Farming the Artificial Sea: Growth of Clams in a Recirculating Seawater System

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ABSTRACT

Eight groups of hatchery-reared clams were cultured for 22 weeks from setting in a recirculating seawater system. Each of the eight groups was fed a different diet. An extrapolated growth rate for the fastest growing group would yield animals with a shell height of 1.6 cm after 1 year. This growth rate is faster than those reported for animals growing in natural situations. It appears that the culture of market-size hard clams in recirculating systems is technically possible.

INTRODUCTION

In spite of a large amount of research upon the problem of the nutritional requirements of filter-feeding bivalve molluscs, we must "admit with complete candor and humility that we are still not in a position to say with certainty just what this mollusc (*C. virginica*) can or cannot use as food" (Nelson, 1947). Ukeles (1971) points out that this statement is as true today as in 1947. Ukeles (1971) goes on in her extensive review of the field to summarize three main schools of thought concerning bivalve nutrition: (1) That first proposed by Putter (1909) wherein dissolved organic material was the main nutritional source for the animals. (2) That first voiced by Petersen and Jensen (1911) where inanimate detritus was the main component. (3) That first supported by Dean (1887) wherein phytoplankton constitute the main food. While bivalve molluscs almost certainly derive some nutritional value from dissolved organics (Collier, 1959) and from detritus (Gavard, 1927), the view that phytoplankton are the main food source of these animals has gained widest acceptance.

Much of the recent work concerning the nutritional value of phytoplankton has been conducted upon bivalve larvae. This body of work (Davis, 1950; Davis, 1953; Davis and Chanley, 1956; Davis and Guillard, 1958; Guillard, 1958; Imai et al., 1949; Imai et al., 1950; Loosanoff and Marak, 1951; Loosanoff et al., 1955; Loosanoff and Davis, 1963; Walne, 1956, 1963, 1965) has shed considerable light upon the problem concerning which phytoplankton types are

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good foods for bivalve larvae. Since the technical problems in holding and feeding large numbers of post-larval bivalves for long periods of time are immense, progress in this area has lagged. The present authors have initiated a study where we are attempting to culture hard clams from setting to commercial size in a totally recirculated seawater system. We are feeding experimental diets composed of mixtures of four species of algae to eight groups of animals. No other particulate food source is available to the animals. We present preliminary results in this paper.

MATERIALS AND METHODS

Hatchery Techniques

Clams used in these experiments were hatchery-reared. Techniques for conditioning and spawning the brood stock were those described by Maurer and Price (1967). The larvae were reared in 400-liter conical tanks. The water was changed and the larvae fed daily. The larvae were given a mixture of *Monochrysis lutheri, Isochrysis galbana,* and *Nannochloris* sp; the ratio of cell numbers of the respective species was 2:2:1, while the total concentration of algal cells in the larval growing tanks was 5×10^4 cells/ml.

Growing Tanks

The clam larvae were allowed to set directly in the growing tanks. Eight growing tanks of 120 liters each were used in the experiment. The eight tanks were situated above an 8,000-liter waste treatment apparatus (Fig. 1). The water in each growing tank was recirculated independently. After 24 hours of recirculating, the water from each tank was drained into the waste treatment apparatus. The tanks were immediately refilled with water from the reservoir of the waste treatment system. Since the waste treatment module was itself a recirculating system, the entire culture scheme was a closed seawater cycle.

The waste treatment apparatus consisted of a submerged biological filter, an ultraviolet treatment component and an activated carbon filter. The apparatus was described in detail by Epifanio et al. (1973).

Water Quality

The levels of ammonia, pH and dissolved oxygen were measured in the growing tanks three times a week. The measurements were taken after the water had been in the growing tanks at least 20 hours. Levels of ammonia, nitrates, reactive phosphorous, pH, alkalinity, salinity and dissolved oxygen were measured within the waste treatment reservoir weekly. Temperature was measured in the water daily. Techniques for water quality analysis were those described by Srna et al. (1973) and Epifanio et al. (1973).

Diets

There were eight groups of animals in the experiment. Each group received a different diet (Table 1). The initial size of each group was 2.5×10^5 animals; this

