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Growth and Yield of Pink Shrimp (*Penaeus duorarum duorarum*) in Feeding Experiments in Concrete Tanks

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ABSTRACT

The paper gives results of two 63-day feeding experiments conducted with pink shrimp, *Penaeus duorarum duorarum*, in 36 concrete tanks, each 2 m^2. Foods tested included a commercial catfish food, wheat bran, wheat straw, hay and bagasse. Postlarval shrimp 25 days old were stocked at densities of 7.5 and 15 per m^2. Marl substrate vs. no substrate was also tested, in most cases, as was the effect of feeding rate.

Average yield (g/m^2) of shrimp was higher in tanks to which catfish food was added than in those to which wheat bran was added, it was higher at the lower stocking density, and it increased with increase in feeding rate. Average final weight per shrimp did not differ significantly between these two foods, thus the difference in yield was represented by greater survival of shrimp in tanks to which catfish food was added. Average final weight per shrimp was higher at the lower stocking density. Marl substrate was associated with lowered mean dissolved oxygen concentration but also with higher yield of shrimp.

Tanks to which wheat bran was added produced larger shrimp and higher yield than those to which wheat straw, hay, or bagasse were added.

In the commercial culture of penaeid shrimp there remains a need for reducing the costs of growing the animals from postlarvae to marketable size (Anderson and Tabb 1971). In this regard, the pink shrimp (*Penaeus duorarum duorarum*) has been the subject of our investigations because it is among the most important species of commercial shrimp of the United States and because it is readily available from south Florida waters. One of our approaches to reduction of costs has involved tests of wheat bran as an artificial detritus food for pink shrimp (Caillouet, Heinen, and Tabb 1973; Caillouet et al. 1974).

Dall (1968) suggested that large amounts of unrecognizable material in the gut of penaeid shrimps form the main component of their natural diet and that the shrimp derive nourishment by browsing on microorganisms growing on the surface of this material. Heald (1971) found that the leaves of red mangrove (*Rhizophora mangle*), the dominant primary producer in a south Florida nursery area for pink shrimp, are enriched as food for detritus feeders when they are degraded by micro-organisms. Odum (1971) showed that pink shrimp consume this mangrove detritus.

We emphasize that the artificial detritus method of supplemental feeding is much simpler than feeding formulated diets to shrimp. For the latter, feeding rates usually are dependent upon the number and size of shrimp being fed, so population size and growth rate must be known. In the artificial detritus method, detritus producing materials are added at rates (usually constant) which will not cause oxygen depletion, and these rates are for the most part independent of number and size of shrimp. These materials presumably are enriched by microbial protein, and this enriched material provides nourishment for the shrimp. It is also expected that this material forms a food source for other detritus feeders which are also eaten by shrimp.

Caillouet et al. (1973) used wheat bran as an artificial detritus food for pink shrimp, and its use showed promise in reducing costs of food and labor required for rearing shrimp from postlarval to bait shrimp sizes. Caillouet

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TABLE 1.—*Proximate analysis (percent based on wet weight) of wheat bran and catfish food.*[a]

Constituent	Wheat bran	Catfish food[a]
Protein	14.5	26.0
Fat	3.5	2.5
Fiber	11.0	7.0
Soluble carbohydrate (by difference)	52.5	ND[b]
Ash	4.0	ND
Moisture	14.5	ND

[a] Master Mix Catfish Developer 934, Central Soya and Subsidiaries, Fort Wayne, Indiana 46802.
[b] No data.

et al. (1974) compared wheat bran to Master Mix Catfish Developer 934[4] (Table 1) in a feeding experiment with pink shrimp in ponds. The purposes of the feeding experiments described herein were (1) to compare wheat bran to the same catfish food as foods for pink shrimp reared in concrete tanks, and (2) to compare wheat bran, wheat straw, hay (a mixture of alfalfa, timothy, and clover) and bagasse (fibrous waste from sugar cane refining) as artificial detritus foods for pink shrimp in concrete tanks. Our experiments were conducted concurrently with that of Caillouet et al. (1974).

We are aware that pesticide residuals may have been present in some or all of the food materials tested and that such residuals could have influenced results. However, materials used were those available commercially. Any that showed promise in enhancing growth and yield of shrimp would need further evaluation prior to use in commercial culture of shrimp.

