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Some Aspects of the Population Biology of the Sunset Elongate Clam *Gari elongata* (Lamarck 1818) (Mollusca, *Pelecypoda: Psammobiidae*) from the Banate Bay Area, West Central Philippines

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Abstract

The study presents a first report on the population and reproductive biology of the psammobiid clam *Gari elongata* from west central Philippines. The species was found to prefer areas with salinities of less than 15 ppt, and most especially freshwater. A related species *P. virescens*, predominates in estuarine habitats within the same general vicinity. Although both species are reported in taxonomic literature as predominantly estuarine, the present distribution pattern of *G. elongata* indicates possible upstream transport and consequent adaptation to lower salinities. Based on the Bhattacharya method, a mean growth rate of 0.13 ± 0.06 mm d^{-1} was estimated for the species. The growth parameters derived using the ELEFAN I method are $L_\infty = 93$ mm and $k = 1.0 \cdot yr^{-1}$, corresponding to a growth index ($Ø'$) of 3.94. Growth estimates based on the two methods are reasonably comparable, both indicating that the species is a fast-growing, short-lived species, which is typical for tropical species.

Based on length-converted catch curve analysis, the total mortality (Z) of the population is estimated to be $2.95 \cdot yr^{-1}$, which also corresponds to the natural mortality (M), this being an unexploited population. The derived recruitment pattern for the species shows two pulses of unequal strengths and duration, dividing the year into a 7-5 month pattern, which is comparable to the known monsoon-driven fish and invertebrate populations in the Philippines. Although reproduction is continuous throughout the year, the observed recruitment pattern could very well result from a major and a minor spawning peak occurring between December-January and May-June, respectively. These two spawning peaks may most likely be influenced by the monsoons, which in turn, affect the precipitation and salinity levels in the species' habitat. The average size at sexual maturity in the species is about 40 mm, the minimum harvest size that a fishery should allow to ensure the viability of future recruits. Future studies are needed to confirm the reproductive pattern of the species, the factors that affect spawning periodicity, and the specific causes of natural mortality in the species.

Introduction

The clam *Gari elongata* Lamarck 1818 belonging to Family Psammobiidae, is locally known in Iloilo, Philippines as “bayuyan”, and is known to occur primarily in freshwater. The literature reports its distribution to be littoral and sublittoral (FAO 1998; Matsukama 2000). FAO (1998) also lists *G. elongata* as having *Psammotaea elongata* and *P. minor* among its several frequent synonyms/misidentifications. *G. elongata* has previously been unreported in the Philippines.

In Banate Bay, Panay, harvests of *G. elongata* appear to be unpredictable and thus, the species is irregularly encountered in the local markets. So far, there have been no assessments conducted to determine the status of exploitation of these species. Based on interviews with locals in Banate Bay, the species used to be more common in the past. The reasons for the seasonality of harvests and/or decline are however, not clear at the present. However to ensure that these resources continue to be viable, there is a need for studies on the biology and fishery of the species, so that a rational exploitation or management scheme can be established.

The present paper therefore aims to study some aspects of the population biology of *G. elongata*, as an attempt to contribute knowledge to its overall biology. This paper 1) describes its habitat and distribution according to salinity, 2) determines its growth rates, recruitment pattern and total mortality rate, and 3) determines the annual spawning pattern based on relative gonad weights.

Materials and Methods

Study area and survey

The study was conducted in Bugnay, Barotac Viejo, Iloilo, Panay Island, in west central Philippines (11°03' N; 122°50' E)(Fig. 1). To determine the distribution of individuals at different salinity levels, a line-

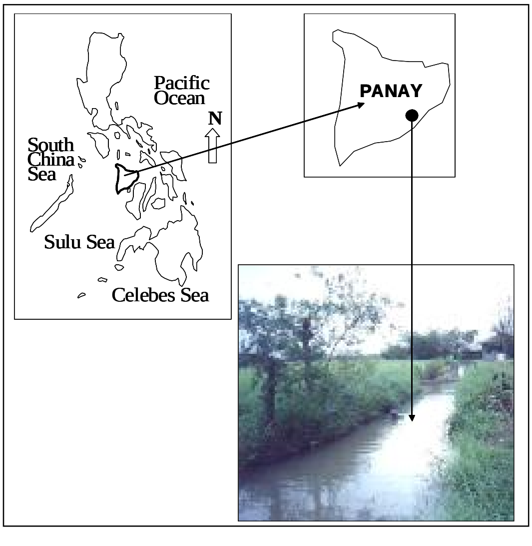

Fig. 1. Site of collection of the clam *Gari elongata*: irrigation canal (depth ~0.5m) in Barotac Viejo, Iloilo, Panay Island, Philippines