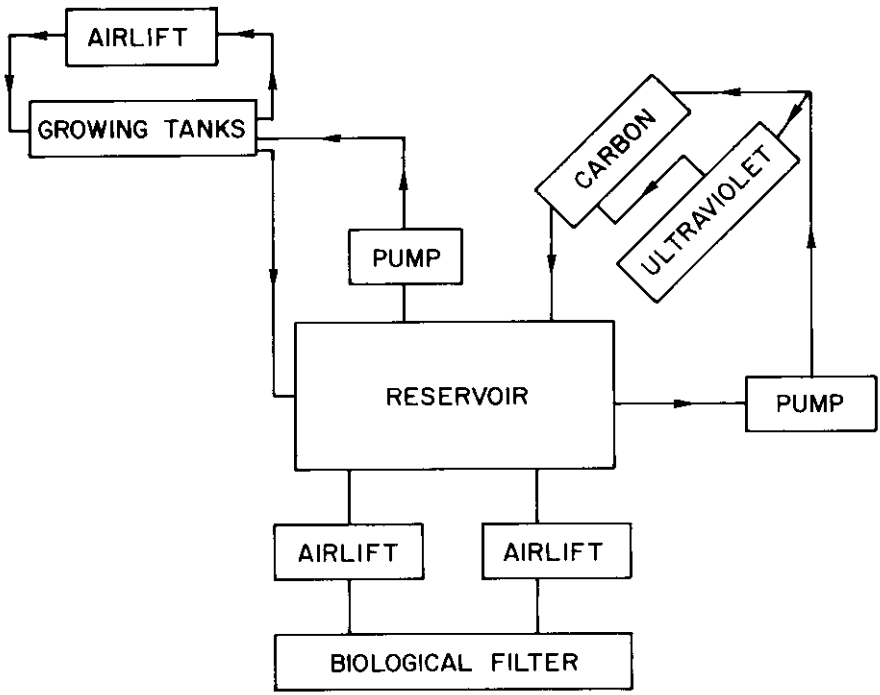


Fig. 1. Schematic of culture system.

number was pared as the animals grew. The numbers of animals in each tank were maintained at similar levels throughout the entire course of the experiment.

A batch method of feeding was used where the concentration of algal cells in each growing tank was brought up to 5 x 10^4 cells/ml and the animals allowed to deplete it. The animals were fed only once a day. A ninth group of animals was placed in raw flowing seawater and given no ancillary food. An episode of "bad water" so decimated this population, however, that this part of the experiment was deleted.

The algae were cultured in 200-liter glass tanks located in a controlled temperature room equipped with cool white fluorescent lights. The culture media was a modified version of that given by Matthiessen and Toner (1966).

Observations

Shell height was used as an indicator of growth. Measurements of animals less than 2 mm in shell height were made using an ocular micrometer and a dissecting microscope. Measurements of larger animals were made by photographing the animals over a grid of known size and subsequently measuring the photographs of the animals with a micrometer calibrated to the grid.

Table 1. Composition of Diets

Diet	Algal Species	Cell Count Ratio
A	*Phaeodactylum tricornutum*	--
B	*Phaeodactylum tricornutum* + *Platymonas* sp*	1:1
C	*Phaeodactylum tricornutum* + *Rhodomonas* sp.**	1:1
D	*Phaeodactylum tricornutum* + *Isochrysis galbana*	1:1
E	*Phaeodactylum tricornutum* + *Platymonas* sp. + *Rhodomonas* sp.	1:1:1
F	*Phaeodactylum tricornutum* + *Platymonas* sp. + *Isochrysis galbana*	1:1:1
G	*Phaeodactylum tricornutum* + *Rhodomonas* sp. + *Isochrysis galbana*	1:1:1
H	*Phaeodactylum tricornutum* + *Rhodomonas* sp. + *Platymonas* sp. *Isochrysis galbana*	1:1:1:1

* *Carteria* sp. was occasionally substituted for *Platymonas* sp.
** *Cryptomonas* sp. was occasionally substituted for *Rhodomonas* sp.

RESULTS

Figure 2 shows the quality of the water in the reservoir of the waste treatment apparatus. The levels of the monitored variables are well within the presently accepted safe limits for marine invertebrates (King, 1973; Spotte, 1971). Table 2 gives the ranges of variation in the levels of each of the monitored variables in the growing tanks. These also fall into the safe category.

Figures 3 to 10 depict the growth curves for the eight groups of experimental animals. Figure 11 is a histogram showing the relative sizes of the animals in each group after 22 weeks of growth. The size shown for animals fed *Phaeodactylum* is actually that of the animals after 15 weeks. None of those animals survived past 15 weeks. Table 3 shows the results of an ANOVA treatment of the data