METHODS

Tabb et al. (1969) and Caillouet et al. (1973) described the facilities used for shrimp culture research at Turkey Point in southeast Florida (Fig. 1). Each of the 36 concrete tanks (numbered 1 through 36 in a linear array from north to south) used in our study has a bottom surface area approximately 2 m^2, and each was filled to a depth about 87 cm. Water (Table 2) from Loch Rosetta or the turning basin (Fig. 1) extending from nearby Biscayne Bay was filtered through polyethylene bags of 345 micron (bar measure) mesh before it was introduced into tanks. Tanks were filled over a 3-day period beginning March 18, 1972. On May 25, and at 2-week intervals thereafter, water lost from tanks through evaporation was replaced with water from the turning basin or Loch Rosetta. The tanks were covered with netting to exclude avian predators.

Experiment 1 was conducted in tanks 13–36, and Experiment 2 in tanks 1–12. All tanks were stocked on May 25, 1972 with 25-day-old pink shrimp postlarvae averaging 0.01 g. All tanks were drained on July 27, 63 days after the day of stocking, and surviving shrimp were counted and weighed (heads-on). In both experiments, weighed food was added once daily (except inter-

[4] The use of brand names throughout this paper does not imply endorsement of commercial products.

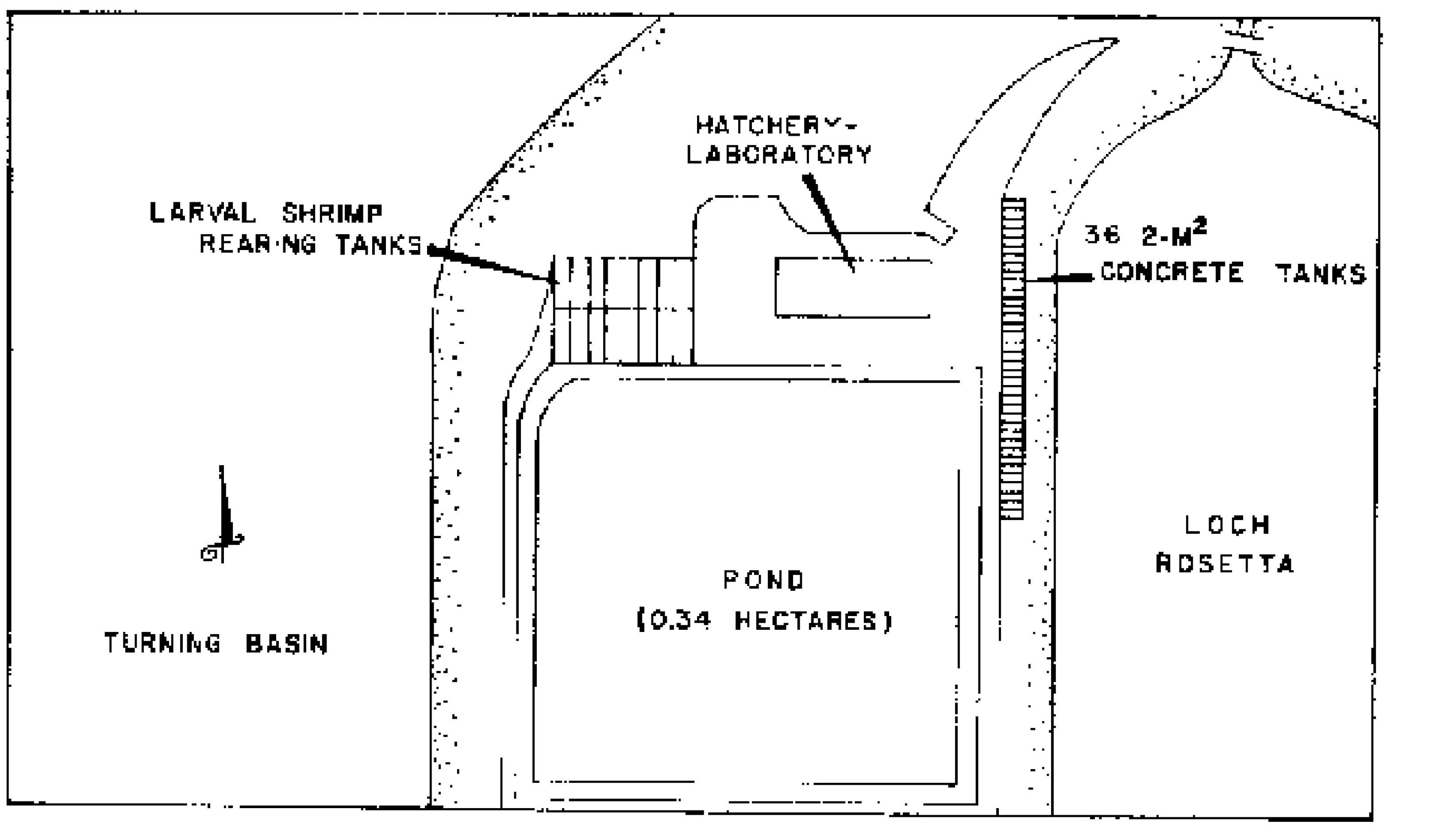

FIGURE 1.—*Diagram of shrimp culture research facilities at Turkey Point, Florida. Each of the 36 concrete tanks has a bottom surface area approximately 2 m^2.*