transect survey was conducted from the inner rice farm irrigation canals down to the mouth of the Alacaygan River, which empties into Banate Bay. A total of 8 permanently submerged stations; approximately 300-500 m apart were sampled. A 0.5 x 0.5 m quadrat was used to determine densities (ind. m^{-2}) at each station. Salinity was measured in each station using a refractometer. Water depth in the stations was ≤ 1 m. After determining the distribution, monthly sampling through random hand-gathering, was conducted over a one-year period (February 2001 to January 2002), at the station where the highest densities were found. Monthly measurements of at least 300 individuals (returned after measurements) were taken using a vernier caliper. Shell widths (SW in mm), or the perpendicular distance from the umbo to the valve margin, were measured.

Laboratory and data analyses

The clams do not exhibit external sexual dimorphism and therefore, a random subsample of 60 individuals per month was brought to the laboratory for gonad analysis. In the laboratory, total wet weights with shell (TW to the nearest 0.01 g) were taken using a digital electronic balance. The shells were separated and viscera weights (VW in g) were determined. The individuals were further dissected and the gonad weights (GW in g) were also determined. SW-TW, SW-VW, and SW-GW relationships for the species were established through regression analyses. The gonadosomatic index (GSI in %) of each individual was computed according to the equation:

$$GW/VW \times 100 \qquad (1)$$

Individual GSI values for four selected months (April, July, Oct, Jan) representing one quarter of the year were plotted against size (SW in mm) to assess the average GSI value representing the sexually mature condition. Averaged monthly GSI values were also plotted against time (months). Due to limitations in logistics, no histological analysis of the gonads was conducted.

Monthly length measurements were grouped into 5 mm size classes (0-4.99, 5-9.99, 10-14.99, etc. mm) and analyzed using the Bhattacharya (1967) method, useful for splitting a composite distribution into separate normal distributions when several age groups (cohorts) are contained in the same sample. The Bhattacharya routine is incorporated in the FiSAT software (Gayanilo et al. 1998). To compute growth rates ($mm \cdot day^{-1}$) by cohort, increments between the modal lengths (mm) derived using the Bhattacharya method, were divided with their respective time increments (days). Mean growth rates for each cohort were averaged to estimate the annual mean growth rate for all cohorts. The growth parameters L_∞ and k were derived using ELEFAN I, also part of the FiSAT package. The growth index Ø' was computed according the equation of Pauly and Munro (1984) as follows:

$$Ø' = \log k + 2 \log L_\infty \qquad (2)$$

The mean recruitment patterns, as well as the instantaneous total mortality (Z, yr^{-1}) were determined using the ELEFAN II software. In this method, the recruitment pulses are reconstructed from the length-frequency data to determine the number of pulses per year and the relative strength of each pulse. Total mortality Z was derived using the length-converted catch curve analysis, based on the equation:

$$Z = F + M \tag{3}$$

where Z = total mortality, F = fishing mortality and M = natural mortality. The monthly collection of 60 individuals for this study is considered negligible, compared to harvesting by a regular fishery. Thus, aside from this collection, this particular population of *G. elongata* is known to be unexploited. Based therefore on equation 3, F is equal to 0, and Z = M.

Results

Habitat and distribution

Individuals of *G. elongata* show a burrowing habit, whereby the anterior end is sunk into the substrate and the posterior end exposed in the overlying water. In this burrowed position, the valves are partially opened, with the siphons extending out from the posterior end. The organisms occur in non-vegetated rice paddy irrigation canals and riverine tributaries, which are less than 1 m in depth.

In terms of distribution, they were found mostly in areas of lower ($0^{-1}0$ ppt) than higher salinities (>10 ppt) (Fig. 2). Density was found to be highest (100 inds. m^{-2}) at Station 1 (0 ppt or freshwater), consistently decreasing to 30 inds. m^{-2} at Station 4 (~4 ppt), which marks the boundary of the riverine/brackishwater stations. Density at the river mouth (Station 8), where salinity was measured to be 15 ppt, was < 10 inds. m^{-2}.