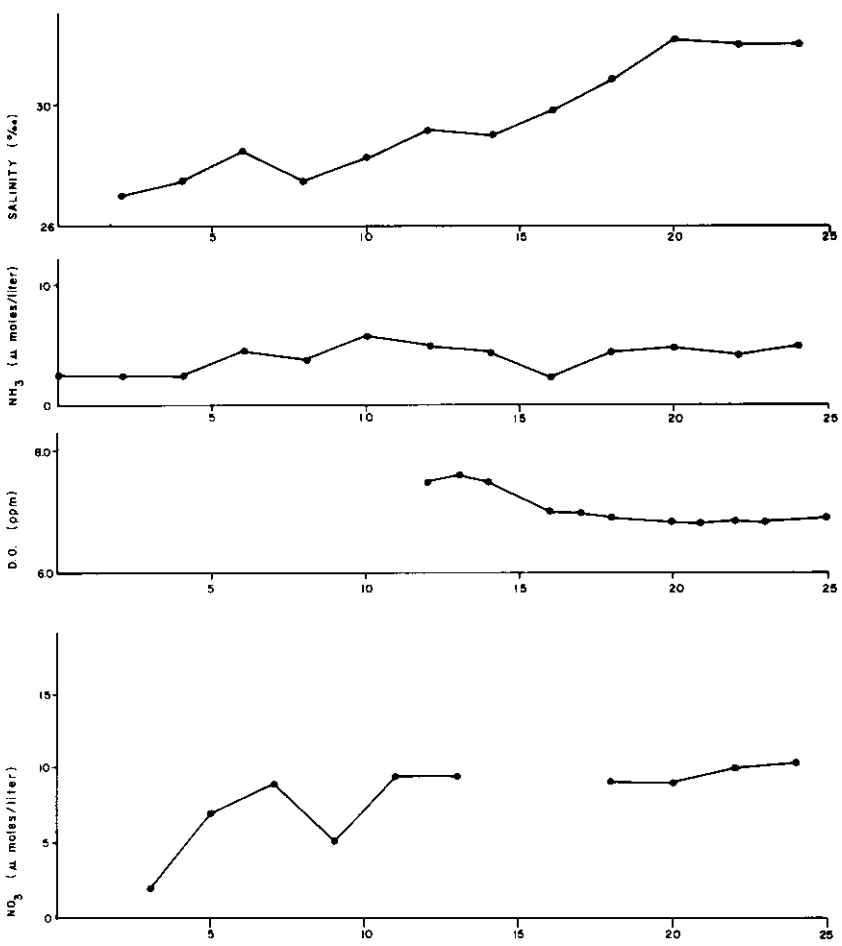


Fig. 2. Water quality in culture system.

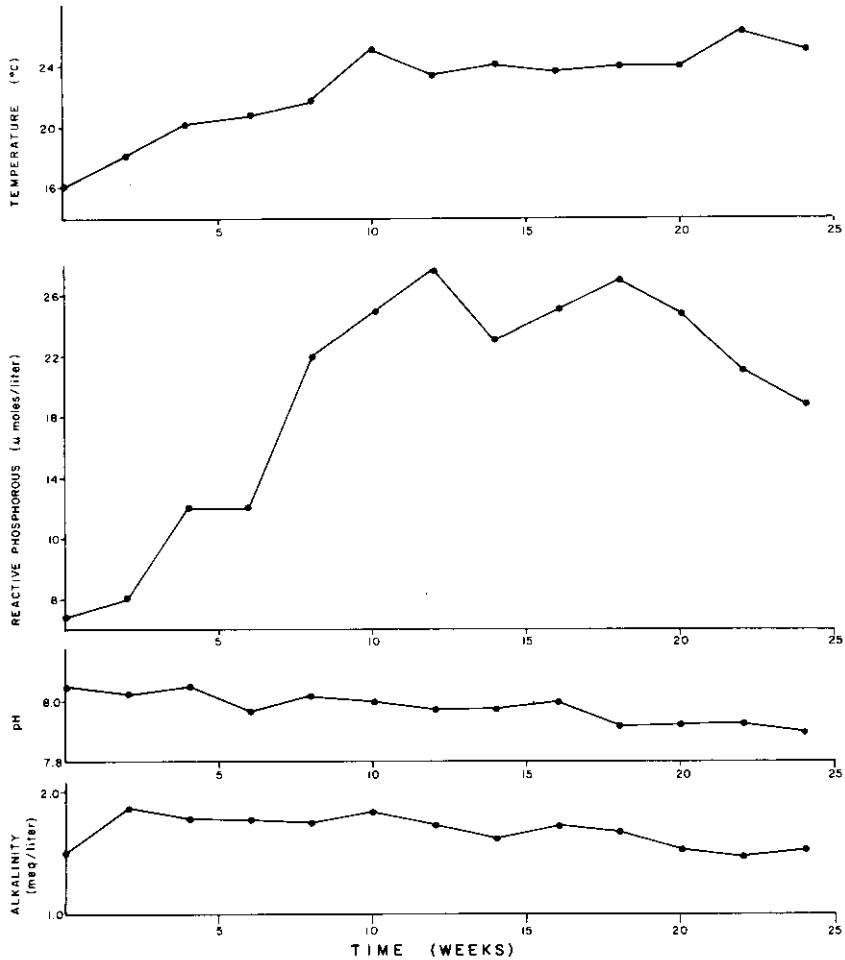


Fig. 2 (cont.) Water quality in culture system.

Table 2. Water Quality in Growing Tanks

Variable	Range
Dissolved oxygen	6.8-7.4 ppm
pH	7.75-8.3
NH_3	3.0-57.5 micro-moles/liter

from Figure 11. Figure 12 is the growth curve of Group F extrapolated to 1 year.

