THE POLYCulture OF Penaeus stylirostris STIMPSON
AND Penaeus azteicus IN TANKS

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ABSTRACT

Penaeus azteicus, obtained from the wild, and hatchery-reared P. stylirostris were placed together in 65 liter tanks in 5 ratios (0:100, 25:0:50, 75:25 and 100:0). Two experiments were done. The first consisted of 4 replicates of each ratio at 20°C and 30°C and 2 tanks of each of the 100% ratios at 25°C. Initial size of P. azteicus and P. stylirostris were 0.12 and 0.07 g, respectively. In the second experiment initial sizes of the wild P. azteicus and Pond-reared P. stylirostris were 1.30 and 0.89 g, respectively. The second experiment consisted of 4 replicates of each ratio at 25°C. The mean weight gain, mortality and biomass (actual and that expected on the basis of monoculture) calculated.

In the first experiment, the 50% treatment had the highest mean weight gain for both species. In both experiments, decreasing numbers of P. stylirostris (increasing numbers of P. azteicus) in a treatment resulted in a better growth of P. azteicus in the treatment. The survival of the species decreased as the percentage of P. azteicus increased. Survival was influenced by temperature, density, and species interaction. The largest difference between actual and expected biomass was to be for P. azteicus at 30°C, notably in the 75% P. azteicus treatment.

P. azteicus does not seem to be influenced by the presence of P. stylirostris as much as P. stylirostris is influenced by P. azteicus in the tank.

INTRODUCTION

Polyculture is the culture of two or more species together in the same facility. The biological basis of this concept calls for more efficient use both of a facility's environment and of available foods by stocking different species of organisms with varied requirements and feeding habits (Rabanal 1963). This idea of mixed culture can be found in many areas of the world including Asia and the Far East (Rabanal 1963; Villaluz et al. 1970; Liao 1977; Ling 1978; Tal Ziv 1978), the Middle East, Russia and the Mediterranean area (Yashou 1966), and the United States (Fielding 1966; Bardach et al. 1972; Lovell 1979).

The first organisms purposely cultured together were various species of fish (Rabanal 1963). Penaeid shrimp have been cultured along with fish such as pompano (Tatum and Trimble 1978; Trimble 1980), mullet and catfish (Silva et al. 1977) and tilapia (Gundermann and Popper 1977). The polyculture of several species of shrimp usually has occurred by chance in ponds (Lunz 1951; Parker and Holcomb 1973) and in rice fields (Winkins 1976). Controlled polyculture in ponds has been done using P. japonicus, P. semisulcatus, P. monodon, and Metapenaeus monoceros (Lee and Liao 1970), P. indicus, M. dossoui, M. monoceros and M. affinis (George 1975). P. merguensis, P. japonicus and P. monodon (Gundermann and Popper 1977) and P. stylirostris and P. vannamei (Chamberlain et al. 1981). There has been only one previous report of tank polyculture of penaeid shrimps, with P. monodon and P. penicillatus in Taiwan (Liao 1977).

Tanks were used in this study to permit observation both of competitive behavior and species interactions (e.g., cannibalism, day-night activity, response to food) that cannot be determined directly during pond studies. Experimental temperatures were chosen to include values that might affect survival as well as growth for the species tested. The study thus assessed the reciprocal of the two species P. azteicus and P. stylirostris by evaluating combinations of the two in terms of factors such as increased weight and survival under the influence of controlled laboratory conditions in tanks.

MATERIALS AND METHODS

Aquarium tanks were placed in 3 temperature control rooms at the National Marine Fisheries Service (NMFS) Laboratory at Galveston, Texas. Each 75 x 32 x 31 cm tank was equipped with a "Eureka" undergravel filter covered by oyster shell and sand as described by Zein-Eldin (1963). These tanks were filled with filtered (5 micron cellulose filter) and sterilized (quartz ultraviolet light sterilizer) natural seawater from the adjacent Gulf of Mexico. The tanks had a cycle of 12 hours light and 12 hours dark and were set at 20, 25 and 30°C (68°F) in the first experiment and 25°C (77°F) in the second experiment.

