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FILTRATION AND RESPIRATION RATES OF THE ELONGATE SUNSET CLAM GARI
ELONGATA LAMARCK 1818 UNDER NATURAL LIGHT CONDITIONS

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ABSTRACT This study is a first step in evaluating the potential of the suspension-feeding clam Gari elongata as a biofilter in
lake/pond polyculture systems. Filtration and respiration rates across all sizes of G. elongata were measured in the laboratory under
natural light conditions. Filtration rates (F) were determined in a batch system at four concentrations (10, 25, 50, and 100 \times 10^3 cells
mL\(^{-1}\)) of the phytoplankton Isochrysis galbana. Filtration rates were higher at lower concentrations but decreased with the highest
concentration, indicating a possible overloading of the gill sorting mechanism. For the given conditions, mean F at 45.11 h\(^{-1}\)g\(^{-1}\)
was considered optimal at 25 \times 10^3 cells mL\(^{-1}\). This value proves to be the highest F value reported so far, for bivalves. The results further
qualify the species as a biofilter in fresh- to brackishwater polyculture setups. F values were further observed to decrease with body
weight, although there was a wide variation. The F:W exponent computed for the species was inconsistent with reported trends, which
may be due to either light conditions or algal cell size. There was no increase in the species’ respiration rate (R) with feeding. For unfed
clams, R decreased with size, but there was high variation, and the relationship was not significant. At optimum algal concentration,
R per unit body mass for fed clams, decreased with size, and the computed R: W exponent value points to a less rapid increase in
size-respiration rate than most other bivalves.

KEY WORDS: filtration rates, respiration rates, Gari, body size, algal concentration, physiology

INTRODUCTION

Intensification in aquaculture has become a choice option to ensure food security in the face of an ever-increasing population and parallel demand for fishery products. Hence, there is a continuous effort to increase production in fishponds, pens and cages (Briggs & Funge-Smith 1994, Funge-Smith & Briggs 1998).

Along with this effort, however, are emergent concerns relating to the environmental impact of aquaculture, specifically the increased organic loading from excess feeds and wastes, observed in freshwater lakes and coastal habitats.

In the light of these concerns, polyculture with biofilters, or co-rearing invertebrates and aquatic macrophytes with fish and/or crustaceans, may serve as the solution (e.g., Shpigel & Fridman 1990, Shpigel & Blaylock 1991, Shpigel et al. 1993, Ahlgren 1998). These filter- (e.g., bivalves) or deposit- (e.g., sea cucumbers) feeding invertebrates and seaweeds can help maintain water quality by using up excess bottom-accumulated organic matter (e.g., excess feeds, fecal material) and suspended dissolved nutrients, thereby converting these to usable or harvestable biomass.

Although polyculture in marine waters has received ample attention, using bivalves in freshwater systems is a relatively new topic. A possible biofilter species is the filter-feeding psammobid clam Gari elongata Lamarck, a lesser-known bivalve species that burrows in shallow, freshwater to brackish (0–15 %/oo) waters in Panay island, located in the west central Philippines (del Norte-Campos, submitted). It is characterized as having brownish black, elongated, and moderately thick shells. This species may be a potential polyculture species in tilapia cage culture (lakes) and/or carp and catfish ponds. It is harvested and sold for food in local markets, albeit at low prices and quantities. Although abundant, the species has received little scientific attention, possibly because they closely resemble the more popular and studied, brown mussel (Modiolus metcalfei) in appearance.

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This study on G. elongata had the overall goal to quantify the components of the species’ energy budget, C = f + U + P + R (modified from Windell 1978), where the energy of the food consumed (C) is apportioned to the energy lost in the form of feces (f), urine or excreta (U), and respiration or metabolic cost (R) and gained in the form of tissue growth (P). Food consumption (C) in filter-feeding bivalves is a function of filtration (F) and absorption (A).

The specific objectives of the present work were to measure the 1) filtration rates (F) of the species, in terms of body size and algal concentrations and 2) respiration rates (R) for unfed and fed individuals of various size classes.

MATERIALS AND METHODS

Study Area and Laboratory Experiments

The clams used for this study were collected by hand from rice farm irrigation canals in Barotac Viejo, Iloilo province, eastern Panay Island in west central Philippines (Fig. 1). Water depth in the area was around 1 m, with salinity ranging from 0 to 10 ppt. Bottom substrate was muddy to silty. These canals drain into the Alacayagan River, which empties into the Banate Bay. The clams were brought to the laboratory and acclimated for at least 3 days prior to the start of the experiments. Although the species tolerates salinities of up to 15 ppt (del Norte-Campos, submitted for publication), all experiments were conducted using freshwater, with water temperatures ranging from 26 to 30°C.