DISCUSSION

While the data presented here are certainly preliminary, they do indicate that it is possible to culture *M. mercenaria* in a recirculating seawater system. It is clear that a diet consisting of the diatom, *Phaeodactylum tricornutum,* alone is insufficient. An analysis of variance indicated that there was a highly significant difference among the shell heights of clams in groups B to H after 22 weeks of growth. A subsequent Student-Newman-Keuls test suggested that the diets fed groups E and F (both three-part diets containing *Platymonas*) supported fastest growth while the diet fed group C (*Phaeodactylum* + *Rhodomonas*) yielded slowest growth. There was no statistical difference in the mean shell height of animals in groups B, D, G, or H. Inferences concerning the relative food value of each algal species would be premature at this time.

Figures 4 to 10 show that the rate of growth in groups B to H increased sharply after the first 13 weeks. This increase in growth rate does not appear to be related to any change in environmental conditions (Fig. 2). We might conclude, then, that this pattern of early growth in *M. mercenaria* is characteristic of the species; Ansell (1968) mentioned an inflection in the growth curves of young clams lying somewhere between 10 and 35 mm in shell height. Unfortunately, he did not cite the source of this information. Alternatively, we

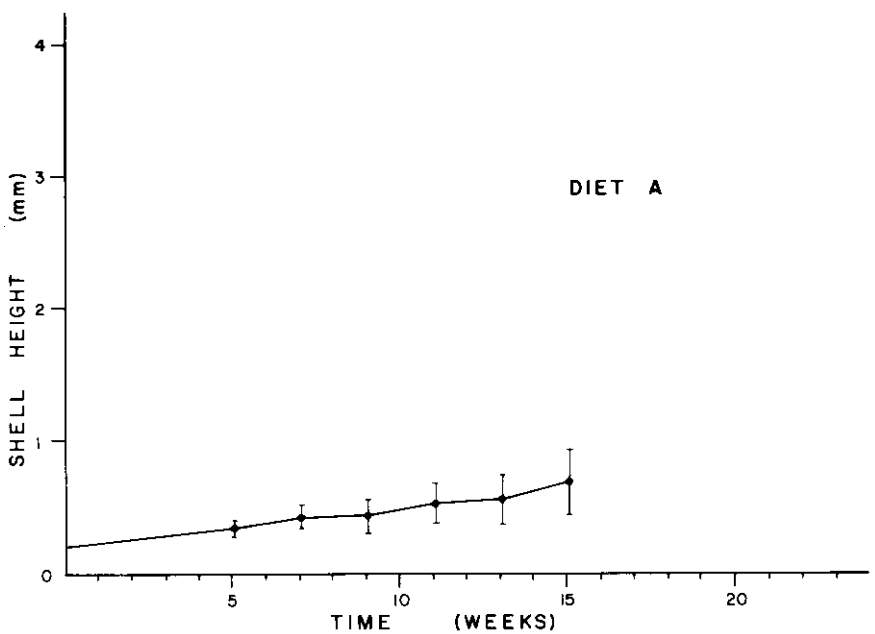


Fig. 3. Growth rate of animals fed *Phaeodactylum.*

might conclude that none of the diets which we tested were very good for newly metamorphosed clams but that several were quite good for somewhat larger clams.

Ansell (1968) has reviewed the literature concerning field-determined growth rates for *M. mercenaria* throughout its geographical range. While there have been few reported experimental studies of the growth rates of newly settled clams, he was able to construct curves relating size to age in animals from different areas. His curves indicate that clams from Delaware Bay grow to a shell height of about 0.9 cm during their first year of life. Animals in North Carolina had a similar growth rate. The most rapid growth reported from any Florida location yielded yearling clams of about 1.0 cm while the fastest growing clams in Massachusetts and New York grew to only about 0.7 cm during the first year. The fastest growing clams in the present experiment (Group F) had a mean shell height of 0.46 cm after 22 weeks of growth. If this growth rate had been linear from the time of metamorphosis, it would yield a clam of 1.09 cm after 1 year of growth. If, however, the clams were to continue to grow at a growth rate similar to that between the thirteenth and twenty-second weeks, they would grow to 1.6 cm in shell height after 1 year (Fig. 12). It seems very probable, then, that we shall be successful in producing market-size clams in our recirculating system faster than would be possible in natural situations.