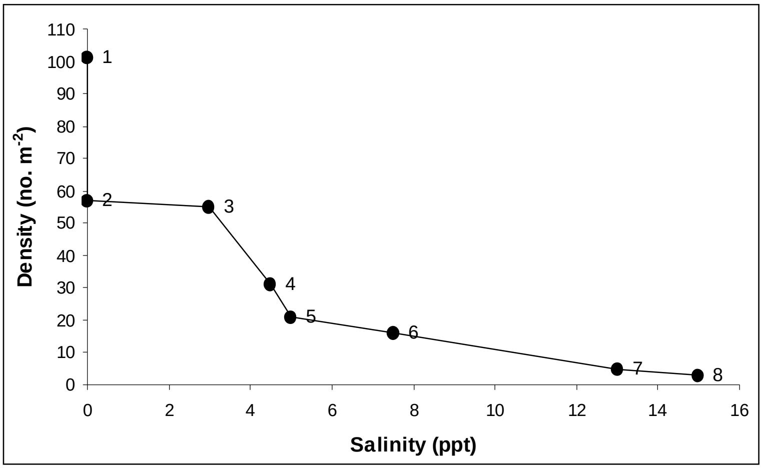

Fig. 2. Population density of *Gari elongata* at different salinity levels. Stns. 1-4: Irrigation canal, freshwater: Stns. 4-8; river (brackish).

Morphometrics and growth

Shell width (SW)-total weight (TW), SW-viscera weight (VW) and SW-gonad weight (GW) relationships for *G. elongata* were all allometric (Figs. 3-5). The derived equations are as follows: TW = 0.000535 SW $^{2.5}$ (r^2 = 0.926; n = 300) (Fig. 3); VW = 0.000285 SW $^{2.42}$ (r^2 = 0.945; n = 300) (Fig. 4); and GW = 0.0000761 SW $^{2.41}$ (r^2 = 0.870; n = 300) (Fig. 5). All slopes in the regressions were found to be highly significant ($p < 0.01$).

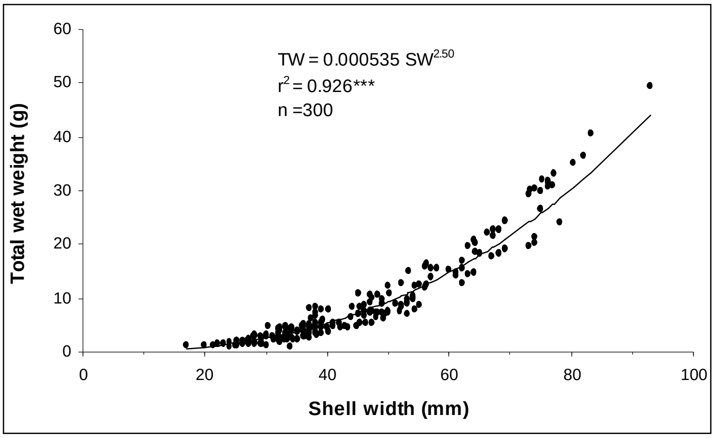

Fig. 3. Shell width (mm) vs. total wet weight (g) relationship in *G. elongata*

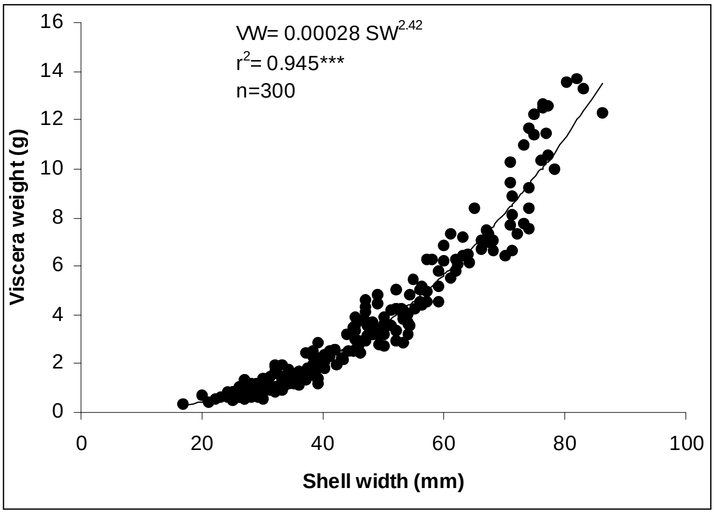

Fig. 4. Shell width (mm) versus viscera weight (g) relationship of *Gari elongata.*