TABLE 2.—*Analysis of oolitic marl and seawater (values are in parts per million, unless otherwise indicated).*

	Before being introduced into tanks		After being introduced into tanks (March 28)	
	Marl	Seawater	Seawater in tanks with marl	Seawater in tanks without marl
Nitrogen (as nitrate)	40	<0.1	0.2	0.1
Phosphorus	0.1	0.1	<0.1	<0.1
Potassium	18	500	400	380
Calcium	150	400	500	480
Chloride	900	17,900	21,000	21,000
Conductivity, mhos $\times 10^{-5}$	120	4,500	5,000	5,000
pH	7.95	7.90	8.30	8.25

TABLE 3.—*The feeding rate/substrate factor and two orthogonal comparisons used to test it in Experiment 1.*

	Daily feeding rate[a]					Weight of total food, g/m²	With marl	Without marl[b]
	0.0 g/m²	0.45 g/m²	0.9 g/m²	1.35 g/m²	2.7 g/m²			
	No. days	*No. days*	*No. days*	*No. days*	*No. days*			
Low	17	11	35	0	0	36.4	A	not tested
High	17	0	0	11	35	109.3	B	C

Source of Variation[c]	Orthogonal Comparison	Explanation
R1	A and B vs. C	Both feeding rates with marl vs. the high feeding rate without marl
R2	A vs. B	The low feeding rate with marl vs. the high feeding rate with marl

[a] The 0.0 g/m² daily feeding rate represents no feeding, and the 17 days of no feeding occurred intermittently rather than consecutively during the experiment. Under each feeding rate, initial quantities of food were increased to higher quantities during the experiment.
[b] The low feeding rate was not tested without marl thus only three of the four possible combinations of daily feeding rate and substrate were tested.
[c] See Table 6.

mittently when no food was added, to avoid oxygen depletion) to each tank in late afternoon. Under each feeding rate, initial quantities of food added daily were changed to higher quantities during the experiments (Tables 3 and 4).

Experiment 1

Experiment 1 tested the main effects and interactions of food type (wheat bran vs. catfish food), stocking density (7.5 shrimp/m² vs. 15 shrimp/m²), and three levels of feeding rate/substrate (Table 3) on growth and yield of pink shrimp in tanks. Before tanks were stocked with shrimp and once thereafter, fertilizer (Table 5) was added to tanks to stimulate algal blooms. A factorial arrangement of treatment combinations (Table 6) was used, and each of the 12 treatment combinations was replicated twice in a randomized complete block design. Tanks 13–24 were used for replication 1, and tanks 25–36 for replication 2.

The feeding rate/substrate factor (Table 3) consisted of two feeding rates ("low" and "high") tested in tanks containing oolitic marl (Table 2) substrate, and one feeding rate ("high") tested in tanks containing no substrate (Table 3). For the 16 tanks with substrate, marl was placed on the bottom of each tank to a depth of 8–10 cm on March 16, before water was introduced. The other 8 tanks had no substrate. The comparison between marl substrate and no substrate was made to determine whether marl substrate influenced growth and yield in shrimp. Use of marl substrate in tanks also made them more comparable to the ponds which have marl bottoms (see Caillouet et al. 1974).

Water temperature, dissolved oxygen, and salinity were measured in each of the 24 tanks between the hours of 0800 and 1000

TABLE 4.—*Feeding rates used in Experiment 2.*

	Daily feeding rate[a]						Weight of total food, g/m²
	0.0 g/m²	0.9 g/m²	1.35 g/m²	1.8 g/m²	2.7 g/m²	3.6 m/m²	
	No. days	*No. days*	*No. days*	*No. days*	*No. days*	*No. days*	
Low	17	11	0	35	0	0	72.9
Medium	17	0	11	0	35	0	109.4
High	17	0	0	11	0	35	145.8

[a] The 0.0 g/m² daily feeding rate represents no feeding, and the 17 days of no feeding occurred intermittently rather than consecutively during the experiment. Under each feeding rate, initial quantities of food were increased to higher quantities during the experiment.