Two sets of experiments were done using the native species P. azteicus and the non-indigenous species P. stylirostris. For the first experiment, P. azteicus were collected along the shore of a small bay near Galveston, Texas. The P. stylirostris (from Costa Rica) were hatched at the NMFS Galveston Laboratory, shipped to the Oceanic Institute for larval rearing (Kanehala, Hawaii), and returned to the NMFS Laboratory for this experiment. Animals were blotted, weighed individually to the

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statistical analysis was done on the combined data (weight gain, survival and biomass) of each replicate (tank) within a treatment using the statistical analysis system (SAS) programs (SAS Institute Inc., Cary, N.C.). Most data were analysed using the contrasts procedure of the general linear models procedure (GMM). Dunnet's Multiple Range Test was used for additional analysis between treatments.

RESULTS AND DISCUSSION

MEAN WEIGHT GAIN AND GROWTH RATE

Mean weight gains at 20°C were 0.05, 0.08, 0.08 and 0.06 g for the 25, 50, 75 and 100% P. stylirostris treatments, respectively (Fig. 1). At 30°C, the gains for this species were 0.12, 0.17, 0.17 and 0.15 g for the 25, 50, 75 and 100% P. stylirostris treatments, respectively. Although the 50% P. stylirostris treatments had higher mean weight gains than other treatments at both temperatures, results of the contrast procedure (GMM) indicated no significant differences in mean weight gain when comparing either (p<0.0196) or ratio-temperature interactions. Overall, neither the presence of the second species nor its percentage in the treatment affected the mean weight gain of P. stylirostris (p=0.8607).

PENAEUS STYLIROSTRIS
EXPERIMENT 1

<table>
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<th>PERCENT</th>
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</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0.04</td>
</tr>
<tr>
<td>50</td>
<td>0.08</td>
</tr>
<tr>
<td>75</td>
<td>0.12</td>
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<tr>
<td>100</td>
<td>0.16</td>
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</tbody>
</table>

![Graph](image)

Figure 1. Mean weight of lab-hatched Penaeus stylirostris (0.07 g initial weight) held 30 days at 20°C and 30°C in the first experiment.
The initial mean weight of *P. stylirostris* was 0.07 g and the weight at the conclusion was 0.13 g at 20°C, 0.14 g at 25°C (two monculture tanks) and 0.22 g at 30°C, resulting in daily growth rates of 0.04 g/day at 20°C and 25°C, and 0.027 g/day at 30°C. The growth (P=0.0001) at 30°C was expected since the optimum temperature for this species in the wild has been reported to range from 27 to 32°C (Kand Bowers 1980). However, tank growth rates are much slower than those reported for pond growth (0.06 g/day at 27°C in nursery ponds) of *P. stylirostris* cultured with *P. vannamei* (Chamberlain et al. 1981).

*P. aztecs* did show some difference in mean weight gain between monoculture and polyculture treatments in the first experiment. Mean weight gains in the individual treatment combinations were 0.19, 0.24, 2 and 0.20 g at 20°C, and 1.21, 1.27, 1.15 and 0.94 g at 30°C for the 50, 75 and 100% *P. aztecs* treatments, respectively. In this experiment, growth of *P. aztecs* may have been affected by *P. stylirostris* at 30°C. The contrast procedure of GLM revealed that there was a significant difference (P=0.005) in weight increase between *P. aztecs* alone when cultured with *P. stylirostris* at 30°C. It is not possible to determine whether the growth of *P. aztecs* was positively affected by the presence of *P. stylirostris* in high numbers (15-20 animals) or by a reaese in number of *P. aztecs* (5-10 animals). At both temperatures highest mean weight gain for each species occurred in the 50% treatment. There was a significant difference in mean weight gain within monoculture treatments (P=0.02) at 30°C and Duncan's Multiple Range Test revealed that treatments containing only 25 and 50% *P. aztecs* in polyculture yielded significantly higher weight gains (P=0.05) than treatments with 75 or 100% *P. aztecs*. At 20°C there were no significant differences in weight gain of *P. aztecs* (Fig. 2) between monoculture and polyculture treatments (P=0.35) or between ratios (P=0.43).