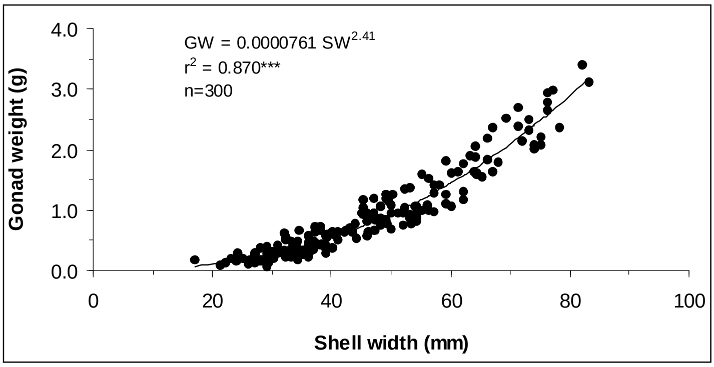

Fig. 5 . Shell width (mm) versus gonad weight (g) relationship of *Gari elongata.*

Size frequency data collected from February 2001 to January 2002 are plotted in Figure 6. The smallest individuals ($5^{-1}5$ mm SW) of the population showed highest abundance in December 2001, but new recruits (< 10 mm SW) were also observed in May, June and October 2001, as well as in January 2002. On the other hand, the largest sizes (> 80 mm) were available almost the whole year round. Most individuals of the population however, fell within the range of 35-70 mm SW.

Based on the Bhattacharya analysis, a total of 8 cohorts were derived, with each cohort sampled between 2-7 times (Table 1, Fig. 6). Daily growth rates ranged from 0.03 - 0.26 mm•day^{-1}, with a mean annual growth rate computed to be 0.13 ± 0.06 mm•day^{-1} (n = 26). Mean rates by cohort were comparable and were within a narrow range of values (0.11-0.16 mm•day^{-1}),

Table 1. Growth rates of the derived cohorts of *G. elongata* sampled from Feb 2001 to Jan 2002 in the Banate Bay area, west central Philippines

Cohort No.	Collection Dates	No. of Times Sampled	Mean W (mm)	$W_2 - W_1$ (mm)	$t_2 - t_1$ (days)	Growth Rates (mm day^{-1})
1	Feb. 18, 2001	3	53.34	-	-	-
	Jun. 16, 2001		74.39	21.05	118	0.18
	Aug. 11, 2001		75.78	1.39	55	0.03
3	Feb. 18, 2001	5	31.45	-	-	-
	Jun. 16, 2001		47.76	13.31	118	0.11
	Jul. 17, 2001		52.98	5.22	31	0.17
	Sept. 22, 2001		60.00	7.02	67	0.10
	Oct. 13, 2001		61.18	1.18	21	0.06
2	Mar. 17, 2001	7	48.51	-	-	-
	Apr. 7, 2001		53.92	5.41	21	0.26
	May 5, 2001		55.88	1.96	28	0.07
	Jun. 16, 2001		58.21	2.33	42	0.06
	Sept. 22, 2001		75.00	16.79	98	0.17
	Oct. 13, 2001		77.84	2.84	21	0.14
	Nov. 11, 2001		79.87	2.03	29	0.07
4	Mar. 17, 2004	6	28.89	-	-	-
	May 5, 2001		34.51	5.62	49	0.11
	Aug. 11, 2001		48.29	13.78	98	0.14
	Nov. 11, 2001		54.89	6.60	92	0.07
	Dec. 9, 2001		57.99	3.10	28	0.11
	Jan. 13, 2002		63.13	5.14	35	0.15
5	Jul. 17, 2001	5	27.50	-	-	-
	Aug. 11, 2001		32.41	4.91	25	0.20
	Oct. 13. 2001		40.74	8.33	63	0.13
	Dec. 9, 2001		44.99	4.25	57	0.07
	Jan. 13, 2002		50.31	5.32	35	0.15
6	May 5, 2001	3	10.00	-	-	-
	Sept. 22, 2001		27.17	17.17	140	0.12
	Nov. 11, 2001		36.18	9.01	50	0.18
7	Oct. 13, 2001	3	16.86	-	-	-
	Dec. 9, 2001		27.23	10.37	57	0.18
	Jan. 13, 2002		36.75	9.52	35	0.27
8	Dec 9, 2001	2	10.95	-	-	-
	Jan. 13, 2002		13.65	2.7	35	0.08
					Mean =	**0.13**
					SD =	**0.06**
					N =	**26**

except in cohort 7, with a mean growth rate of 0.23 mm•day^{-1}. The latter is presumably due to the faster growth rates of mostly smaller sizes represented in the cohort.

