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Experimental Culture and Particle Filtration by Asian Moon Scallops, *Amusium pleuronectes**

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Abstract

Growth rates were determined for scallops (35-75 mm valve height) held in pocket nets and lantern nets at varying densities. The Ford-Walford linear transformation of the von Bertalanffy growth equation was used to allow quantification of food-limited stunting. Pocket nets allowed for greater growth of scallops than did the lantern nets at all stocking densities. The growth rates of scallops in pocket nets, nevertheless, were well below the growth of scallops in the wild. Clearance rates of Caribbean strains of *Isochrysis galbana* (C-Iso) and *Chaetocerous gracilus* (C-Cg) were determined for moon scallops, *Amusium pleuronectes*, in static chambers at 28°C. The scal-lops have a great capacity to filter both species of phytoplankton. Clearance rates ranged from 2.84 to 12.13 $l\cdot(g\cdot h)^{-1}$ dry weight (4.7×10^6 to 9.8×10^6 $cells\cdot min^{-1}$ or 1.3×10^8 to 2.8×10^8 $cells\cdot[g\cdot h]^{-1}$) in pre-conditioned 70-mm animals. The threshold cell concentration for the beginning of pseudofeces production is <20,000 C-Cg $cells\cdot ml^{-1}$. The high rates of particle clearance and con-comitant water transport by *A. pleuronectes* are adaptations to their native warm oligotrophic waters. These high clearance rates, coupled with their habit of active swimming (>9 m per swim), may limit this species to low density bottom pen culture methods.

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Introduction

The Asia moon scallop, *Amusium pleuronectes*, is found in Southeast Asia from the Ryukyu Islands of southern Japan to Thailand and Indonesia (Habe 1964). In the Philippines, moon scallops are caught throughout the archipelago in small-scale trawl fisheries (Llana 1983; Del Norte et al. 1988). A number of studies have focused on aspects of reproduction, recruitment, growth and mortality of natural populations of these scallops as they relate to the capture fisheries (Llana and Aprieto 1980; Del Norte 1988). The reported rapid growth of this species (≈2-year life span), its relatively large asymptotic size (H_∞=106 mm), some promise in development of spawning and larviculture techniques, and its relatively high viscera and adductor muscle-weight to shell-weight ratio make this species attractive to study as a potential aquaculture prospect (Belda and Del Norte 1988; Del Norte 1991).

In many developing nations, bivalve molluscs are attractive as a culture species because they are filter feeders, utilizing low food chain phytoplankton, detritus and other suspended particulates (see Newkirk 1992 for a recent review). Concomitant with culture of filter feeding bivalves is the recognized effect of reduced growth with increasing stocking density (e.g., Eldridge et al. 1975; Eversole et al. 1990; Newell 1990). Because of this, it is of practical interest to determine optimum stocking densities as part of an economic feasibility analysis. The primary aim of this study is to gather information germane to the evaluation of the technical and economic feasibility of growout culture of *A. pleuronectes*.

Feeding rates of bivalves in relation to available food supply are an important factor influencing growth of animals in suspended culture (Incze et al. 1981). Thus a secondary aim of this study is to estimate the particle filtration rates of individual scallops.

Materials and Methods

A. pleuronectes (35-75 mm in valve height) were caught by small-scale commercial trawlers in the Sulu Sea near Palawan, Philippines, and kept in buckets of aerated seawater while aboard the boats. Onshore, scallops were transported in 500-ml plastic bags (two to three scallops per bag) with approximately 200 ml seawater (34 ppt) and inflated to full capacity with pure oxygen. Bags were placed in styrofoam fish transport boxes with gel-ice packs for overland transport to the study site at Ulugan Bay (10°02'N, 118°48'E), on the South China Sea coast of Palawan. Transport survival of scallops was near 100%.

The seawater of Ulugan Bay is oligotrophic (average >10 m Secchi depths), supporting fringing reefs beyond lightly exploited intertidal mangrove forests. During the growth study period, August-October 1991, salinities and water temperatures averaged 34 ppt and 31°C, respectively.

Variously sized and individually marked scallops were placed at varying densities (10, 20 and 40 scallops per 1,140 cm2) on shelves of lantern nets with exterior netting mesh of 4 mm. Larger mesh netting allows for nipping of scallop tentacles by grazing fish (Siganidae and others). Pocket nets with dimensions of 1 x 1.5 m were constructed of 4 mm mesh outer nylon netting sandwiching an inner 25 mm mesh net. The pocket nets accommodated a total of 192 scallops (96 per side). Both lantern nets and pocket nets were suspended at 2 m intervals from a 30-m subsurface longline set at right angles to the prevailing tidal currents. All gear were constructed of materials locally available in the Philippines.