TABLE 5.—*Schedule of fertilization of tanks 1–36.*

Date of application		Fertilizer	Rate of application, g/m^2 Tanks 1–12 (Experiment 2)	Tanks 13–36 (Experiment 1)
March	19	Armour[a]	1.1	1.1
	24	Armour	1.1	1.1
	30	Prepared[b]		2.2
April	4	Prepared		2.2
	7	Wheat Bran[c]		15.0
	13	Prepared		4.4
July	7	Armour		2.2

[a] Armour Fish Pond Fertilizer, 20-20-5 analysis.
[b] Mixture of ammonium nitrate and phosphoric acid, 20-33.5-0 analysis.
[c] Not considered here as shrimp food, since it was added to each of the tanks before they were stocked with shrimp.

eastern standard time (EST) during the experiment; dissolved oxygen was measured on 49 days during the experiment, temperature on 59 days, and salinity on 21 days.

Experiment 2

Experiment 2 tested the main effects and interactions of food type (wheat bran, wheat straw, hay, and bagasse) and three feeding rates ("low," "medium," and "high," Table 4) on growth and yield of pink shrimp in tanks. Before tanks were stocked with shrimp, fertilizer was added to tanks to stimulate algal blooms, but none was added thereafter (Table 5). All tanks were stocked at 15 shrimp per m^2. A factorial arrangement of treatment combinations (Table 7) was used, and each of the 12 treatment combinations was replicated only once within tanks 1–12, which contained no substrate. Experiment 2 is considered to be only a "screening" experiment involving a search for the major sources of variation.

TABLE 6.—*Main effects and interactions tested by analysis of variance in Experiment 1.*

Source of variation[a]	Degrees of freedom
Replication	1
Main effects	
Food type, F	1
Stocking density, D	1
Feeding rate/substrate, R (see Table 3 for details)	
R1	1
R2	1
Interactions	
F × D	1
F × R1	1
F × R2	1
D × R1	1
D × R2	1
F × D × R1	1
F × D × R2	1
Experimental error	11
Total	23

[a] Each main effect and interaction represents an orthogonal comparison among the 12 treatment combinations.

TABLE 7.—*Main effects and interactions tested by analysis of variance in Experiment 2.*

Source of variation[a]	Degrees of freedom
Main effects	
Food type, F	
F1 (Bran vs. straw)	1
F2 (Hay vs. bagasse)	1
F3 (Bran and straw vs. hay and bagasse)	1
Feeding rate, R (see Table 4 for details)	
RL (Linear)	1
RQ (Quadratic)	1
Interactions	
F1 × RL	1
F1 × RQ	1
F2 × RL	1
F2 × RQ	1
F3 × RL	1
F3 × RQ	1
Total	11

[a] Each main effect and interaction represents an orthogonal comparison among the 12 treatment combinations.

Water temperature, dissolved oxygen, and salinity were measured in each of the 12 tanks between 0800 and 1000 EST during the experiment; dissolved oxygen was measured on 52 days during the experiment, temperature on 59 days, and salinity on 22 days.

RESULTS

Experiment 1

For dissolved oxygen, temperature, and salinity in each of the 24 tanks (13–36), the daily observations were averaged, and the 24 means for each of these three environmental variables were subjected to analysis of variance (see Table 6).

Only the two orthogonal comparisons involving feeding rate/substrate (see Table 3) were significant[5] sources of variation in mean dissolved oxygen concentration. In the tanks containing marl substrate, mean dissolved oxygen concentration was lower (5.0 mg/liter) at the "high" feeding rate than at the "low" feeding rate (6.1 mg/liter). The highest mean oxygen concentration, 7.7 mg/

[5] Refers throughout this paper to 95% level of confidence.