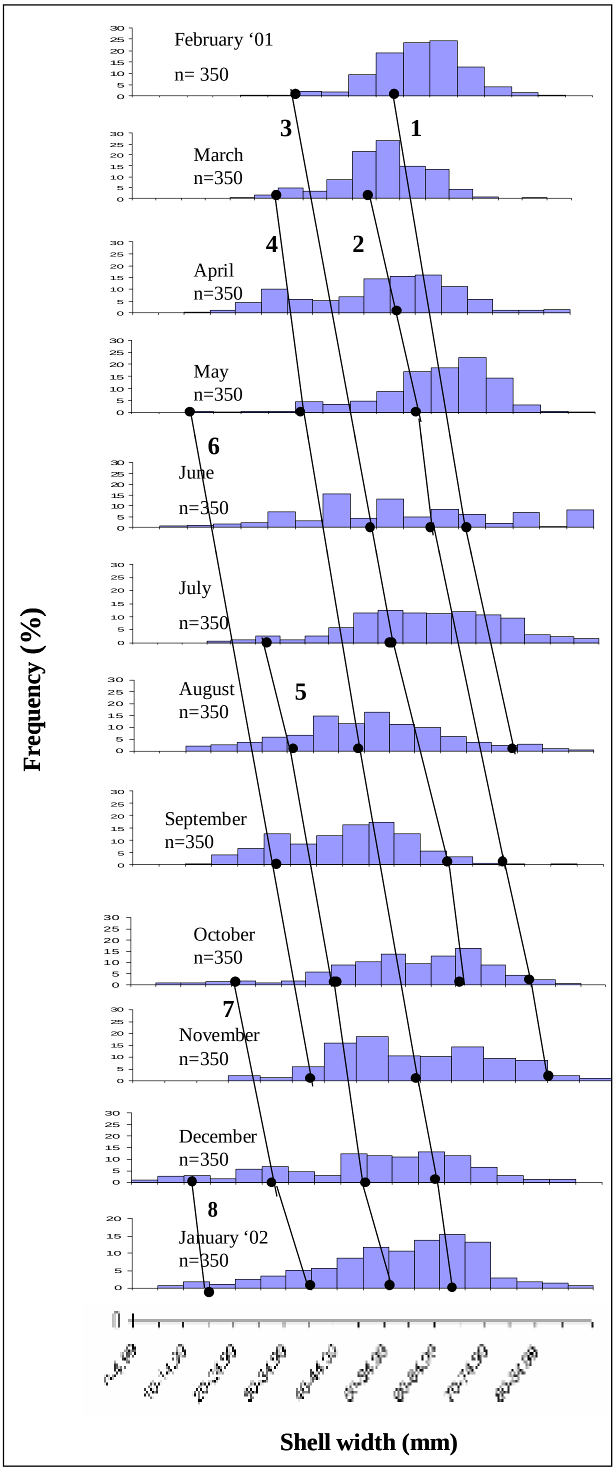

Fig. 6. Shell width - frequency distributions of *P.elongata*, February 2001 - January 2002, with superimposed modes of cohorts as identified from the Bhattacharya method

The VBGF parameters derived for the species using ELEFAN I were L_∞ = 93 mm and k = 1.0•yr^{-1}. Based on these parameters, the computed growth index (Ø') of the species is equivalent to 3.94. Based on the Bhattacharya results, the L_∞ of 93.0 mm can be attained in two years, and thus, may be assumed as the longevity period of the species.

Recruitment pattern and mortality

The recruitment pattern of *G. elongata* derived using the FiSAT software, consists of two pulses, of unequal strengths and durations (Fig. 7). Based on the length-frequency data, the highest recruitment occurred in December to January, which could be taken to correspond to the major recruitment pulse. The minor pulse, on the other hand, occurred sometime between May to June. Therefore, these two pulses divide the year into a 7-5 month pattern.

Based on the catch curve analysis, the total mortality (Z), and hence natural mortality (M) of the species, is equivalent to 2.95•yr^{-1}.

Notes on reproduction

Based on preliminary histological analysis of the gonads, *G. elongata* was found to be dioecious, but does not exhibit any external sexual dimorphism. The gonads are for both sexes, creamy white in color, regardless of the stage of maturity. It was therefore, not possible to evaluate the sexual maturity of the individuals based on external appearance of the gonads. Averaged monthly GSI values plotted against months did not show significant fluctuations within the entire year (Fig. 8), indicating that reproduction was continuous throughout the year. This is further shown by the GSI values plotted against size for the months of April, July, October and January (Figs. 9a-d). A wider range of GSI values can be observed for clams with shell widths > 40 mm, indicating the most active gonad activity. This could thus be taken as the average size at sexual maturity for the species. Based further on these, the widest range of GSI values for most sizes was observed in January (Fig. 9d), which could be assumed as coinciding with the major peak in the annual reproductive (spawning) cycle. This time period is likewise consistent with the months during which, most recruits were observed

