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Seasonal variation in two species of unionid clams from Manitoba, Canada: biomass

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The relationship between dry weight and shell length for *Anodonta grandis* and *Lampsilis radiata* is log dry weight = a + 3.0317 log shell length, where a varies seasonally. Average water content of clams varies seasonally from 83.18% for both species in February and May to 85.02% for *L. radiata* in July and 87.56% for *A. grandis* in July and October. Mean ash content of *L. radiata* (19.21%) is higher than that of *A. grandis* (12.68%) except in October (20.94%) when marsupia are filled with glochidia. Differences in reproductive timing and length of glochidial retention contribute to some of the seasonal variations in biomass in *A. grandis* and *L. radiata*.

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La relation entre le poids sec et la longueur de la coquille chez *Anodonta grandis* et *Lampsilis radiata* s'exprime comme suit: log poids sec = a + 3,0317 log longueur de la coquille; a varie selon la saison. Le contenu hydrique moyen des moules varie en fonction de la saison de 83,18% chez les deux espèces en février et en mai à 85,02% chez *L. radiata* en juillet et 87,56% chez *A. grandis* en juillet et en octobre. Le contenu moyen en cendres de *L. radiata* (19,21%) et plus élevé que celui d'*A. grandis* (12,68%), sauf en octobre (20,94%), alors que les sacs marsupiaux sont remplis de glochidies. L'asynchronisme des périodes de reproduction et les différences de durée d'incubation des glochidies expliquent les variations saisonnières de biomasse d'*A. grandis* et de *L. radiata*.

[Traduit par le journal]

Introduction

Estimates of biomass for populations and individuals are important for population and community energetics studies. Recognizing this, a few investigators have published methods for estimating biomass (weight) of various molluscs (e.g., Eckblad 1971; Davis and Fenner 1977). These studies do not always account for seasonal changes in weight which frequently occur in bivalves (e.g., Griffiths and King 1979; Taylor and Venn 1979). Ideally, to be most useful in ecological work, the predictor of biomass should be easily obtained under field conditions (i.e., a linear measurement rather than weight).

This paper presents regression equations for estimating seasonal dry weights, wet weights, and ash-free dry weights for two freshwater mussels, *Anodonta grandis* and *Lampsilis radiata*, from Lake Minnedosa, Manitoba, Canada.

Materials and methods

Specimens of *Anodonta grandis* and *Lampsilis radiata* were collected in February, May, July, and October (too few specimens of *L. radiata* were obtained in October) from the substrate at depths of 1–2 m near the outflow of Lake Minnedosa. Animals were kept in the laboratory with unfiltered, dechlorinated, running water at seasonal temperatures. No apparent differences in length–weight relationship existed regardless of whether clams were used immediately or after several weeks.

Valve length of each clam was measured to the nearest 0.1 mm with Vernier calipers; clams longer than 130 mm were measured to the nearest 1.0 mm with a ruler. Clam flesh was removed from the shell, blotted on absorbent paper, and weighed to the nearest 0.01 g to obtain wet (fresh) flesh weights. At this time, sex, reproductive condition (including state of gametes in the gonads and larvae in the gills), and the presence, but not identity, of mites and trematode larvae were noted. To measure dry weight, clams were dried 24–72 h (to a constant weight) at 60–70°C and reweighed. A sample of these clams was ashed at 600–650°C for 24 h in a muffle furnace enabling calculation of ash-free dry weights.

Regression analysis and tests of significance were done according to Snedecor and Cochran (1967) and Zar (1974). Unless otherwise indicated, significance was determined using an F test at the 5% level.

Results

Mites were present in many of the specimens of *L. radiata* and almost all the *A. grandis* examined. As Davids (1973) found in his study, the mites did not appear to be inflicting damage on the clams. Trematode larvae were rarely noted in *L. radiata*, but *A. grandis* (particularly females) were frequently infected with trematode larvae in the gonad, especially in the fall after breeding was completed (see below).