As with *P. stylirostris*, *P. aztecs* grew larger at the warmer temperature. The initial mean weight of *P. aztecs* was 0.12 g while final means were 0.66 g at 20°C, 0.70 g at 25°C (two monoculture tanks) and 1.26 g at 30°C. These values represent daily growth rates of 0.02 g/day at 20 and 25°C, and 0.04 g/day at 30°C, resulting in a highly significant difference (P=0.0001) between the weights gained at 20 and 30°C. A similar growth rate at 30°C was also reported by Fenucci and Zein-Eldin (1979), using the same equipment, procedures and feed (0.44 g initial weight).

In the second experiment mean weight gains for *P. stylirostris* were 0.19, 0.19, 0.22 and 0.19 g in the 25, 50, 75 and 100% treatments, respectively (Fig. 3), while *P. aztecs* had mean weight gains of 1.31, 1.26, 1.04 and 1.00 g in the 25, 50, 75 and 100% treatments, respectively. At this one temperature (25°C), there were no statistically significant differences in mean weight gain between all polyculture treatments and monoculture of *P. stylirostris* (P=0.54) or *P. aztecs* (P=0.17). As in the first experiment, although 25 and 50% *P. aztecs* treatments had a higher mean weight gain than the 75 and 100% treatments, the treatment pairs were not significantly different (P=0.1393).

![Graph](image)

**Figure 2.** Mean weight gain of wild *P. aztecs* (0.12 g initial weight) held 30 days at 20 and 30°C in the first experiment.

![Graph](image)

**Figure 3.** Mean weight gain of wild *P. aztecs* (1.30 g initial weight) and pond-reared *P. stylirostris* (0.89 g initial weight) held 20 days at 25°C in the second experiment.
The initial mean weights were 0.89 and 1.30 g for *P. stylirostris* aztecus, respectively. *P. stylirostris* had a final mean weight of 2.45 g for a daily growth rate of 0.007 g. The mean weight for *P. aztecus* after 28 days was 2.45 g, giving this species a growth of 0.04 g. Growth rates for each species at 25°C were the same as that at 20°C in the first experiment, thus higher than at 25°C in the first experiment. Daily rate of growth of shrimp expressed as weight per day was both upon temperature and initial size. Smaller animals usually grew more than larger animals of the same age; thus, the initial larger size of *P. aztecus* affected the *P. stylirostris* negatively or that the group of cultured *gilostris* had a much lower growth potential in tanks.

**NT SURVIVAL**

Percent survival varied with temperature in both species, with survival better at 20°C than at 30°C. The overall survival rates of *P. stylirostris* were 72 and 48% at 20 and 30°C, respectively (Fig. 4). *P. aztecus* had higher survival rates of 96 and 81% at 20 and 30°C, respectively, with a highly significant difference (P=0.0001) between survival at 20 and 30°C (*P. stylirostris* and *P. aztecus*). The survival of *P. aztecus* at 30°C is similar to the 80% survival observed by Forster (1974) for this species in a tank (66 x 72 x 40 cm) experiment 9°C after 28 days with 15 shrimp (0.3 g initial weight) per tank.

There was an overall difference (P=0.02) of combined survival rates between treatments (ratsios) in the warmer temperature. Within the 30°C temperature (Fig. 4), *P. stylirostris* survived best in the 100% treatment (62%) while only 25% survived in the 25% *P. stylirostris* treatment (Fig. 4). This low survival was due in part to one tank having no survival of *P. stylirostris*. In contrast, 90% of the *P. aztecus* survived the 50% treatment, while the lowest survival (68%) was found in the 100% *P. aztecus* treatment (Fig. 4).