Morphometrics

Shell length (in mm) was measured with the use of a vernier caliper. Filtration and respiration rates were determined for six size classes: 10–19.99, 20–29.99, 30–39.99, 40–49.99, 50–59.99, and 60–69.99 mm. Wet and dry weights (g) of individuals from across all size ranges were taken. Soft tissue was dried at 60°C to constant weight. The relationship between shell length and dry soft tissue weight was derived through regression analysis. For each size
class, three trials (replicates) were conducted, with each trial consisting of three individuals.

Microalgae

The phytoflagellate *Isochrysis aff. galbana* Tahitian (*F-Iso*), harvested during its logarithmic phase of growth, was used as food. The species was selected for its relatively small size (mean cell diameter approx. 4 µm), and nutritional value, that it is therefore, widely used in mariculture (Taylor et al. 1997, Brown et al. 1999, Phatarpekar et al. 2000).

Filtration Rates

Four microalgal concentration levels were tested: 10, 25, 50, and $100 \times 10^3$ cells mL$^{-1}$. These values correspond to levels that are normally encountered in aquaculture ponds (Duerr et al. 1998). The desired concentration and volume was obtained through dilution.

The volume of water that each bivalve filtered of particulate material ($F$, h$^{-1}$; or the indirect method of Jorgensen 1990) was determined from separate containers (V approx. 8 L) holding the bivalves. Water sampling was done every thirty minutes during a 3-h experiment. A 5-mL sample was collected each time from the center of the containers and immediately fixed with two drops of Lugol’s solution to prevent further reproduction of the algal cells. The density of the algal population in every sample was measured by direct algal cell count using a hemocytometer and a microscope. Three replicate counts were made for each sample. A parallel control set-up showed no significant change in algal cell densities during the 3-h observation period.

For each clam, the filtration rate was determined using the formula $F = V/r$, where $r$ is the rate constant (h$^{-1}$), or the negative of the slope obtained from regressing ln $C$ or cell concentration (mL) against time (h) and $V$ is volume of the diluted algal suspension containing the clams. Because filtration rates were measured in a batch system where algal concentrations do not remain constant, only the descending limb of the curve was included in the determination of the slope, that is, the flatter portion (asymptote) was excluded. Derived filtration rates were compared for the four algal cell concentrations, and based on this, an optimal cell concentration was chosen. For the optimum concentration, the relationship between $F$ and dry wt (g) was derived, and compared with reported values. To show the relationship of filtration rates with size, filtration rates were expressed in terms of the dry weight of the organisms (h$^{-1}$ g$^{-1}$) and plotted against the corresponding dry weights (g) of the organisms.

**Respiration Rates**

Respiration rates were measured for both unfed (ration = 0; starved for 24 h) and fed clams. The latter were also given F-Iso at the observed optimal algal concentration in a holding container for at least 15 min. prior to respiration measurements. For both unfed and fed clams, three individuals per size class were placed in a sealed transparent Plexiglas chamber (15 × 15 × 15 cm, or 3.4-L capacity). Oxygen concentration in each chamber was measured at 30-s intervals using a YSI DO meter. A parallel control with no clams was run to test the stability of the chamber. Respiration rate ($R$, mL O$_2$ ind.$^{-1}$ h$^{-1}$) was determined as the negative of the slope of ln O$_2$ concentration vs. time (h). Initial data plots served as bases to decide the time series portion that was included. The relationship between $R$ and dry wt was likewise derived, and compared with reported values in the literature. To show the effect of size as in above, respiration rates were also expressed in terms of the dry weight of the organisms (mL O$_2$ h$^{-1}$ g$^{-1}$) and plotted against the dry weights (g) of the organisms.

**RESULTS**

The range of sizes used in the experiments was 11.8–67.9 mm, corresponding to 0.008–1.298 g dry weight. Filtration rates ($F$) for the algal concentrations of 10, 25, and $50 \times 10^3$ cells mL$^{-1}$ averaged for all sizes were found to be higher (81.3, 45.1, and 68.5 L h$^{-1}$ g$^{-1}$ resp.) and lowest (25.9 L h$^{-1}$ g$^{-1}$) at the highest algal concentration of $100 \times 10^3$ cells mL$^{-1}$ (Fig. 2). Although the differences were found to be statistically significant, the optimum algal cell concentration selected was $25 \times 10^3$ cells mL$^{-1}$, as this was the median of the range of concentrations where F values were higher. This would further be the logical choice considering that among all four concentrations, it was with this concentration that the F was

![Figure 2](image-url)
highest for four size categories (20, 30, 40, and 50 mm) out of the six (excluding 10- and 60-mm size classes; Fig. 2).

