The relationship of shell dimensions and shell volume to live weight and soft tissue weight in the mangrove clam, *Polymesoda erosa* (Solander, 1786) from northern Australia

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Abstract

Shell dimensions (length, height, width) and shell volume were evaluated as estimators of growth for *Polymesoda erosa* in northern Australia. Each parameter was a good estimator when applied to live weight (r^2 values of 76-96 percent), but not to soft tissue weight (wet, dry, or ash-free dry weight) (r^2 values of 13-32 percent). The b value for shell volume to weight relationship of clams collected during the dry season (June to October) was significantly different than for those collected in the wet season (February to April).

Introduction

Polymesoda (Geloina) erosa is a large and fleshy bivalve that attains a shell length of up to 11 cm. Indigenous communities living in the coastal regions of northern Australia exploit it as an important subsistence food source (Meehan 1982). It is a sturdy animal and has excellent attributes for mariculture (Morton 1976).

Studying bivalve growth and establishing allometric relationships are essential for generating useful information for managing resources and understanding changing environmental conditions and pollution (Palmer 1990; Boulding and Hay 1993). Often growth is estimated by measuring shell dimensions or the volume of the animal (Hibbert 1977; Bailey and Green 1988; Rodhouse et al. 1984; Ross and Lima 1994; Ravera and Sprocati 1997; Rueda and Urban 1998; Deval 2001), because they are simple, non-destructive methods that can be easily completed in the field (Ross and Lima 1984). Once the allometric relationship is established, shell measurement is a sufficient surrogate to estimate biomass and total flesh production (Hibbert 1977; Rodhouse et al. 1984; Ross and Lima 1994; Thórarinsdóttir and Jóhannesson 1996; Ravera and Sprocati 1997; Deval 2001).

However, shell variables sometimes fail to estimate the flesh weight of an organism due to certain conditions. Factors such as the reproductive state of the animal (Rueda and Urban 1998), population density (Seed 1968), and physical and biological variables of habitat (Thórarinsdóttir and Jóhannesson 1996) are known to affect the growth of bivalves and can change the allometry between the shell and the flesh. Therefore, before using shell measurement to estimate soft tissue growth in a bivalve population, the robustness of the relationship between the shell morphology and total tissue component should be established (Ross and Lima 1994).

This study was conducted to determine whether shell dimensions (length, height, width) and shell volume have a strong relationship that can be used to monitor biomass production in populations of *P. erosa* in northern Australia. Variation in the allometric relationship may occur between sexes, reproductive seasons and changing environmental conditions. Therefore, the study also examined differences in shell-biomass relationships between females and males collected during the dry and wet seasons.

Materials and Methods

Adult *P. erosa* (shell length 60-90 cm) were hand collected at monthly intervals (June 2001-September 2002) during low tide from mangrove forests in Maningrida (12.05S;134.23E), Northern Territory, Australia (Figure 1). The live clams collected were airfreighted dry in styrofoam boxes to an experimental hatchery at the Northern Territory University. Here they were cleaned and maintained in 5 000 l static fibreglass tanks containing aerated sand-filtered seawater of 20 ppt salinity. They were left overnight to clear their guts. After this, samples of 30 to 50 clams with minor shell damage were randomly selected for measurement. The maximum dimension of the anterior-posterior axis was recorded as shell length and the maximum lateral axis as shell width. Due to most shells having eroded umbo, the maximum dimension along the shell hinge to the ventral side was recorded as shell height. All measurements were made to the nearest 0.01 cm using Vernier callipers. Total body volume