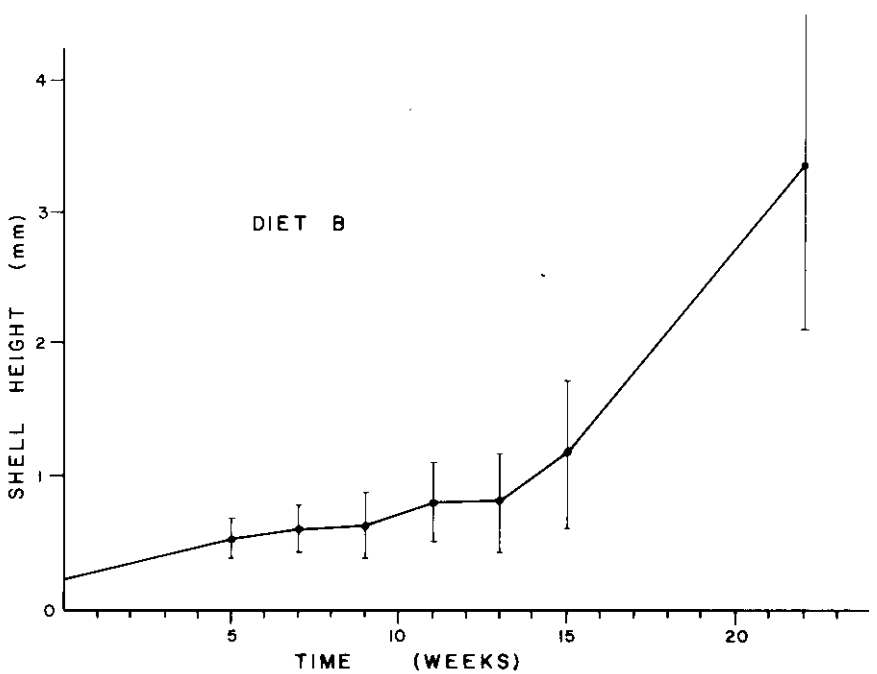


Fig. 4. Growth rate of animals fed *Phaeodactylum* and *Platymonas*.

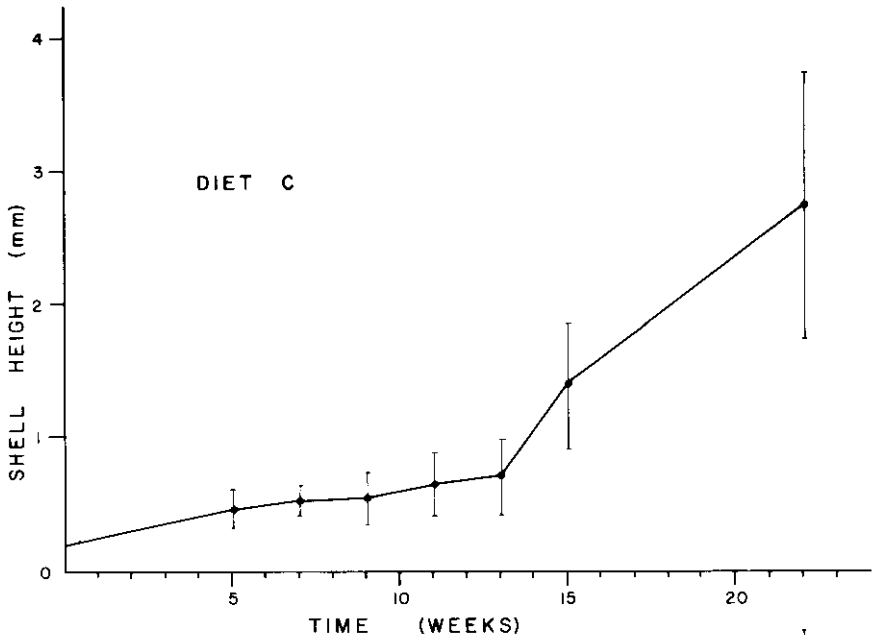


Fig. 5. Growth rate of animals fed *Phaeodactylum* and *Rhodomonas*.