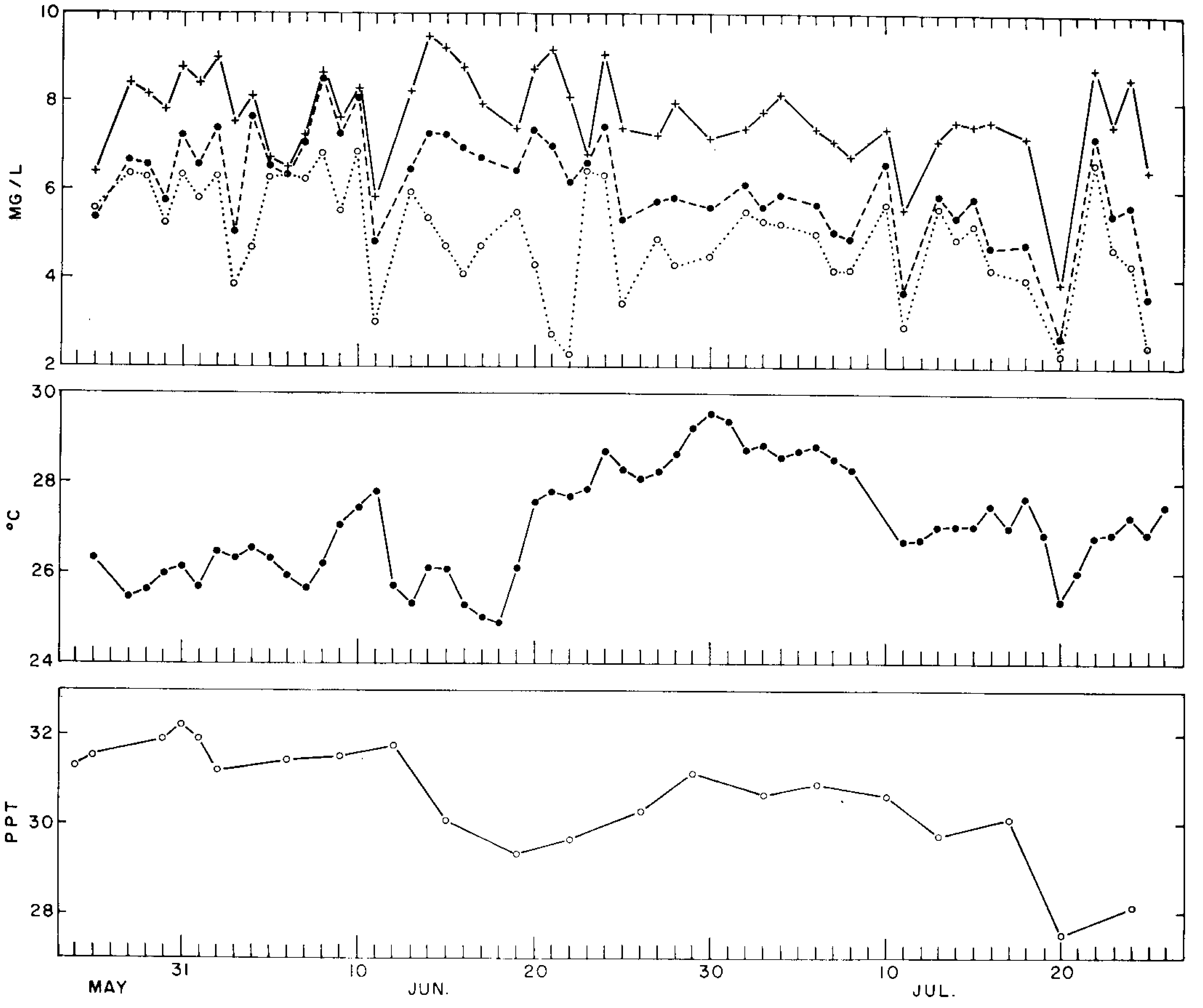

FIGURE 2.—*Mean dissolved oxygen concentrations (mg/liter) for three levels of feeding rate/substrate (low feeding rate, with marl, ● - - - - ●; high feeding rate, with marl, ○ · · · · ○; high feeding rate, without marl, + ——— +), mean temperature (C), and mean salinity (parts per thousand) in Experiment 1 (tanks 13–36). See Table 3 for details on the feeding rate/substrate factor.*

liter, was attained in tanks containing no substrate, even though these received the "high" level of feeding. As expected, oxygen loss was greater in tanks containing substrate than in those without substrate, and additional food further decreased oxygen concentration. Daily averages of dissolved oxygen concentration are plotted in Figure 2 for the three feeding rate/substrate treatments.

For mean water temperatures and mean salinities, differences were too slight to be of consequence, though significant differences were detected. Daily averages are shown in Figure 2.

Analysis of variance (Table 6) of average final weight per shrimp for the 24 tanks detected a significant effect of stocking density. Shrimp stocked at 7.5 per m^2 grew to an average size of 3.4 g, and those stocked at 15 per m^2 grew to an average size of 2.0 g.