Filtration rates (L h\(^{-1}\) g\(^{-1}\)) plotted against dry weight (g) was shown to decrease with size with the slope equivalent to -1.1196 and \(r^2 = 0.9723\) (Fig. 3). The regression was found to be significant (\(P < 0.01\)), i.e. the intercept and slope are significantly different from 0.

Respiration rates in terms of weight (mL O\(_2\) h\(^{-1}\) g\(^{-1}\)) plotted for both unfed (Fig. 4) and fed (Fig. 5) clams were observed to decrease with size. The relationship for the latter was significant, with a slope of -0.6712 and \(r^2 = 0.848\). The mean computed rate for unfed clams were 0.61 mL O\(_2\) ind\(^{-1}\) h\(^{-1}\), whereas at optimal algal concentration values ranged from 0.11 to 0.96 mL O\(_2\) ind\(^{-1}\) h\(^{-1}\).

**DISCUSSION**

The observed initial increase and subsequent decrease in filtration rates of *G. elongata* with increasing cell concentration (Fig. 2), is similar to several results on different lamellibranch bivalves (e.g., Winter 1970, Tenore & Dunstan 1973, Schulte 1975, Gerder 1983) indicating that filter feeding is affected by cell concentration. This has likewise been observed even for bivalve larval stages. In the oyster *Ostrea edulis* for example, ingestion ration was correlated with algal cell concentration, whereby further increases in the latter failed to support higher ingestion rates and faster growth rates (Beiras & Perez Camacho 1994). It is apparent therefore, that bivalves regulate the amount of water filtered in relation to food concentration. The increase in filtration rates would suggest sub optimal algal concentrations, whereas inhibition of filtering activity would indicate a possible overloading of the gill sorting mechanism at higher cell concentrations (50 to 100 x 10\(^4\) cells mL\(^{-1}\); Winter 1978). This adjustment behavior, which could possibly be linked to siaty, was further observed to be coupled with mucus secretion and pseudofeces production at high cell concentrations, meaning that the digestive capacity of the clams has been exceeded (Riisgård & Möhlenberg 1979).

The filtration rates measured for this species proved to be the highest of values reported for bivalves (Table 1). As shown in Table 1, literature values for tropical and subtropical species measured for a variety of conditions, range from 1.9 to 11.5 L h\(^{-1}\) g\(^{-1}\), with the highest values reported for pearl oysters *Pinctada margaritifera* and *P. maxima* (Yukihira et al. 1998). The filtration rates of temperate bivalves on the other hand, were reported to range from 0.6 to 14.7, with the highest values reported likewise for the pearl oyster *P. fucata martensii* (Numaguchi 1994). The present values refer however, to smaller clams, compared with the bigger sizes of pearl oysters (36–185 mm) used by Yukihira et al. (1998).

Thus, the higher filtration rates of smaller sizes explain the higher mean filtration rates.

Aside from size, the morphology and habit of the species are likewise factors to consider in comparing filtering capacities. According to Yukihira et al. (1998), to maximize growth in pearl oysters, strong and fast water currents is a requisite, especially because they occur in oligotrophic waters. Filtration rates of *G. elongata* are higher compared with those reported for giant clams (0.1 to 3.7 L h\(^{-1}\), with lowest values measured for *Tridacna derasa* and *T. devorac*; Klump & Lucas 1994). Giant clams, however, are both auto- and heterotrophic, and that despite these lower rates, they achieve large sizes by supplementing suspension feeding by translocation of photosynthates from symbiotic zooxanthellae (Lucas 1994). The high filtration rates of *G. elongata* show that the species is well adapted to its environment, characterized by fast-flowing water currents. A mean growth rate of 0.13 ± 0.06 mm day\(^{-1}\) was estimated over a period of 1 year (del Norte-Campos, submitted). Thus for this species, filtering at higher rates could well support high growth rates typical of tropical short-lived species. Furthermore, this ability to filter at higher rates also qualifies it as a biofilter species in fresh- to brackishwater polyculture setups.