Growth of individually marked scallops was determined on a monthly basis from August through October. Data were analyzed by use of the Ford-Walford linear transformation of the von Bertalanffy growth equation:

$$H_{t+1} = a + b\,H_t \qquad \text{...1)}$$

with, $$H_\infty = a/(1-b) \qquad \text{...2)}$$

and $$k = -\ln b \qquad \text{...3)}$$

when, H_t is valve height at time t in year
H_∞ is the asymptotic valve height in mm
and k is the von Bertalanffy growth constant in $year^{-1}$

Clearance rates were determined by using cultured Caribbean strains of *Chaetoceros gracilis* (C-Cg) and *Isochrysis galbana* (C-ISO) at 28°C in 30-l aerated static chambers. Prior to determinations of filtration and ingestion rates, scallops (≈70 mm valve height) were preconditioned for 6 hours in water containing 60,000 $cells \cdot ml^{-1}$. Clearance rates of 5-10 animals per experiment with two replicates were determined by monitoring depletion of phytoplankton from the medium by triplicate hemacytometer counts every 5-10 minutes. Rates were calculated by the equations of Jorgensen (1943) or Coughlin (1969), and expressed as $ml \cdot (g \cdot h)^{-1}$ or cells filtered per unit time:

$$F = V\,[\ln(C_0/C_t)/t] \qquad \text{...4)}$$

when, F is the filtration rate in $ml \cdot hour^{-1}$
V is the volume of the experimental vessel in ml,
$\ln(C_0/C_t)$ is the natural log of the cell concentration at time zero divided by the concentration time t.
and, t is time in hours.

In some experiments, phytoplankton was added at 10-minute intervals in an attempt to maintain constant cell concentrations.

Results

Growth studies suggest that *Amusium* is prone to density-dependent stunting or food-limited growth when held in lantern nets (Table 1, Fig. 1). Scallops held at low densities exhibited a growth check corresponding to transport and initial stocking; growth resumed at a reduced rate. Scallops held at the highest

Table 1. Ford-Walford analysis parameters.

	Theoretical (from Del Norte 1988)	Lantern nets 10 per shelf	Lantern nets 20 per shelf	Lantern nets 40 per shelf	Pocket net
y-intercept	7.831	6.494	2.151	0.762	4.968
(k in yr^{-1})	0.9261	0.9017	0.9664	0.9839	0.9336
intercept on y=x (apparent H_∞ in mm)	106.0	66.1	65.0	47.3	74.8
correlation (r)	-	0.9914	0.9964	0.9966	0.9860

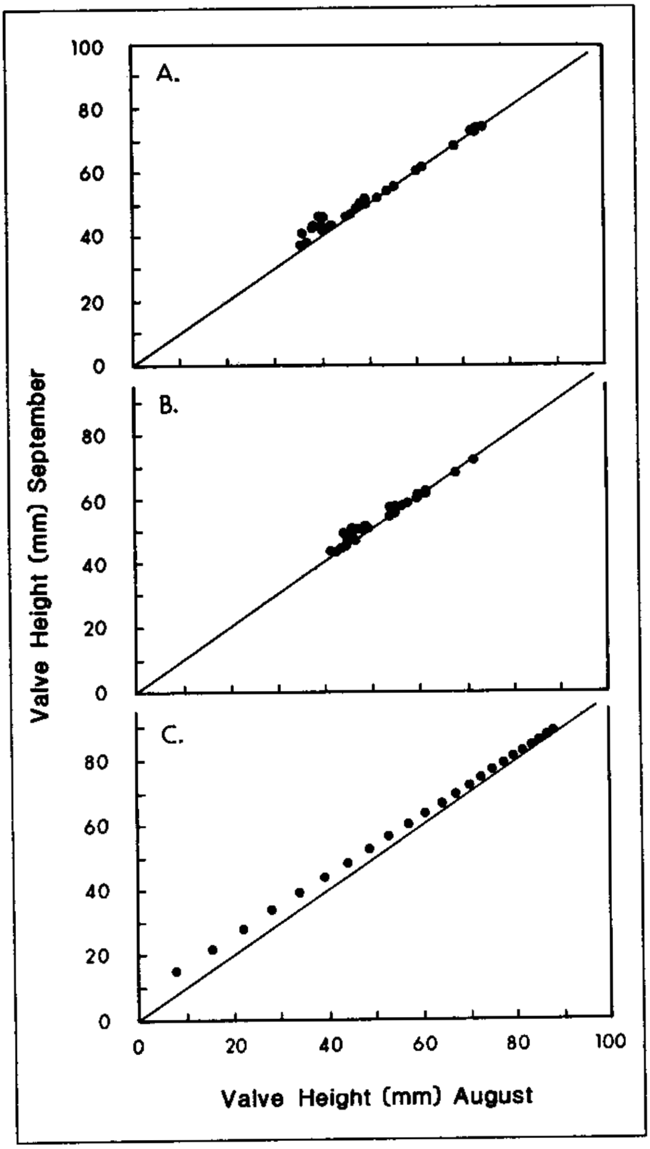

Fig. 1. Ford-Walford plots of scallop growth in lantern nets, pocket nets and in nature: A. Scallop growth in lantern nets stocked at 10 animals per shelf (1 scallop·114 cm^{-2}). B. Scallop growth in pocket nets. C. Scallop growth in nature (points calculated from von Bertalanffy growth parameters of Del Norte [1988]).