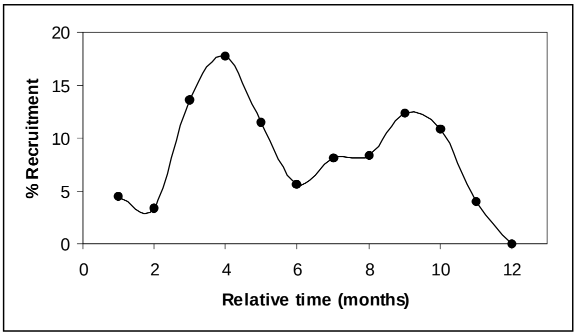

Fig. 7. Recruitment pattern of *G. elongata* derived using FiSAT

(Fig. 6). Therefore, maximum gonad activity in the species presumably occurs during the dry and cooler months (December-January) of the year. Based on the length-frequency data (Fig. 6) and the derived recruitment pattern, a minor spawning peak occurs sometime in May-June, which corresponds to the end of the dry season (and start of the wet season) in the area.

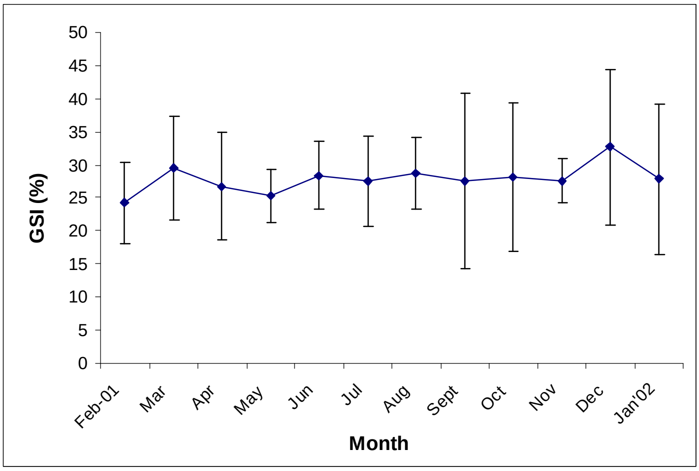

Fig. 8. Gonadosomatic index (GSI,%) of *Gari elongata* from February 2001-January 2002 from Bgy. Bugnay, Barotac Viejo, Iloilo, Philippines

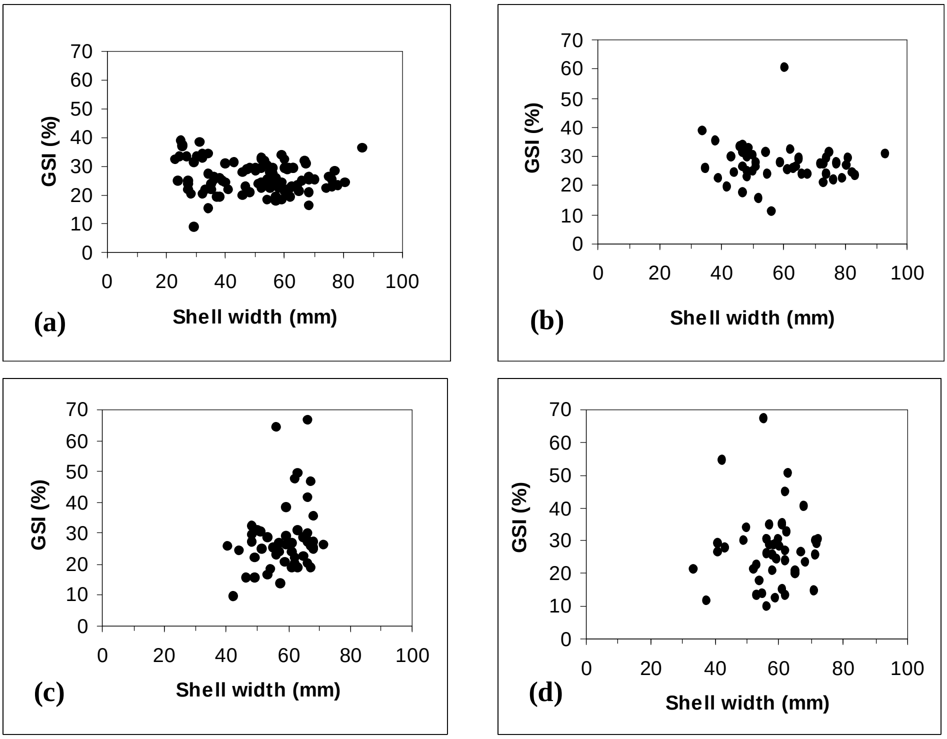

Fig. 9. Gonadosomatic index (GSI %) of *Gari elongata*: a) April 2001; b) July 2001; c) October 2001; d) January 2002. Sample size (n) in all months is at least 60.

