1966) likewise found that juvenile mussels occupied fewer kinds of habitats (silt free but containing organic materials) than did adults.

The age structure of the adult population of mussels in Lake Sebasticook was similar to that in populations of unionids in other freshwater ecosystems (Negus 1966; Magnin and Stanczykowska 1971; Lewandowski and Stanczykowska 1975; Haukioja and Hakala 1978), which suggests low mortalities of adults and considerable year-to-year variation in recruitment. Strayer et al. (1981) reported that the eastern elliptio may live for 16 to 18 years. Magnin and Stanczykowska (1971) wrote that it lived 15 years, and that the lamp mussel lived 12 years in the St. Lawrence River. In Morice Lake, New Brunswick, the maximum age of the eastern elliptio was 15 years (Paterson 1985).

Because the species of mussels present in Lake Sebasticook are long lived, the loss of these animals could have an effect that lasts for several years. At the same time, because the mussels live so long and are highly fecund the few survivors could easily repopulate the lake. Mussels that inhabit Lake Sebasticook have no obvious adaptations to avoid desiccation, such as those found in the unionid bivalve *Asparthia* sp., which can aestivate for as long as 2 years (Beadle 1974). Survival after exposure in the elliptio is longer than the 5 days of the white heelsplitter (*Lasmigona complanata*) (Kaster and Jacobi 1978) and 4 to 7 days of *Corbicula fluminea* (McMahon 1979).

The elliptio survived short exposure, but could not survive the 4- to 5-month period of exposure, before the lake was refilled. In the field we observed that individuals buried themselves as the water receded. The elliptio burrows 6.2 cm in 30 min in clay and 4.3 cm in 30 min in sand, whereas the lamp mussel burrows only 1.3 cm in 30 min in sand (Lewis and Riebel 1984). Burrowing is a survival mechanism that was inadequate for the long exposure of dewatered substrate.

In Lake Sebasticook movement of mussels was random and the mussels did not keep pace with the receding water even though they were capable of moving faster than the water receded. The elliptio is highly mobile and readily moves about its aquatic habitat (Kat 1984). Kaster and Jacobi (1978) also noted that the white heelsplitter was mobile enough to follow receding water, but that many failed to do so. A possible mechanism for escape was observed in the unionid *Quadrula undulata*, which was mobile in water less than 30 cm deep and stationary in water about 90 cm deep (Isley 1914). Even if mussels had escaped to deeper water in Lake Sebasticook they probably would not have survived because of the looseness of the sediments there. Cooper (1984) showed that deposited sediments are detrimental to freshwater mussels.

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