(e.g., *T. mexicanus, Cyclothone acclinidens, C. signata, Sternoptyx diaphana*) is usually quite low. Obviously a dead fish cannot swallow cod end material while a stressed but living fish may. The survival factor may have caused some of the differences between our results and those of Hopkins and Baird (1975); off California the survival rate of trawled specimens is relatively high (Childress et al. 1978) while in the Gulf of Mexico it is very low (T. L. Hopkins and R. C. Baird, pers. commun.). Survival rate is probably influenced by haul duration, the depth and temperature range sampled, cod end design, and net construction.

It is also apparent that specimen size can influence the degree of net feeding. It is not clear whether this is due to the greater survival rate of larger individuals or to their larger mouth size. Within the limits of survival rate and size variables, the degree of exposure to prey in the cod end is a function of haul duration, the depth strata sampled, and the amount of time a fish spends in the cod end. Discrete-depth hauls probably decrease the degree of exposure by limiting the number and diversity of prey items while oblique hauls increase exposure. The data also indicate that small prey are more readily ingested in cod ends than large prey. Accordingly, the bias imparted to stomach content analyses by net feeding would be toward the smaller prey items.

Postcapture ingestion is a complex problem and no clear-cut conclusions can be drawn from the available data except that it occurs to a varying degree and that the extent of its occurrence is subject to fish survival, fish size, and exposure. To gain a predictive capability it will be necessary to investigate these factors further.

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INHIBITORY EFFECT OF THE ALGA *PAVLOVA LUTHERII* ON GROWTH OF MUSSEL, *MYTILUS EDULIS*, LARVAE

The culture of bivalve larvae sometimes appears to be more of an art than a science. Many factors can influence the growth and survival of larvae and it is usually difficult to assign a cause to the failure of a particular culture. In one instance we had set up a large experiment with mussel, *Mytilus edulis*, larvae and noticed after 5-8 days that the larvae had ceased to grow in all of our treatments but that they remained alive and active. During this experiment one factor was known to have been changed: Previously we had been feeding the larvae a mixture of the algae *Isochrysis galbana* and *Pavlova lutherii,* while in this experiment only *P. lutherii* was available.

There has been one account in the literature (Fretter and Montgomery 1968) of *P. lutherii* being toxic; yet Bayne (1965) found *P. lutherii* to support normal growth in *M. edulis* larvae. Davis and Guillard (1958) found *P. lutherii* to be as good as *I. galbana* (and about as good as a mixture of the two) when fed to larvae of *Crassostrea virginica* and *Mercenaria mercenaria*. The results of Wilson (1978) show that *P. lutherii* is as satisfactory as other algae as food for *Ostrea edulis* larvae. In order to determine whether our *P. lutherii* cultures were to blame for the lack of growth we observed, we set up an experiment to compare the growth of mussel larvae when fed several diets of algae.

While testing the species of algae, we decided to include different food levels. If *P. lutherii* were toxic, then its effects may increase with concentration of the algae given to the larvae. Another source of toxic substances could be the algal metabolites which accumulate in the algal cultures. In order to test this, we used two different sources of *P. lutherii*, a young culture and an old one. Bayne (1965) had observed a slightly better growth of *M. edulis* larvae when fed *P. lutherii* from a 4-day-old culture compared with those fed a 13-day-old culture.

Methods

Adult mussels were stimulated to spawn by raising the water temperature from an ambient of 15° C to 22°-24° C. The eggs and sperm from five females and seven males were pooled to give a heterogeneous population of larvae. After 2 days the larvae were placed in the various treatment combinations. In the experiment there were five combinations of algae: a) *Isochrysis galbana* alone; b) *I. galbana* plus *Thalassiosira pseudonana* (added after 1 wk); c) *I. galbana* and *P. lutherii* throughout, plus *T. pseudonana* after 1 wk; d) a young culture of *P. lutherii* harvested 4-7 days after innoculation, and e) an old culture of *P. lutherii* harvested 14-20 days after innoculation. In the mixed algae treatments the two or three species were added in equal proportion by cell number.

There were three feeding protocols used. Cell concentrations were increased gradually over the first week of growth, and although the cell concentrations changed in each protocol they will be referred to as "levels" here for simplicity. The food levels used were: 1) 10,000 cells/ml throughout the experiment; 2) 10,000 cells/ml from day 2 to day 4, 15,000 cells/ml from day 4 to day 6, and 20,000 cells/ml for the rest of the experiment; and 3) 50,000 cells/ml from day 2 to day 4, 100,000 cells/ml from day 4 to day 6, and 500,000 cells/ml for the rest of the experiment.

TABLE 1.—Analysis of variance on size of *Mytilus edulis* larvae as related to food treatment. Analysis performed on mean larval length for 6 replicates per treatment combination.

Source of variation	df	Mean square	*F*
Food level	2	2,477.2	24.7**
Food type	4	5,952.9	59.35**
Food level × food type	8	307.1	3.06**
Residual	75	100.3	

**$P<0.01$.

There were 6 replications in 1 l beakers at each of the food type-food level combinations. All beakers were held at 15° C. The initial density of the larvae at day 2 was 20 larvae/ml. All beakers were sampled when the larvae were 16 days old and up to 10 larvae were measured from each beaker.