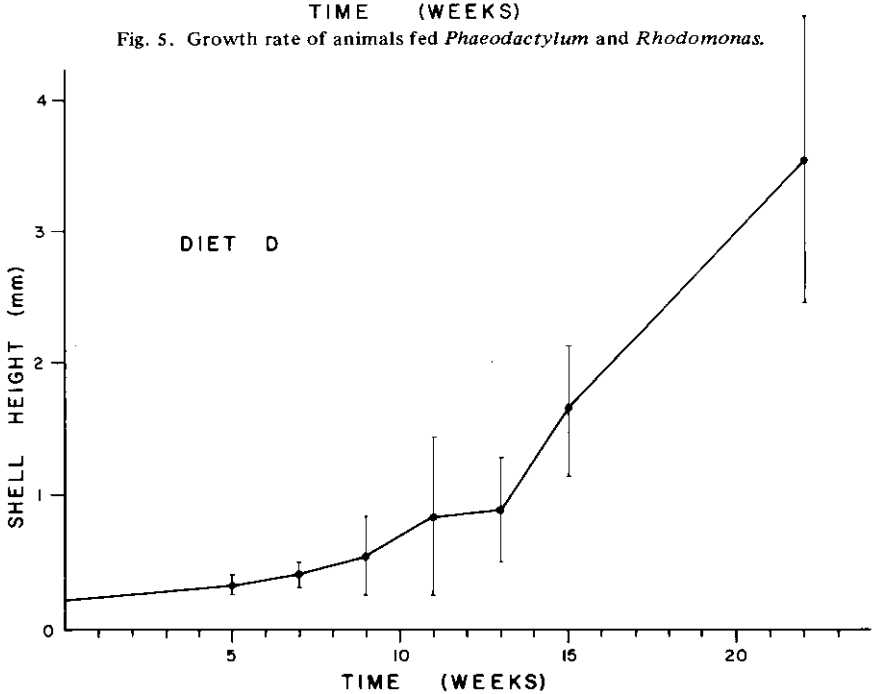
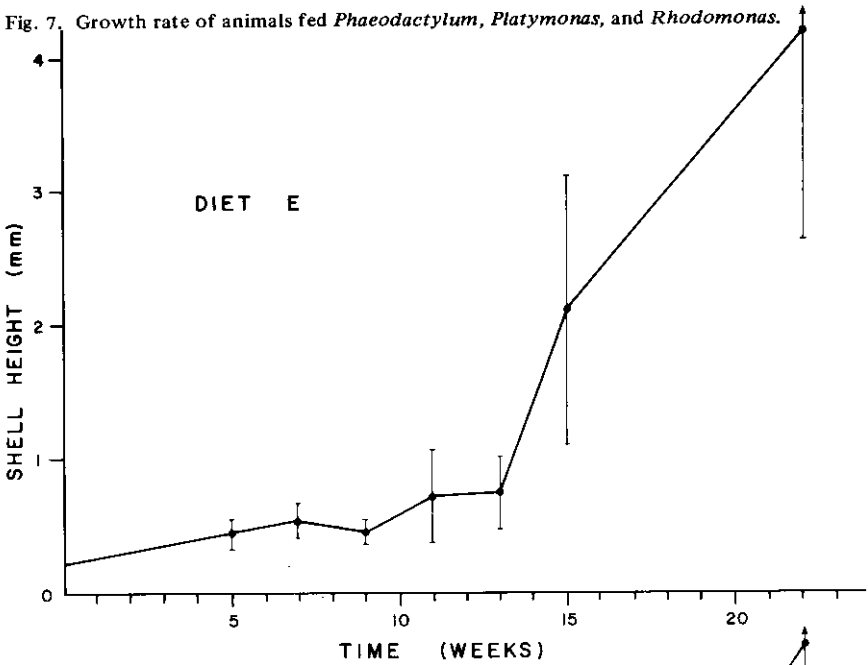


Fig. 6. Growth rate of animals fed *Phaeodactylum* and *Isochrysis*.

Fig. 7. Growth rate of animals fed *Phaeodactylum*, *Platymonas*, and *Rhodomonas*.



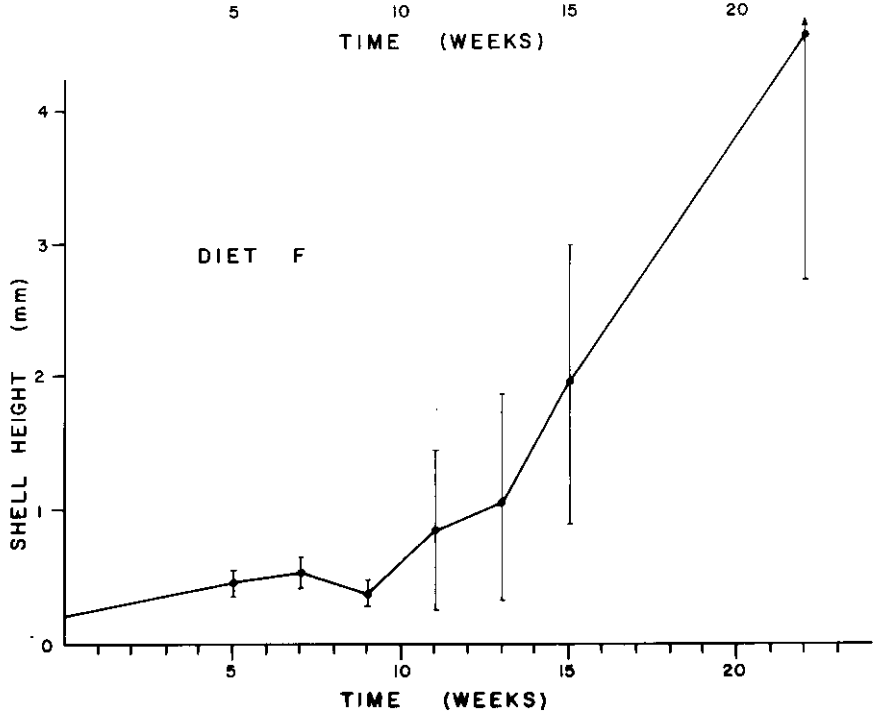


Fig. 8. Growth rate of animals fed *Phaeodactylum*, *Platymonas*, and *Isochrysis*.