densities did not grow. Increasing stocking densities in the lantern nets resulted in a general lowering of the asymptotic valve heights (H_∞), but the von Bertalanffy constants (k) appear to remain unchanged. This suggests that the asymptotic valve heights (H_∞) may be used as an index of the degree of food-limited growth. Scallops held in pocket nets grew faster than scallops in lantern nets, but their growth was, nevertheless, lower than scallops in nature (Table 1, Fig. 1). *Amusium* are prone to swim around the open space of lantern nets when distributed; pocket nets allow individual scallops to be held in place.

Survival of scallops was high (>95% for all densities) during the first month of the study. During the second month, mortalities were approximately 50% in the high density lantern nets. In December, freshets associated with the northeast monsoon lowered the salinity of Ulugan Bay to <25 ppt, killing all scallops.

At average phytoplankton densities of 60,000 cells·ml^{-1}, filtration rates of 70 mm scallops were observed to range from 100 to 427 ml·min^{-1} (2.84-12.13 l·[g·h]$^{-1}$ dry weight) or 1.3 x 10^8 to 2.8 x 10^8 cells·[g·h]$^{-1}$ (Table 2). The threshold cell concentration for the beginning of pseudofeces production is <20,000 cells·ml^{-1} for *C. gracilis*.

Table 2. Results of filtration studies.

	Isochrysis galbana, (at 60,000 cells·ml^{-1}) (n = 15)	*Chaetoceros gracilis* (at 60,000 cells·ml^{-1}) (n = 58)
Mean clearance rate (ml·min^{-1})	204.0	114.2
SD clearance rate (ml·min^{-1})	137.6	86.2
Range clearance rates:		
(ml·min^{-1})	108-427	100-344
(l·[g·h]$^{-1}$ wet wt.)	0.46-1.84	0.43-1.48
(l·[g·h]$^{-1}$ dry wt.)	3.07-12.13	2.84-9.77
Mean clearance rate (10^6 cells·min^{-1})	7.6	6.8
Mean clearance rate (l·[g·h]$^{-1}$ dry wt.)	5.80	3.25

Discussion

The von Bertalanffy (1938) growth equation has been successfully applied to growth of bivalve molluscs (reviewed by Vakily 1992). In a number of studies, von Bertalanffy growth parameters have been used to assess growth and production of bivalve populations in sites with varying hydrographic conditions or positions in the intertidal zone (Bayne and Worrall 1980; Broom 1982), as a means for assessing the impact of pollution on bivalve growth (Appeldoorn 1981), and as an indication of food-limited stunting in particularly dense wild bivalve populations (Rice et al. 1989). In this study we show that von Bertalanffy growth parameters may possibly be used for rapid assessment of growth and production potential for bivalves in off-bottom culture.

The particle clearance or filtration rates of *A. pleuronectes* are high in comparison to some other scallops. Bricelj and Shumway (1991) list the reported clearance rates for a number of species. Dry weight standardized clearance rates ranged from 0.145 to 31 $l \cdot (g \cdot h)^{-1}$ in various species of scallops. The only species with greater filtration rates than *Amusium* were *Chlamys opercularis* and *Pecten furtivus*. Although the reported values for particle clearance by *Amusium* are rather high, it is likely that the cell densities (60,000 $cell \cdot ml^{-1}$) in the experimental chambers may have led to an underestimation of filtration rate in field conditions (Palmer 1980; Doering and Oviatt 1986).

We speculate that high particle filtration rates along with concomitant water transport rates by *A. pleuronectes* are an adaptation to warm oligotrophic waters. Scallops strongly compete for limited food resources when held in high densities. The reduction of apparent maximum valve height is consistent with previous studies that suggest food-limited growth in bivalves (Broom 1982; Rice et al. 1989).

Food limitation is not the only possible explanation for the reduction of apparent maximum valve height, especially among active animals. For example, Creswell (1984) showed that growth of queen conch, *Strombus gigas*, was inhibited when they were held in high densities even though they were supplied ample food. This growth reduction was interpreted to be the result of heightened interaction among the conches and energy losses associated with active behavior. *A. pleuronectes* are known to be among the most active swimming scallops (Morton 1980; Wilkens 1991). Our own observations suggest that they will swim around actively in lantern nets if disturbed. It is reasonable to expect that interactive energy losses would occur in this species as well. Increased growth by scallops held in the pocket nets may be the result of lowered interactive energy losses.

An interesting challenge is presented to those contemplating commercial culture of *A. pleuronectes*. Use of intensive (high stocking density) methods such as traditional lantern nets or pocket nets for growout appears to be economically unfeasible for this species. However, this does not rule out the possibility that larger-scale bottom enclosures with low stocking densities might be a viable culture method.

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