Quantitative results are summarized in Table 1. There are no significant differences among the slopes of the regression equations relating log length to log dry weight where log dry weight = $a + b$ log

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TABLE 1. Seasonal changes in length–weight relationship, percent water (as a function of shell-less wet weight), percent ash (as a function of shell-less dry weight), and percent female dry weight attributable to marsupium and contents for *Anodonta grandis* and *Lampsilis radiata*

Month	N	Original b ± SE	t	r	a adjusted to b = 3.0317	% H_2O ± SE	% ash ± SE	% female dry weight due to marsupium + contents ± SE
Anodonta grandis								
Feb.	15	2.6233±0.2800	9.3705	0.9333	−5.4155	83.21±1.03 n = 15	13.42±1.33 n = 10	12.81±2.67 n = 9
May	19	1.8461±0.4251	4.3422	0.7252	−5.3822	83.40±0.49 n = 15	12.76±1.47 n = 9	8.98±1.14 n = 13
July	32	3.0458±0.1018	29.9279	0.9837	−5.5512	87.60±0.48 n = 29	12.21±0.50 n = 17	12.23±1.49 n = 15
Oct.	43	3.0600±0.0858	35.6551	0.9843	−5.4744	87.53±0.37 n = 44	20.94±1.93[a] n = 18	31.90±2.90 n = 19
Lampsilis radiata								
Feb.	15	1.6712±0.6812	2.4535	0.5626	−5.4693	83.41±0.41 n = 15	18.36±1.17 n = 10	9.19±2.03 n = 5
May	20	0.6305±0.8471[b]	0.7433	0.1728	−5.1970	82.83±0.30 n = 20	20.16±1.23 n = 9	8.21±0.76 n = 15
July	22	3.1113±0.1827	17.0300	0.9672	−5.3577	85.02±0.34 n = 21	17.36±0.77 n = 15	3.81±1.05 n = 10

[a]Males = 14.82 ± 1.32, n = 7; females = 24.94 ± 2.90, n = 8; females without marsupium = 10.06 ± 1.71, n = 8.
[b]Sexes differ, females = 3.9063, n = 15.

length. Therefore the common slope, b = 3.0317, was applied to both species at all seasons. The elevations of the equations, a, differed at each season so a new a value was derived for each season using the common slope and the means of log length and log dry weight for the season. Except for *A. grandis* in July and *L. radiata* in May, the same regression equation applied to both sexes (t-test, 5% level). For both species the clams were heaviest in the spring (May) (Fig. 1).

The water content of both clams was in the range found for other bivalves (Lewandowski and Stanczykowska 1975; Taylor and Venn 1979; Walz 1979). There was no difference in water content of clams (both species) in February and May ($\bar{x}$ = 83.18%, SE = 0.19) or for *A. grandis* collected in July and October ($\bar{x}$ = 87.56%, SE = 0.29). *Lampsilis radiata* collected in July had an intermediate water content which differed significantly from the others ($\bar{x}$ = 85.02%, SE = 0.34).

Ash content of *L. radiata* averaged 18.21% (SE = 0.61) with no significant differences among collection times. Ash content of *A. grandis* collected in February, May, and July averaged 12.68% (SE = 0.69). This differed significantly from *A. grandis* collected in October ($\bar{x}$ = 20.94%, SE = 1.93) and from *L. radiata* at all times.

Since reproductive status, especially of the females might have an effect on measures of

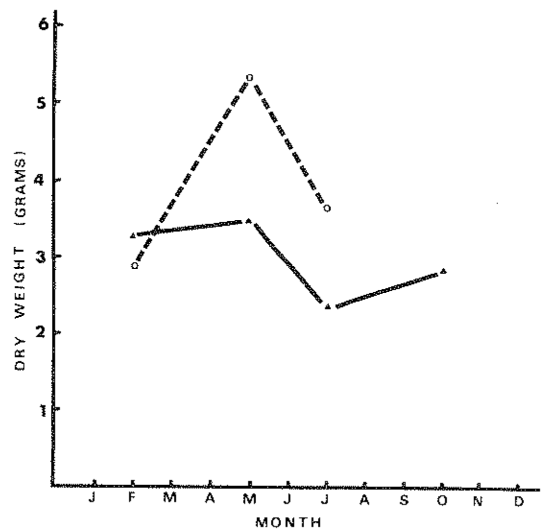

FIG. 1. Seasonal dry weight as a function of shell length for a 90-cm clam. ▲—▲, *Anodonta grandis*; ○--○, *Lampsilis radiata*.