Fig. 9. Growth rate of animals fed *Phaeodactylum*, *Rhodomonas*, and *Isochrysis*.

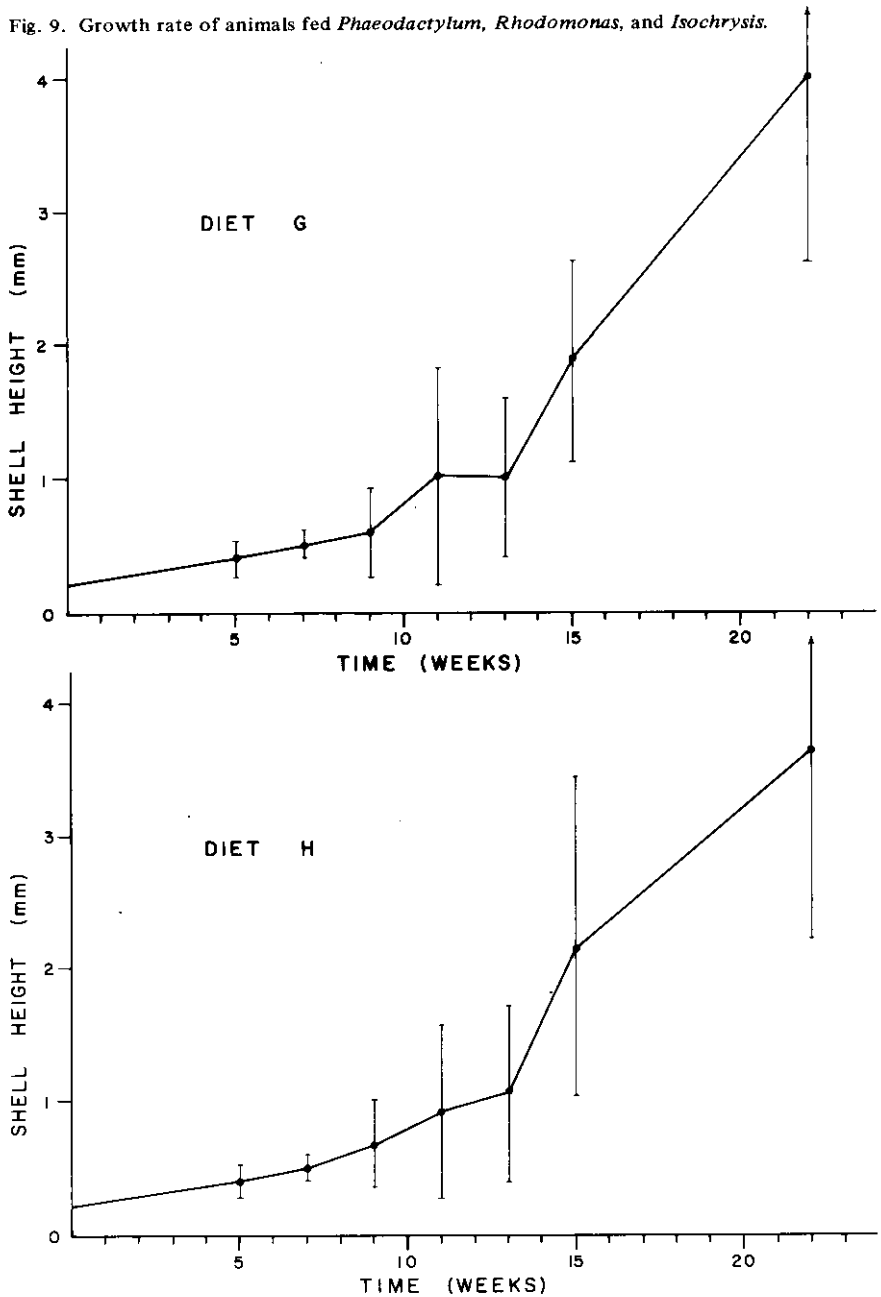


Fig. 10. Growth rate of animals fed *Phaeodactylum*, *Rhodomonas*, *Isochrysis*, and *Platymonas*.