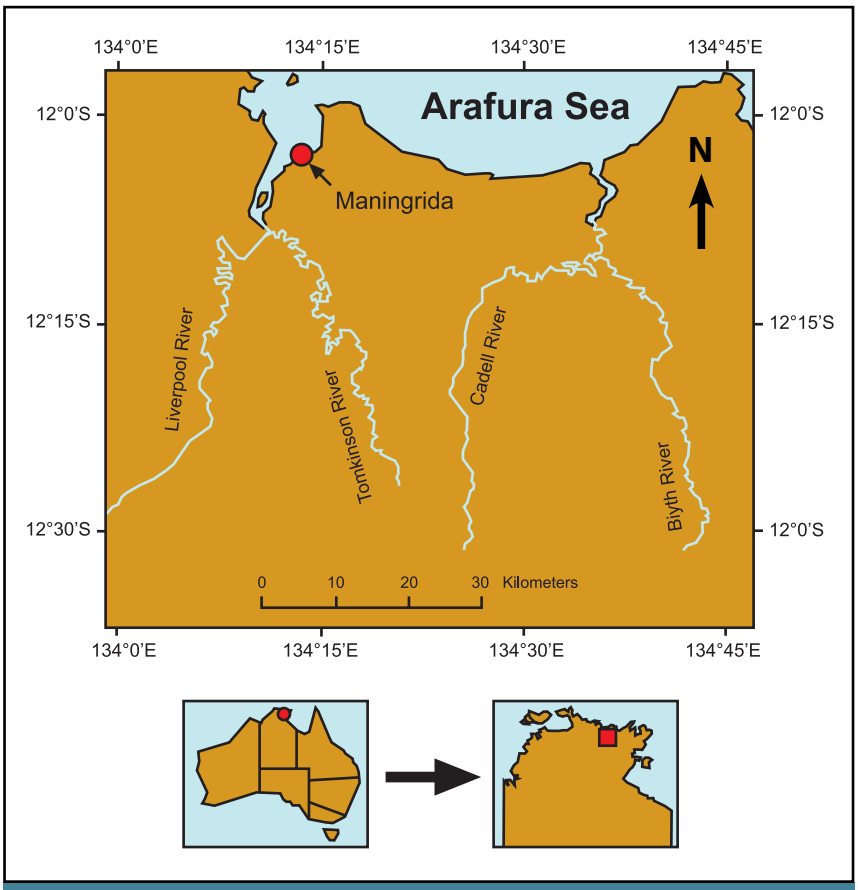

Figure 1. Map of Maningrida Region, Northern Territory, Australia showing the collection site of *Polymesoda erosa*. The animals were collected from a clam bed adjacent to Tomkinson River.

measurements were made to the nearest 0.1 ml by water displacement (Quale and Newkirk 1989). Live weights (LW) to the nearest 0.01 g were determined after drying the shell with paper towels. Sex was determined based on the colour of the gonads. The gonad is black in females and creamy white in males. The wet tissues were blotted and their weights were measured to the nearest 0.001 g with a Sartorius B310S electronic balance. The dry weights (DW) were recorded after freeze-drying the tissue to a constant weight for 72 hours. The ash content was determined after combusting the dry materials for 20 hours at 500°C. The ash-free dry weight (AFDW) was calculated by subtracting ash content from dry weight.

The relationships between shell dimensions (length, height, width) and shell volume to LW, DW and AFDW were independently evaluated using log-transformation of the equation:

$$Y=aX^b$$

where **Y** is LW (g) or soft tissue (WW, DW, or AFDW in grams), and **X** is one of the dimensions (length, height, width in centimeters) or volume (ml), **a** is the intercept and **b** is the slope parameter. The volume-live weight relationship was also evaluated separately for females and males as well as for clams collected during the dry season (June-October) and the middle to end of the wet season (February-April). An ***F***-test was applied to test whether the slopes of the regression lines were significantly different from zero. Differences between regression lines of males and females, and of seasons were tested using the two-tailed Student's *t*-test (Fowler et al. 2000). Routine regression analyses were completed using the Statistica version 6 (Statsoft 2002).

Results

All the slopes of the regression lines are significantly different from zero. Shell length, shell height, shell width and shell volume all show a strong correlation with live weight (Table 1). At least 76 percent of the variation in the latter is accounted for by variation in either shell dimensions or volume. The shell volume is the best estimator of the live weight with $\mathbf{r^2}$ of 95 percent. However, when applied to soft tissue weights, either in wet, dry or ash-free basis, none of these shell variables is a good predictor ($\mathbf{r^2}$ values of 13-32 percent).

Because volume displacement is the best estimator for live weight, we used this variable to show differences in live weight of each sex during the dry and wet seasons (Table 2). The slopes are constantly higher during the wet season, indicating more variability in live weight than that of dry season. The slope of the male's regression line during the dry season is significantly lower than for the wet season (t=3.047, d.f=51, p<0.05), while the slopes for the females do not differ significantly (t=1.234, d.f=51, p>0.05). Combined data for both sexes show a significantly different slope (t=2.016, d.f=106, p<0.05) for clams collected during the dry season than those collected in the wet season. However, when contrasting the two sexes collected in the same season, the result is not significant (dry: t=1.194, d.f=71, p>0.05; wet: t=1.648, d.f=31, p>0.05).

Discussion

The results show a strong linearity between shell dimensions and volume to live weight, but little relationships between shell dimensions and the soft tissue for the clam population in Maningrida. This indicates that the soft tissue did not change much although the clams grew steadily. The **b** value

Table 1. Allometric relationships of shell dimensions (cm) and shell volume (ml) to live weight (g) and soft tissue weight (g) of *Polymesoda erosa*.