Discussion

Habit, habitat and distribution

The genus *Gari* is reported to have an estuarine, littoral to sublittoral habitat (FAO 1998). According to Matsukama (2000), it is usually found in intertidal mud bottoms of embayments. Based on the present results however, *G. elongata* was found in freshwater, with densities decreasing as salinity increases (Fig. 2). Another clam species, identified as *Psammotaea virescens* (pers. com. J. Cabrera, Phil. National Museum), was found only at the rivermouth (estuarine) areas in Banate Bay. This spatial segregation between the two forms might be due to adaptation to upstream habitats in *G. elongata*. Continued flooding from the upper branches of the riverine system, may have resulted in eventual acclimatization of *G. elongata* to lower salinity. Although FAO (1998) reported *G. minor* to be a synonym of *G. elongata*, Matsukama (2000) listed down the occurrence of three *Psammotaea* species namely, *P. elongata*, *P. virescens*, and *P. minor*. The latter species was not encountered in the study area, and its distribution therefore remains unclear. The third species *P. minor* has not yet been observed in the study area. Its distribution therefore, remains unclear. In a separate study, *P. virescens* was also observed being sold in a market in northern Panay Island (del Norte-Campos, et al. submitted), having been collected also in neighboring areas.

As a result of habitat adaptation, the burrowing habits of the *G. elongata* and *P. virescens* also differ. *G. elongata* only partially burrows into the substrate in its freshwater habitat, which always remains inundated. In contrast, *P. virescens* usually found in intertidal habitats, which are exposed during low tide, burrows more deeply. When the areas are submerged, their siphons extend out from the valves, as was observed among live organisms that were kept in the laboratory. Burrowing behavior in some freshwater and estuarine bivalves has been reported to be influenced by such factors as temperature, salinity, alkalinity, presence of metals (e.g. zinc and copper) (John & Fernandez 1989) and emersion (Bryne et al. 1990). The freshwater clam *Corbicula luminalis* was observed to burrow deeper into the substrate when disturbed or when availability of planktonic food becomes insufficient (Johnson 1987). Despite higher risks of predation by epibenthic predators, shallow burying in the intertidal bivalve *Macoma balthica*, in contrast, results in faster growth due to more access to food resources (De Goiej & Luttikhuizen 1998).

Population biology

The allometric shell width and weight relationships (Figs. 3-5) could be explained by the generally elongated (oval) and depressed (thin) shape that the organism attains, i.e. shell (and thus, tissue) growth along the three-dimensional axes is non-uniform, with the horizontal being faster, than the vertical and lateral dimensions.

The growth rates based on the Bhattacharya method and those based on the von Bertalanffy growth formula (VBGF) agree quite well, showing that the use of the two models was appropriate. In general, wider deviations (~85 %) in predicted ages of the cohorts based on these two independent methods were observed in cohorts (i.e. 1 & 2) for individuals > 65 mm. This could be explained by the slowing down of growth in these larger sizes. On the other hand, smaller deviations (5.5-7.6 %) in predicted ages were computed in cohorts (e.g. 3 & 4), predominated by faster-growing and smaller sizes (< 65 mm).

The relatively high growth factor ($k = 1.0 \bullet yr^{-1}$) is consistent with the well-known growth patterns of tropical fast-growing and short-lived species. In these species, temperature effects on growth are almost nil, and thus, no adjustments for seasonal growth were made during data analysis. The lack of smaller sizes could also indicate that present growth estimates are more conservative (Table 1). Growth parameters, etc. for other tropical and temperate bivalves are shown in Table 2 to allow comparisons with estimates for *G. elongata*. The computed growth index of *G. elongata* was higher, compared to the temperate freshwater clam *Corbicula fluminea*, but is more comparable with other temperate coastal bivalve species, such as *Venus antiqua*, *Tagelus dombeii*, and *Ensis macha* (Urban 1996). Reported lifespans of *C. fluminea* and the subtropical species *Scrobicularia plana* are longer (> 3 yrs.) (Table 2) compared to *G. elongata*. Considering the habitat of this species, the effects of precipitation, and thus salinity, on its growth may be more relevant. Seasonal effects of precipitation and evaporation on the growth of the Amazonian freshwater bivalve species *Anodontites trapesialis* were determined using stable isotopes (Kaandorp et al. 2001).