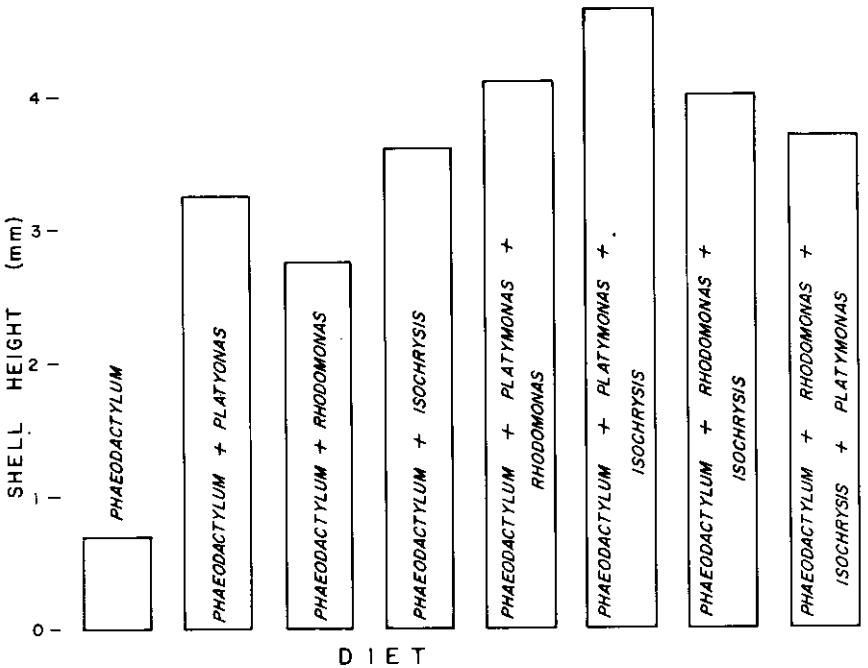


Fig. 11. Size of each group after 22 weeks of growth.

Table 3a. Analysis of Variance Table for Mean Shell Height in Groups B to H after 22 Weeks of Growth

	Sum of Squares	d. f.	Mean Squares	F
Between groups	254.48	6.0	42.41	26.44
Within groups	1166.12	727	1.6	
Totals	1420.60	733		

Table 3b. Results of Student-Newman-Keuls Test (α=0.05) for Differences in Mean Shell Height. Letters Refer to the Respective Experimental Groups of Clams. Underscoring Indicates Overlapping Ranges of Shell Height.

F E G H D B C

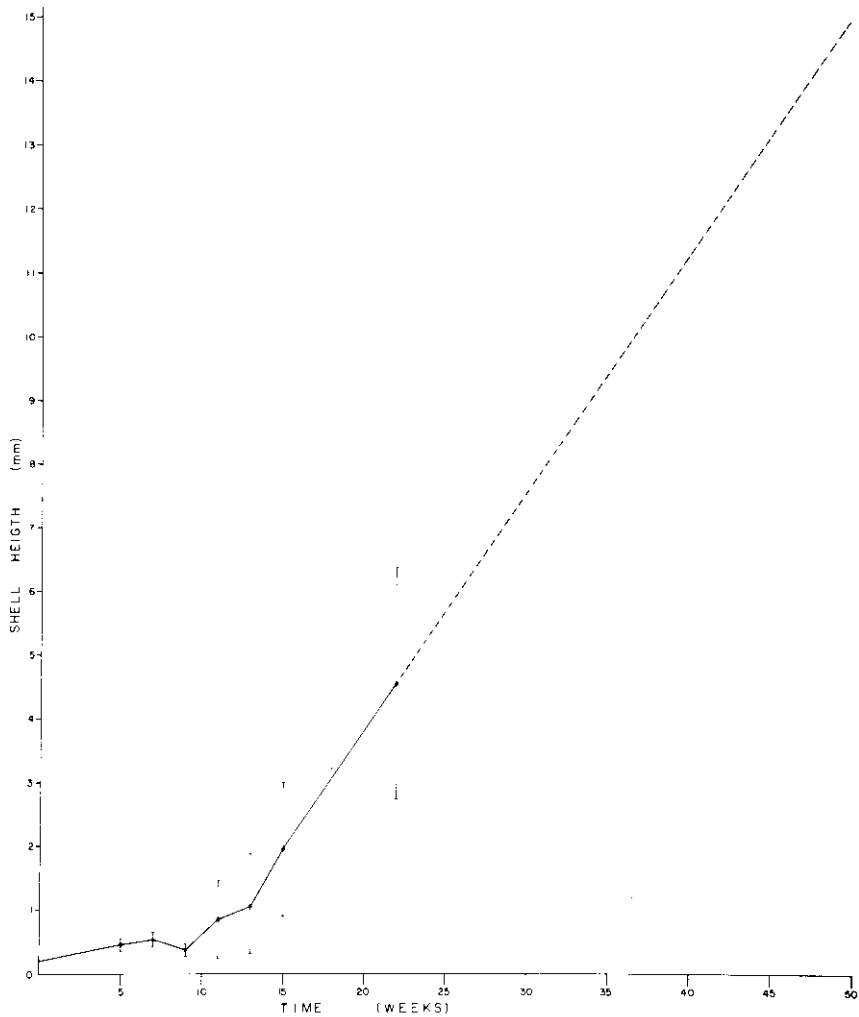


Fig. 12. Extrapolated growth curve for Group F.

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