Within the second experiment at 25°C, survival among *P. aztecus* treatments was not significantly different (P=0.1734), although survival among *P. stylirostris* treatments was significantly different (P=0.004). The overall survival rate for *P. stylirostris* (76%) and *P. aztecus* (74%) were similar (Fig. 4). The 100% *P. stylirostris* treatment had the highest survival of 96%, while the lowest survival for this species was 66% for the 25% (3 animals/tank) and 50% (6 animals/tank) *P. stylirostris* treatments. *P. aztecus* survived best in the 25% treatment (92%) and as in the earlier experiment, the lowest survival was in the 100% *P. aztecus* treatment (62%). *P. aztecus* survival was similar to the range of survival rates (50-100%) found by Zein-Eldin and Al-Birch (1965) in tank experiments. Survival of both species generally decreased at all temperatures as the percentage of *P. aztecus* increased (Fig. 4), suggesting a species effect as well as density and biomass influences. Although total biomass/m² was greater and culture period shorter in this tank experiment than in ponds (the only data available for comparison), *P. stylirostris* survival rates exceeded those reported for combinations of *P. stylirostris* with *P. vannamei* in ponds (Chamberlain et al. 1981).

**BIO MASS**

As expected, temperature affected mean biomass increase, resulting in highly significant differences (P=0.0001) between two temperature treatments (20 and 30°C; all ratios combined) for both species (Table 1). Although mean biomass increase within temperatures tended to increase with the percentage of that species in the treatment, paired comparisons showed that intermediate ratios were not significantly different for *P. stylirostris*.

The mean biomass increase per tank (within each treatment of each species) were 0.20, 0.50, 0.59 and 0.94 g at 20°C and 0.20, 1.10, 1.26 and 2.04 g at 30°C for the 25, 50, 75 and 100% *P. stylirostris* treatments, respectively. There was no significant difference between the 50 and 75% treatments (P=0.05) (Table 1). The mean biomass increases per tank within each treatment were 3.47, 3.14, 2.21 and 0.91 g at 20°C and 12.71, 14.75, 11.39 and 4.90 g at 30°C for the 100, 75, 50 and 25% *P. aztecus* treatments, respectively. Because of the relatively great mean biomass increase in the 75% treatment, there was no significant difference between the 75 and 100% *P. aztecus* treatments (P=0.05) at both temperatures (Table 1).

**Comparisons of actual biomass with that expected on a basis of monoculture indicated that *P. aztecus* in all combinations (except 25% at 20°C) grew greater than in monoculture (Table 2). Conversely, biomass of *P. stylirostris* was less than expected in all combinations at 20°C, and clearly exceeded expectation only at 75% *P. stylirostris* at 25°C. Thus, the initially smaller *P. stylirostris* contributed more weight to the total biomass than expected only at 75% at 25°C.**

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**e 4. Mean survival after 30 days in experiment 1 (20 and 30°C) and after 28 days in experiment 2 (25°C).**
1. Mean Biomass Increase per Tank for the First and Second Experiments. Total initial biomass per tank ranged from 1.4 g (P. astreus) to 2.4 g (P. astreus) in experiment 1. Total initial biomass per tank in experiment 2 ranged from 10.7 g (P. astreus) to 15.6 g (P. astreus). Values with the same letter do not differ significantly (Duncan's Multiple Range Test, α = 0.05).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean biomass increase (g)</th>
</tr>
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<td></td>
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</tr>
<tr>
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<td>20°C</td>
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<tr>
<td>P. astreus (%)</td>
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<td>P. stylirostris (%)</td>
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<td>0.50b</td>
</tr>
<tr>
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<td>0.20c</td>
</tr>
</tbody>
</table>

42% survival.