Relationship	n	a	b ± SE	r^2	F*
Live weight (LW)					
Length vs LW	371	0.374	2.905 ± 0.0679	0.831	1 830.0
Height vs LW	371	1.749	2.249 ± 0.0658	0.759	1 167.9
Width vs LW	371	3.604	2.472 ± 0.0426	0.901	3 357.3
Volume vs LW	134	1.728	0.959 ± 0.0178	0.956	2 903.5
Wet soft tissue weight (WTW)					
Length vs WTW	371	0.142	2.251 ± 0.1958	0.262	132.1
Height vs WTW	371	0.879	1.416 ± 0.1695	0.157	69.7
Width vs WTW	371	0.992	1.786 ± 0.1617	0.246	121.9
Volume vs WTW	134	0.343	0.805 ± 0.1078	0.291	55.7
Dry soft tissue weight (DTW)					
Length vs DTW	371	0.054	1.944 ± 0.1759	0.247	122.1
Height vs DTW	371	0.292	1.158 ± 0.1529	0.132	57.3
Width vs DTW	371	0.309	1.490 ± 0.1466	0.216	103.3
Volume vs DTW	134	0.114	0.694 ± 0.0956	0.280	52.6
Ash-free dry weight (AFDW)					
Length vs AFDW	134	0.023	2.293 ± 0.2886	0.318	63.1
Height vs AFDW	134	0.158	1.416 ± 0.2583	0.179	30.1
Width vs AFDW	134	0.198	1.706 ± 0.2578	0.243	43.8
Volume vs AFDW	134	0.110	0.681 ± 0.0949	0.275	51.5

n=sample size; **a**=intercept; **b**=slope; SE=standard error; $\mathbf{r^2}$=coefficient of determination; * all ***F*** values are highly significant (p<0.001).

Table 2. Allometric relationships of shell volume (ml) to live weight (g) of female and male *Polymesoda erosa* during dry and wet seasons.

Sex	Season	n	a	b ± SE	r^2	F*
Male	Dry	40	1.674	0.967 ± 0.0211	0.982	2 106.3
Male	Wet	15	0.733	1.138 ± 0.0520	0.972	479.0
Female	Dry	35	2.274	0.900 ± 0.0423	0.930	453.9
Female	Wet	20	1.424	0.998 ± 0.0672	0.920	220.4
Male + Female	Dry	75	1.872	0.942 ± 0.0217	0.962	1 889.0
Male + Female	Wet	35	1.145	1.044 ± 0.0457	0.939	521.6

n, a, b, SE, $\mathbf{r^2}$, ***** are as in Table 1.

for the length-weight relationship is within the range for other bivalves (Park and Oh 2002). The lack of a strong correlation between shell size and flesh tissue for *P. erosa* is different from that reported in other bivalves, such as *Mercenaria mercenaria* (Hibbert 1977), *Mytilus edulis* (Rodhouse et al. 1984), *Dreissena polymorpha* and *D. burgensis* (Ross and Lima 1994), *Artica islandica* (Thórarinsdóttir and Jóhannesson 1996), *Chamelea gallina* (Deval 2001) *Pinctada margaritifera* and *P. maxima* (Yukihira et al. 1998). The grown shells make the live animals heavier, either because of increased shell mass or a higher capacity to contain water. The need for strong shells and a high capacity to live in adverse conditions in intertidal areas might direct the allocation of energy to shell growth instead of the soft tissue. This investment of energy on the shell limits the growth of an individual (Currey 1988).

P. erosa habitats in northern Australia are in the high zones around estuaries where long periods of emersion take place. They bury themselves in the mangrove mud, with only small parts of the shell with siphons emerging to filter water. The animals are potentially exposed to desiccation and a wide range of salinities. The clams also experience low pH, as indicated by the shape of the shells, which are badly eroded by acid mangal soils (Morton 1985). To protect the body against adverse environmental conditions and predators, they need thick valves that can be closed tightly. The need for thicker and heavier shells than normal was also reported in *Mytilus edulis* inhabiting periodically dry zones (Seed 1968) and is common in shell-bearing molluscs living in intertidal or shallow marine environments (Tokeshi et al. 2000).

In addition, a low rate of tissue growth is useful for survival of the clams under prolonged exposure. During the periodic emersion, the clams need to maintain a large volume of water inside the shell to create a sufficiently watery environment for survival of the body tissue (Seed

1968). If the soft tissue continues to grow steadily and occupy a large part of the space inside the shell, then there would not be enough water to support the metabolic needs of the increased tissue.

The slope values (**b**) for the shell volume and weight relationship of animals in the wet season are significantly different to those during the dry season. This could be because the animals spawn intensively from the middle to the end of the wet season (Gimin et al. unpublished data).

In conclusion, shell dimensions or volume are not good estimators for the biomass of *P. erosa*. However, the allometric relationship between shell length, width or volume to live weight can be used for monitoring the growth of this species in the natural population.

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