Analysis of variance (Table 6) of final yield of shrimp for the 24 tanks detected significant main effects of food type, stocking density, and the feeding rate/substrate comparison R2 (see Table 3) and a significant three-factor interaction among these three main effects. The highest average yields, 20.2 g/m^2 and 20.5 g/m^2, at both stocking densities, 7.5 and 15 per m^2, respectively, were obtained in tanks containing marl substrate and receiving the highest level of food (Fig. 3), the same level of feeding rate/substrate

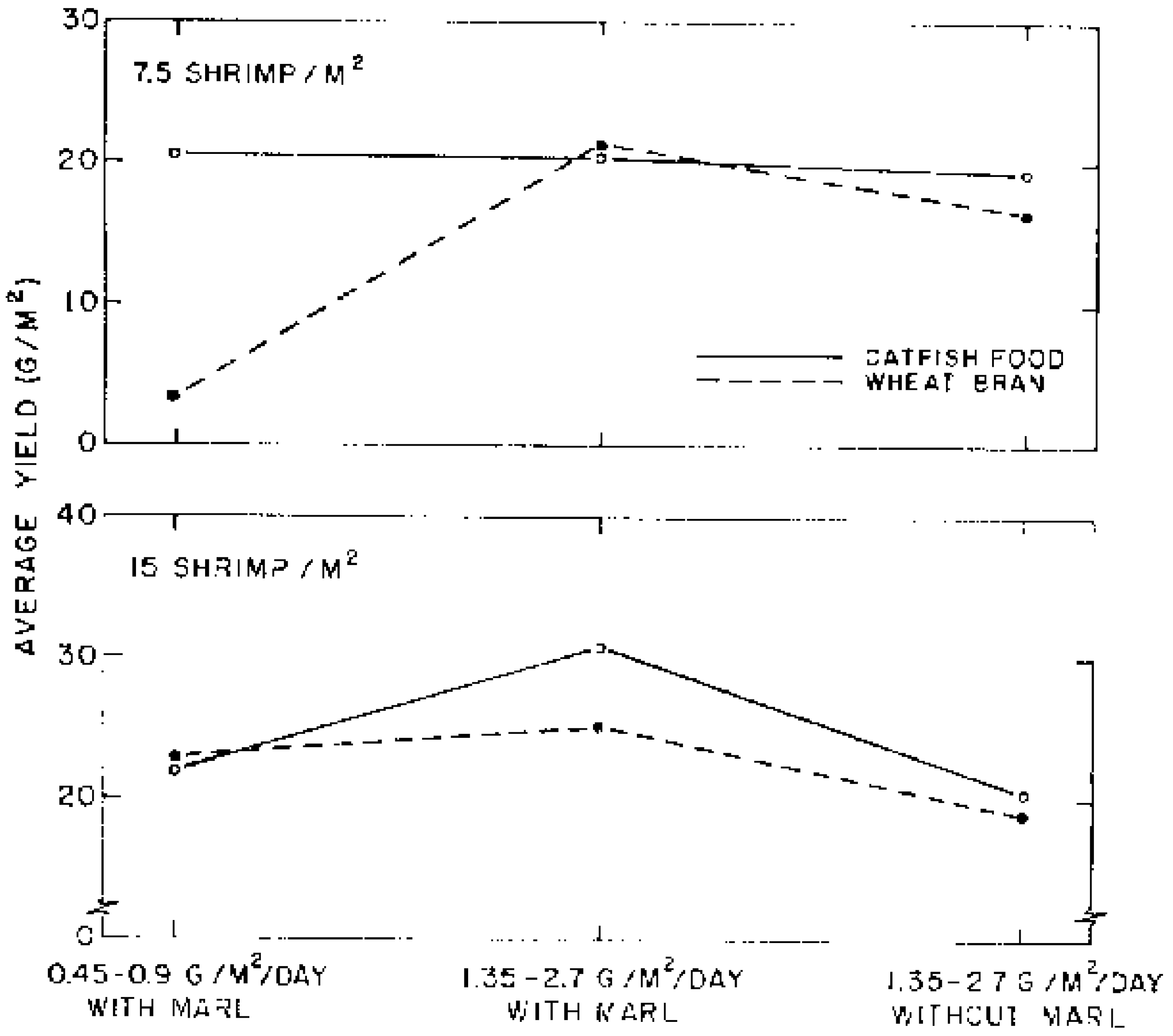

FIGURE 3.—*Average yield (g/m²) of pink shrimp at two stocking densities (7.5 shrimp/m² and 15 shrimp/m²) for two foods (catfish food, ○ ——— ○; wheat bran, ● - - - - ●), and three levels of feeding rate/substrate (low feeding rate, 0.45–0.9 g/m²/day, with marl; high feeding rate, 1.35–2.7 g/m²/day, with marl; high feeding rate, 1.35–2.7 g/m²/day, without marl), Experiment 1. See Table 3 for details on the feeding rate/substrate factor.*

that produced the lowest mean dissolved oxygen concentrations (Fig. 2). Enrichment of the tanks by marl substrate and additional food produced greater yields by enhancing survival, not growth rate. Catfish food produced better yields than did wheat bran in most cases (Fig. 3), but the growth rates of shrimp fed catfish food and those fed wheat bran were similar, showing that survival was better with catfish food.