At 25°C mean biomass increases of the 75 and 100% P. stylirostris treatments were approximately the same, while the other treatments were significantly different (P=0.05, Table 1). In contrast to the earlier experiment, mean biomass increase per tank for P. astreus indicated significant differences between the 100 and 75% treatments, while 75 and 25% treatments were similar (P=0.05).

When comparing the actual biomass with the calculated expected biomass at 25°C (Table 2), the actual biomass for both P. astreus alone and the species combined was higher than expected for all treatments, but 75 and 25% P. astreus treatments showing the largest difference in actual and expected biomass. The actual biomass of the P. stylirostris was less than expected in all but the 75% P. stylirostris treatment. Thus, in both experiments, total actual biomass exceeded predicted biomass in almost all density and temperature combinations (Table 2) which was primarily caused by P. astreus which exceeded expected values in all conditions but 20°C and 25%, while P. stylirostris biomass was less than predicted at nearly all combinations.

**CONCLUSION**

Growth of small P. astreus appeared to be favorably influenced in the presence of P. stylirostris, particularly in the 25 and 50% treatments. Whether the larger mean weight gain of P. astreus (at low percent) was actually related to the higher percentage of P. stylirostris in the tank or to the decrease in biomass (decrease in number) of P. astreus could not be determined. The higher mean weight gain of P. astreus at lower ratios was statistically significant.
Survival was better for *P. aztecs* than *P. stylirostris*, with survival greater than 92% of *P. aztecs* at the lower temperature (20°C) and 78% at 30°C (Fig. 4). This species is normally found in cooler waters, and postlarvae grow and survive well at 20-25°C (Eldin and Griffith 1969). *P. stylirostris* also had a higher survival rate at the 20°C temperature (72%) than at the 30°C temperature (even though *P. stylirostris* is considered a warm water species; an optimum range of 27-32°C (Henz and Bowers 1980)).

At 25°C, *P. stylirostris* had a slightly better overall survival rate (70%) than *P. aztecs* (68%). *P. stylirostris* survival improved with increasing numbers of *P. stylirostris* (3-12 individuals) and decreasing numbers of *P. aztecs* (12-3 individuals) (Fig. 4). Thus, the *P. aztecs* in a treatment, the higher the mortality of both *P. stylirostris* and *P. aztecs*, the higher the contribution of *P. stylirostris* (12.3 g/tank) as *P. stylirostris* (7.4 g/tank). Although there was no evidence of cannibalism of the smaller *P. stylirostris* in these experiments, the native *P. aztecs* reared better in mean weight gain, survival and biomass increase than non-indigenous, hatchery-reared *P. stylirostris*. Overall, the increase in weight of *P. aztecs* was 5 times at 20°C, 6 times at 25°C (2 and 10 times at 30°C. However, *P. stylirostris* doubled its weight ) and 25°C and only tripled its weight at 30°C. *P. stylirostris* have been expected to produce higher growth rates (in terms of weight/unit weight/unit time) at 30°C than *P. aztecs* because initial size of *P. stylirostris* should have resulted in an essentially higher growth rate than the larger *P. aztecs*.

Survival of both species depended on the number of *P. aztecs* in treatment with low numbers of *P. aztecs* in the treatment resulting in higher survival rates. The largest difference between actual and expected total biomass in a combination was for the 50% *P. aztecs*:50% *P. stylirostris* treatments. The largest differences between actual and expected total biomass were found for *P. aztecs* at 30°C. *P. aztecs* does not appear to influence the presence of *P. stylirostris* as much as *P. stylirostris* influence by the presence of *P. aztecs* in the same tank. Therefore, *P. stylirostris* are possible candidates for small polyculture systems such as *P. stylirostris* did not adversely affect the primary species (*P. aztecs*) but increased the total production in at least some situations.

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