In relation, the clearance rates measured for phytoplankton taxa and cyanobacteria filaments in the likewise freshwater (lake) bivalve *Dreissena polymorpha* were in contrast, reported to be lower, ranging from 0.2 to 0.34 L h\(^{-1}\) (Horgan & Mills 1997). The latter may thus be possibly due to the species’ adaptation to a habitat with lesser turbulence.

Furthermore, Jørgensen (1990, 1996) concluded that the capacity of water processing in bivalves is evolutionarily adapted to the

![Figure 3](image3.png)  
**Figure 3.** Filtration rate (L h\(^{-1}\) g\(^{-1}\)) of *G. Elongata* versus dry weight (g). \(F = 2.0853 DW^{-1.1196}; r^2 = 0.9723, n = 18\). X-axis in log scale.

![Figure 4](image4.png)  
**Figure 4.** Respiration rate (mL O\(_2\) h\(^{-1}\) g\(^{-1}\)) of *G. elongata* versus dry weight (g) for unfed individuals (\(R = 0.5062 DW^{-1.1114}; r^2 = 0.955, n = 21\)). X-axis in log scale.

![Figure 5](image5.png)  
**Figure 5.** Respiration rate (mL O\(_2\) h\(^{-1}\) g\(^{-1}\)) of *G. elongata* versus dry weight (g) for fed individuals (\(R = 0.4620 DW^{-0.6712}; r^2 = 0.848, n = 18\)). X-axis in log scale.
TABLE 1.
Filtration rates (F, l h⁻¹) and respiration rates (R ml O₂ h⁻¹) for various bivalve species size-standardized for 1 g dry soft tissue weight (*exceptions indicated under Conditions) (* as cited in Yukihiro et al 1998).

<table>
<thead>
<tr>
<th>Species</th>
<th>F</th>
<th>R</th>
<th>Conditions</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical/Subtropical bivalves Clams</td>
<td></td>
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<tr>
<td>Gari elongata</td>
<td>45.1</td>
<td>0.11–0.96</td>
<td>Fed with Tahitian Isochrysis galbana (T-iso) at 250 T cells ml⁻¹, 28 °C; for size range 11.8–67.9 mm</td>
<td>Present study</td>
</tr>
<tr>
<td>Arca zebra</td>
<td>3.13</td>
<td>0.30</td>
<td>*0.82 g dry tissue wt. Chaetoceros calcitrans (15 T cells ml⁻¹), 30 ± 0.5 °C</td>
<td>*Widdows et al (1990)</td>
</tr>
<tr>
<td>Pearl oysters</td>
<td></td>
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</tr>
<tr>
<td>Pinctada imbrica’s</td>
<td>5.2</td>
<td>1.04</td>
<td>Natural particles (3.1 mg l⁻¹), 22 °C</td>
<td>*Ward &amp; MacDonald (1996)</td>
</tr>
<tr>
<td>P. margaritifera</td>
<td>11.5</td>
<td>1.05</td>
<td>T-iso (~5T cells ml⁻¹), 28 °C; 36–152 mm SH</td>
<td>*Yukihiro et al (1998)</td>
</tr>
<tr>
<td>P. margaritifera var. cunningi</td>
<td></td>
<td>0.10</td>
<td>*Oyster of 100 g total wt, 28 °C</td>
<td>*Shigiyama &amp; Tomori (1988)</td>
</tr>
<tr>
<td>P. maxima</td>
<td>6.8</td>
<td>0.34</td>
<td>Routine rate, C. calcitrans and T-Iso (50 T cells ml⁻¹)</td>
<td>*Stiger (1993)</td>
</tr>
<tr>
<td>Scallops</td>
<td></td>
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<tr>
<td>Anadumia pleurocetes</td>
<td>11.5</td>
<td>0.86</td>
<td>T-iso (~5 T cells ml⁻¹), 28 °C; 37–185 mm SH</td>
<td>*Yukihiro et al (1998)</td>
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<tr>
<td>Mussels</td>
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<tr>
<td>Perna perna</td>
<td>6.8</td>
<td>0.41</td>
<td>I. galbana (60 T cells ml⁻¹), 28 °C</td>
<td>*Rise et al (1994)</td>
</tr>
<tr>
<td>P. viridis</td>
<td>2.3</td>
<td>0.43</td>
<td>Natural particles (POM: 1.3 mg l⁻¹), 28 °C</td>
<td>*Van Erkom Schurink &amp; Griffiths (1992)</td>
</tr>
<tr>
<td>Gigant clams</td>
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<tr>
<td>Hippopus hippocus</td>
<td>0.52</td>
<td>0.10</td>
<td>Natural particles or Dunalia teriolacta, 24–27 °C</td>
<td>*Krishnakumar et al (1990)</td>
</tr>
<tr>
<td>Tridacna crocea</td>
<td>0.58</td>
<td>0.61</td>
<td></td>
<td></td>
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<tr>
<td>T. gigas</td>
<td>3.68</td>
<td>1.06</td>
<td></td>
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<tr>
<td>T. squamosa</td>
<td>0.32</td>
<td>0.48</td>
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<tr>
<td>T. derasa</td>
<td>0.12</td>
<td>0.16</td>
<td>*Size-standardized for 1 g wet tissue wt, 20–26 °C</td>
<td>*Klampff &amp; Lucas (1994)</td>
</tr>
<tr>
<td>T. levora</td>
<td>0.14</td>
<td>0.29</td>
<td></td>
<td></td>
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<tr>
<td>Temperate bivalves Clams</td>
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<tr>
<td>Mercenaria mercenaria</td>
<td>2.6</td>
<td>0.56</td>
<td>Dyes as suspension, 18–20 °C</td>
<td>*Klampf &amp; Griffiths (1994)</td>
</tr>
<tr>
<td>Rangia cucullata</td>
<td>0.56</td>
<td>0.16</td>
<td>I. galbana and T. fluviatilis mixed, 21.1 °C</td>
<td>*Hartwell et al (1991)</td>
</tr>
<tr>
<td>Oysters</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Crassostrea gigas</td>
<td>3.65</td>
<td>0.54</td>
<td>Natural particles (100 mg l⁻¹), 15–18 °C</td>
<td>*Barille et al (1997)</td>
</tr>
<tr>
<td>C. virginica</td>
<td>2.55</td>
<td>0.24</td>
<td>I. galbana and Thalassiosira fluviatilis mixed, 21.1 °C</td>
<td>*Hartwell et al (1991)</td>
</tr>
<tr>
<td>Ostrea edulis</td>
<td>0.36</td>
<td></td>
<td>*1 g AFDW, 5 °C</td>
<td>*Rodhouse (1978)</td>
</tr>
</tbody>
</table>