biomass, I calculated the percent of female dry weight comprising the marsupial gills and their contained embryos and glochidial larvae. The percent of female dry weight attributable to the marsupium and contents of *L. radiata* was significantly lower in July ($\bar{x}$ = 3.81, SE = 1.05) than in February or May ($\bar{x}$ = 8.45, SE = 0.74). In *A. grandis*, the percent female dry weight due to the marsupium and contents was significantly higher in October ($\bar{x} = 31.90$, SE = 2.90) than at other collection times ($\bar{x} = 11.23$, SE = 0.98).

Discussion

It is evident from the data presented here that more accurate estimates of biomass can be obtained with knowledge of seasonal variations. Much of the variation in freshwater mussels is probably due to reproduction as well as to changes in feeding and food availability. Based on examination of dissected clams the following reproductive patterns emerge.

Lampsilis radiata—Fertilization, and development of glochidia probably occur in late winter or early spring since the majority of females collected in February have empty marsupial gills. Glochidia are released between late May (when most female marsupia contained glochidia) and mid-July (when most marsupia are empty and the percent female dry weight due to marsupia and contents is lowest), not retained in the marsupium over the winter as found by some earlier investigators (e.g., Conner 1909).

Anodonta grandis—Fertilization, and development of glochidia probably occur in early to middle summer. Females collected in May have empty marsupia while those collected in July have embryos (rather than glochidia) in the gills and mature eggs in the ovary. In October the marsupia of almost all females are full of glochidia and the marsupia plus contents represents a high percent of the total dry weight at this time. Eggs found in the ovaries at this time are all immature. The finding that many females collected in February have empty gills and relatively small marsupia is likely due to the premature release of glochidia (witnessed in one-third of these females) in the laboratory where the water temperature was about 5°C as compared with field water temperatures of 0–1°C at this time. It is likely that in nature the glochidia are actually released in early spring since by May all females were free of glochidia. This pattern of reproduction involving overwintering of the glochidia is similar to that of other species of *Anodonta* (Heard 1975).

Body weight fluctuates seasonally so that both species are "meatiest" in the spring as is the case for *Dreissena* (Skirkyavichena 1970, cited in Walz 1979). The dramatic increase in weight for *L. radiata* (Fig. 1) between February and May is probably because of the presence of glochidia in the gills at this time. This is also the only time of year when male and female *L. radiata* differ significantly in their length–weight relationships. The relatively slight difference in weight between February and May of *A. grandis* (Fig. 1) may be caused by increased feeding in nature or may be an artifact resulting from release of glochidia in the lab in February. I cannot explain the apparent drop in weight, nor the difference between the sexes in July because glochidial release has already occurred and new embryos are now present in the gills. Two possibilities present themselves: (1) food availability or quality has dropped at this time when high temperatures are elevating respiration rates (Huebner, in preparation) causing animals to draw on previously accumulated reserves, or (2) as seen in *Dreissena* (Walz 1979), very rapid shell growth, not matched by tissue accumulation, is occurring. If either of these hypotheses is true, it may also be contributing to the apparent reduction in *L. radiata* weight at this time.

Ash content of *A. grandis* is influenced by the reproductive status of the clams. The rise in ash content of females in October is due to the glochidia which have an extremely high ash content (marsupia plus glochidia = 47.50%, SE = 2.38) and which constitute a large proportion of the body weight at this time. there is no difference between the ash content of males collected in October and clams collected at other seasons.

Although the ash content of glochidia of *L. radiata* is also high (marsupia plus glochidia = 57.78%, SE = 3.73), the overall ash content of clams in May when marsupia are full was only slightly above that at other times. This may be related to the much smaller percent of female body weight attributable to marsupia plus contents in *L. radiata* than *A. grandis* even when the majority of females contain glochidia.

Estimates of biomass for *A. grandis* and *L. radiata* from Lake Minnedosa can be calculated from seasonally adjusted equations relating length to dry weight. In conjunction with data presented on percent water and ash, these equations allow estimation of wet weight and ash-free dry weight. Thus three measures of biomass can easily be collected from large numbers of mussels under field conditions.

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