Experiment 2

Since the 12 treatment combinations were not replicated in Experiment 2, there was no experimental error term in the analysis of variance (Table 7), so no tests of significance were made. Rather, any source of variation that contributed 10% or more to the total sum of squares in the analysis of variance was considered to be of practical interest.

For dissolved oxygen, temperature and salinity in each of the 12 tanks (1–12), daily observations were averaged, and the 12 means for each of these environmental variables were subjected to analysis of variance (Table 7).

TABLE 8.—*Mean dissolved oxygen concentrations (mg/liter) by feeding rate and food type in Experiment 2.*

Feeding rate[a]	Food type: Wheat bran	Wheat straw	Hay	Bagasse
Low	7.9	8.2	7.9	8.5
Medium	7.6	9.1	7.1	8.4
High	8.1	8.6	8.3	8.5

[a] See Table 4.

Food type (orthogonal comparisons F1 and F2, see Table 7) and two interactions between food type and feeding rate (F1 × RQ and F3 × RQ) each contributed more than 10% of the variation to the total sum of squares for mean dissolved oxygen concentrations (Table 8). The food type comparisons were stronger sources of variation than were the interactions. Mean oxygen concentrations were higher in tanks receiving wheat straw than in those receiving wheat bran, and they were higher in tanks receiving bagasse than in those receiving hay. For mean water temperatures and mean salinities, differences were slight. Daily averages of dissolved oxygen, temperature, and salinity are shown in Figure 4.

The only important source of variation in average final weight per shrimp and in final yield among the 12 tanks was the comparison between wheat bran and wheat straw (Table 9). Tanks to which wheat bran was added produced the largest shrimp, averaging 1.3 g, and the highest yield, 19.6 g/m².

DISCUSSION

Caillouet et al. (1973) conducted one wheat bran feeding experiment with pink shrimp which bears some similarity to our Experiments 1 and 2. They stocked pink shrimp

TABLE 9.—*Average final weight (g) per shrimp (heads-on) and final yield (g/m²) by food type in Experiment 2.*

	Wheat bran	Wheat straw	Hay	Bagasse
Average final weight, g	1.3	0.5	0.9	0.6
Final yield, g/m²	19.6	6.1	13.5	8.7