The peaks of the distributions of the smallest sizes in the data (Fig. 6) were not that pronounced, and this is due to the limitations in sampling these sizes in highly turbid areas. Nevertheless, new recruits or modal peaks

Table 2. Growth parameters, lifespan and timing of recruitment of some freshwater and estuarine bivalve species ($Ø' = \log k + 2 \log L_\infty$).

Species	L_∞ (mm)	k(yr^{-1})	Ø'	Lifespan (years)	Recruitment	Habitat	Literature
Tropical/ Subtropical							
Gari elongata	93.0	1.0	3.94	~2	Year-round with 2 pulses: Nov/Dec and May/June	Fresh- to brackishwater, Panay, Philippines	This study
Scrobicularia plana				>3	Jan-Jul to Oct-Dec	Bidasoa Estuary, Spain	Sola (1997)
Temperate							
Venus antiquata	73.9	0.218	3.08	>3	Mainly summer	Soft bottom coastal zone, *Chile (36 deg. S)*	Urban (1996)
Tagelus dombeii	88.5	0.232	3.27	“	“	“	“
Ensis macha	189.9	0.210	3.88	“	“	“	“
Corbicula fluminea	32	0.65	2.83	“	Oct-Nov	Parana River delta, Argentina	Cataldo and Boltovskoy (1998)

(< 10 mm) in the distributions of *G. elongata* were observed especially in the late (October and December 2001) and early (January 2002) months of the year (Table 1; Fig. 6). In addition, cohort 6 was first sampled in May 2001. Despite the lack of smaller sizes, it can be assumed that recruitment for this tropical species is year-round, in contrast to subtropical to temperate species, which predominantly recruit during summer.

The GSI plot against months (Fig. 8) did not show pronounced peaks in the annual periodicity of gonad development through time. This could be due to the fact that tropical species such as *G. elongata* exhibit protracted spawning, and that individuals with mature gonads can be found at any time of the year, with the absence of a period predominated by a spent or quiescent stage. The major and minor spawning peaks (January and June, respectively) assumed for the species coincide with the dry and wet seasons, respectively. Therefore, it is possible that the timing of spawning activity, and hence, recruitment pattern, in the species is influenced most especially by the monsoon periods, i.e. northeast and southwest monsoon that predominate in the area. The monsoons influence the amount of precipitation, and thus salinity in the species' habitat. Although there was a slight difference in the recruitment timing, the observed pattern (unequal 7-5 month pattern) is close to the general 8-4 pattern reported for Philippine marine fishes (Pauly and Navaluna 1983), or other bivalves, e.g. scallops (del Norte 1988).

This unexploited population presented a rare opportunity to estimate natural mortality in a bivalve population. Without harvesting/fullblown fishery, deaths in this population would primarily be caused either by old age, diseases, or predation. The first may be least likely, as no individuals > 90 mm were found. However, possible diseases or specific predators that could affect the individuals of this species are still unknown. Aside from physical factors, bivalve populations are generally controlled and structured by genetic background (Sato 1999), human influence (e.g. eutrophication) and biotic interactions (Ravera & Sprocati 1997; Defeo 1998). For the present study, although a combination of these factors most likely affects the population of *G. elongata*, further studies can show which among these factors predominate.

In conclusion, this is a first known study on the burrowing bivalve species *G. elongata*. It is found to occur predominantly in freshwater, and to a lesser extent, in estuarine areas of the Banate Bay area, west central Philippines. The estimated growth rates based on the Bhattacharya and VBGF methods were comparable (0.13 ± 0.06 mm d^{-1} and $L_{\infty} = 93$ mm, $k = 1.0 \cdot yr^{-1}$, resp.), with an estimated longevity of 2 years. Recruitment appears to be in two unequal pulses, most likely influenced by the monsoon seasons. Instantaneous annual total (Z) and natural mortality (M) were estimated to be $2.95 \cdot yr^{-1}$. Reproduction is protracted over the year, with 40 mm shell width as the average size at sexual maturity. In the future, this could be used as basis for promulgating harvesting regulations for the species.

Future studies should conduct more detailed gonad analyses of both sexes of the species. Factors affecting spawning periodicity, notably lunar cycle and salinity need to be investigated. Knowledge on the natural causes of mortality of the species is also valuable information on the biology of this species.

Acknowledgments

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