Concentrations of suspended food, primarily phytoplankton. Initial experiments showed that G. elongata had higher filtration rates under dark feeding conditions (Piñosa, unpublished observations), and this could perhaps be explained by the natural water conditions (silty) in the clam’s biotope. Difference in day and night feeding was similarly observed in the zebra mussel D. polymorpha inhabiting freshwater lakes (Horigan & Mills 1997).

The decrease in filtration rate per unit body mass with increase in size (Fig. 3) is consistent with reported trends (e.g., Widdows 1978). However, the computed F-W exponent value (2.0753) does not fall within the range (0.3 to 0.8, mean = 0.62) reported for several filter-feeding bivalves (Bayne & Newell 1983). This may be attributed to the wide variability in the results. However at the same time, there are also reports regarding the absence of relationship between filtering activity and sizes (e.g., Horigan & Mills 1997). The present results may likewise, be due to less preferred light conditions used in the experiments. Preliminary work on the species’ filtration rates also suggested that the highest preference was for the smallest algal size, that is, Nannochloropsis sp. (Piñosa, unpublished observations). It may be possible then, that the cell diameter of T-iso is still somewhat large for G. elongata.

Reported respiration rate values (Table 1) range from 0.3 to 1.05 ml O₂ h⁻¹ g⁻¹ in tropical and subtropical bivalves, 0.1 to 1.06 ml O₂ h⁻¹ g⁻¹ for giant clams, and 0.06 to 0.93 ml O₂ h⁻¹ g⁻¹ for temperate bivalves. Thus, the values for G. elongata of 0.11–0.96 ml O₂ h⁻¹ fall within the reported range. Bayne & Newell (1983) gave about 0.7 (range 0.4 to 1.0) as the mean value of allometric exponents for the R-W relationship for a variety of marine mussels. Thus the value (0.4620; Fig. 5) for fed G. elongata from this study fall in the lower range, which means that there is less rapid increase in the size-specific metabolic rate of this species than most other bivalves.

The study showed that the species is suitable for use as a biofilter organism. This could further be verified by conducting experiments in polyculture set-ups, both under laboratory and field conditions.

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LITERATURE CITED