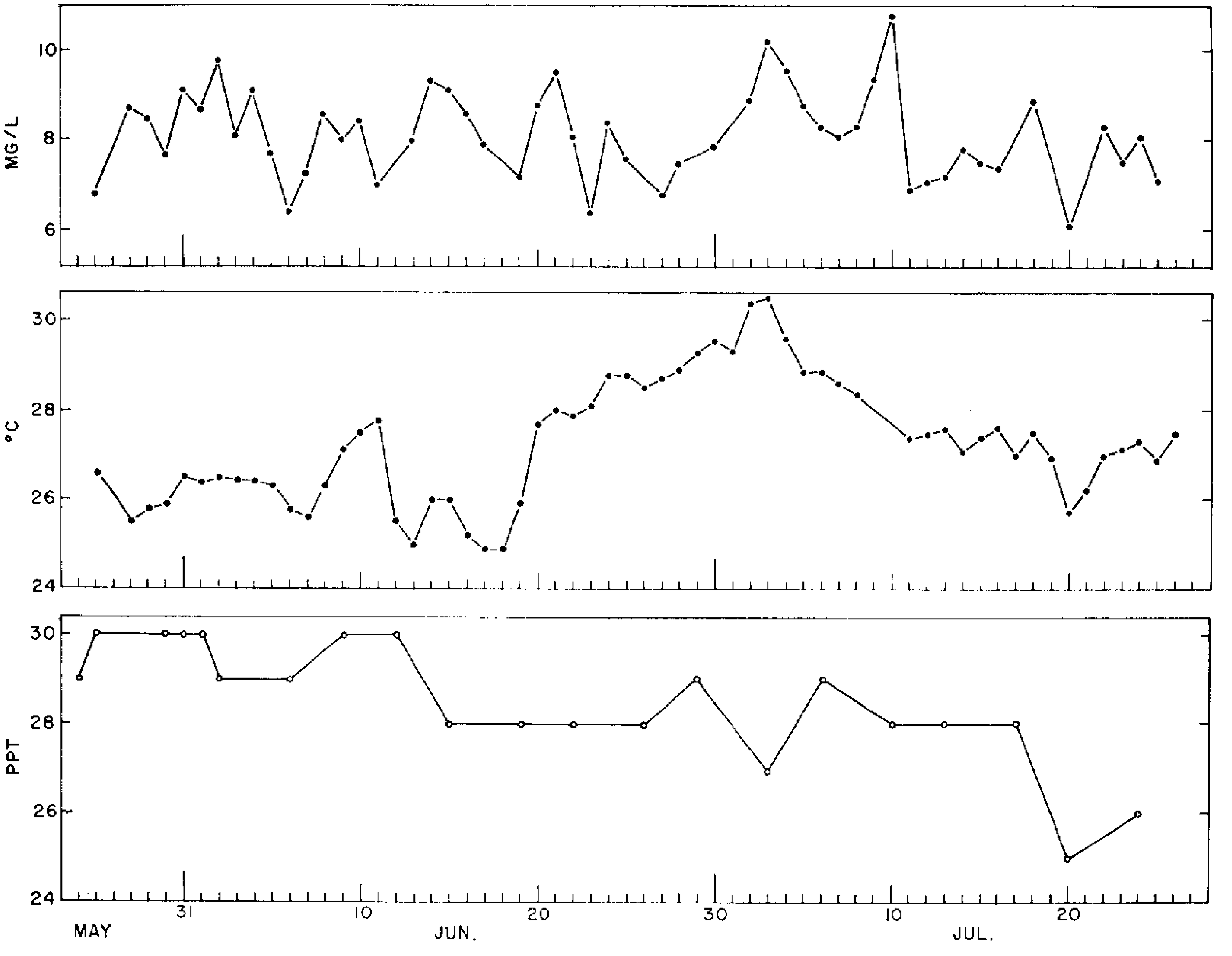

FIGURE 4.—*Mean dissolved oxygen concentration (mg/liter), mean temperature (C) and mean salinity (parts per thousand) in Experiment 2 (tanks 1–12).*

postlarvae averaging 0.04 g at three densities, 4, 8, and 16 per m^2, in the concrete tanks on October 11, 1971, and harvested 51 days later. The best shrimp growth and yield in their experiment were observed in tanks to which the wheat bran was added daily at 2.7 g per m^2. Survival was 96% or higher at all three stocking densities. The average final weight per shrimp (heads-on) was 2.7 g, 1.5 g, and 1.0 g at stocking densities 4, 8, and 16 per m^2, respectively. The average final yield of shrimp (heads-on) was 10.8, 11.9, and 15.0 g/m^2 at stocking densities 4, 8, and 16 per m^2, respectively. At stocking densities of 7.5 and 15 shrimp per m^2 in our first experiment, wheat bran produced average final weights per shrimp (heads-on) of 3.4 g and 2.0 g, respectively; highest final yields were 20.2 g/m^2 and 20.5 g/m^2, respectively. In our second experiment wheat bran produced an average final weight per shrimp of 1.3 g and a final yield of 19.6 g/m^2 at a stocking density of 15 shrimp per m^2.

Stocking densities in our Experiments 1 and 2 fall within those used in the experiment by Caillouet et al. (1973); our experiments were 12 days longer, they were conducted in spring-summer rather than in fall, and our feeding levels were lower than theirs. With wheat bran in Experiment 1 we obtained better growth and yield, and in Experiment 2 comparable growth and better yield, than did Caillouet et al. (1973) at comparable stocking densities. Both temperature and salinity were generally higher in our experiments than in theirs, and this might account in part for the differences.

Though Experiments 1 and 2 were purposely designed to be of relatively short duration, the results are still indicative of conditions which might enhance growth and yield of pink shrimp in a commercial shrimp farming operation. Though catfish food produced better yield, it did not produce better growth at the stocking densities of Experiment 1.

As expected, marl substrate was associated with lowered dissolved oxygen concentration but also with higher shrimp yield, in most cases. The experimental capabilities of the concrete tanks in simulating, on a small scale, conditions in ponds, are enhanced by the use of substrate similar to that in the ponds.

Wheat bran seemed superior to wheat straw, hay, and bagasse as an artificial detritus food in Experiment 2, but additional tests (with replication) should be conducted prior to a choice among these materials.

We believe that the results of our experiments may be applicable to commercial production of live bait shrimp, but not to the production of shrimp for food, because of the relatively short duration of the experiments.

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