Results

The main source of variation in the larval lengths at day 16 was due to the food type, with a smaller but significant portion attributable to the food level and the interaction of these two effects (Table 1). The largest source of variation among the types of food was the difference between the larvae fed only *P. lutherii* and those fed the other food types (Figure 1). There was slightly better growth with the young *P. lutherii* as food at the

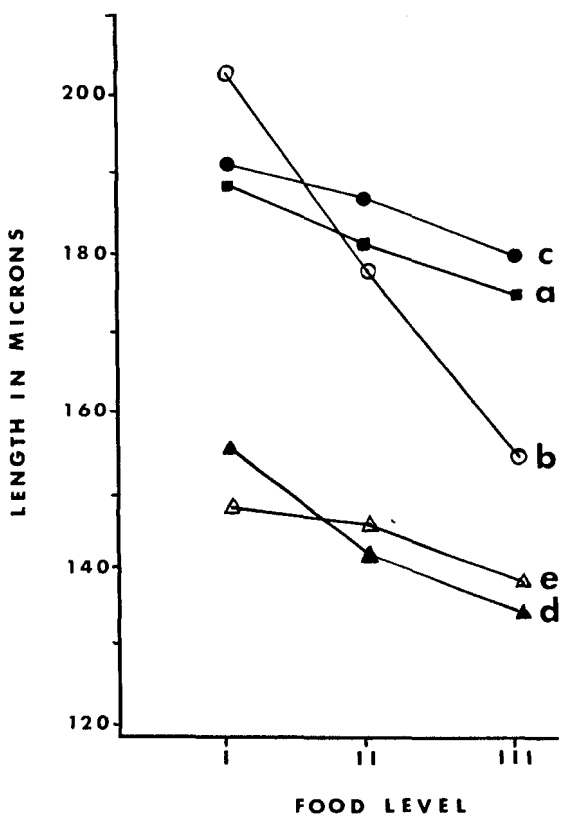

FIGURE 1.—Mean size of mussel larvae at 16 days when grown at three different algal food levels and on five combinations of algal types: a) *Isochrysis galbana* only; b) *I. galbana* and *Thalassiosira pseudonana*; c) *I. galbana*, *T. pseudonana*, and *Pavlova lutherii*; d) young *P. lutherii*; and e) old *P. lutherii*. Means are based on 10 animals from each of 6 replicates at each of the treatment combinations. See text for description of food levels used.

lowest food level compared with the old culture. The interaction of food level and food type was probably in large part due to food type b (*I. galbana* and *T. pseudonana*), which gave the best growth at food level 1 but poor growth at food level 3.

The effect of the food level was to produce higher growth rates at the lower food concentrations. This occurred for all five food types (Figure 1).

Discussion

Contrary to published reports on various bivalve larvae (Guillard 1959; Bayne 1965; Wilson 1978), we have observed poor growth of *M. edulis* larvae when fed only *P. lutherii*. This was true at all three food levels tested and whether the *P. lutherii* culture was young or old. There was no apparent inhibitory effect by the *P. lutherii* on larval growth when fed in combination with the other two algal species. It would appear that the suppression of growth of the larvae when fed only *P. lutherii* was the result of a dietary deficiency. If it were due to toxins in the algal cells, one would expect to see a greater suppression of the growth rate in the larvae at food level 3 when *P. lutherii* was combined with the other algal species.

If the inhibitory effect of *P. lutherii* were primarily due to the accumulation of metabolites in the medium, there should be a more consistent difference between the *P. lutherii* cultures of different age. In fact, there was only a small difference at food level 1. This may indicate that there is some effect of metabolites which were in low enough concentration in the young culture to be diluted at food level 1 but not at the other food levels. Nevertheless, it appears that the main effect of *P. lutherii* is or is equivalent to a dietary deficiency. This could be due to the biochemical compostion of the algal cells such that they are not digested, lack of some essential nutrient, or are not even ingested. The cells are not much bigger than *I. galbana*, especially when fast growing, and there was no evidence of clumping of the cells into large aggregates.

There is some evidence in the data presented by Davis and Guillard (1958) and Bayne (1965) of a suppression of larval growth at high concentration of *P. lutherii*. But to our knowledge there are no reports of suppression of growth in bivalve larvae at lower concentration of *P. lutherii*. This algae has been reported as producing substances toxic to four species of prosobranch larvae (Fretter and Montgomery 1968). Apparently, a toxic substance is emitted by the algae, which accumulates in the algal culture.

The results of the different food levels are not new (Davis and Guillard 1958; Bayne 1965; Rhodes and Landers 1973). The purpose of using different food levels in this experiment was to look for interaction with food type.

At this point we can only speculate as to the reasons for the lack of growth of larvae fed *P. lutherii*. We would not want to generalize and say that all *P. lutherii* could produce the same results. Obviously others have obtained good results with their cultures. (All our algal cultures are grown in the f/2 medium of Guillard (McLachlan 1973), which is commonly used in growing algae for shellfish culture.) One explanation would be that we have inadvertently developed through genetic change a strain of *P. lutherii* which is of inferior quality. Fretter and Montgomery (1968) have suggested that bacteria can metabolize the toxic substance produced by *P. lutherii* and render the algae culture harmless to bivalve larvae. Perhaps the absence of bacteria in our *P. lutherii* cultures, or at least the appropriate bacteria, would explain the discrepancy between our results and others. Unfortunately, we did not check the algal cultures for the presence of bacteria.

The importance of our observations with *P. lutherii* need to be assessed by other workers. The culture conditions of algae will vary from lab to lab and could easily have an influence on the growth of bivalve larvae.

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