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Salinity Preference of Postlarval Brown and White Shrimp (*Penaeus aztecus* and *P. setiferus*) in Gradient Tanks

RICHARD K. KEISER, JR. and DAVID V. ALDRICH

Department of Wildlife and Fisheries Science
Texas Agricultural Experiment Station

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ABSTRACT

Salinity Preference of Postlarval Brown and White Shrimp (*Penaeus aztecus* and *P. setiferus*) in Gradient Tanks

Brown and white postlarval shrimp (*Penaeus aztecus* and *P. setiferus*) were collected at the beachfront and tested at constant low level red illumination in tanks containing salinity gradients ranging from 0 to 50 ppt and 0 to 70 ppt and in control tanks having uniform salinity. Gradients were stable for as long as 119 hours with maximum deviations in salinity of 3 ppt. Generally, final gradient salinities were identical to initial gradient salinities or differed at a given point by only 1 or 2 ppt.

Postlarvae of both species sought salinities lower than those generally found in the open Gulf of Mexico. It is suggested that postlarval shrimp orient to bays by utilizing natural salinity gradients that extend seaward from the estuaries. Proposed water diversion projects, such as the Texas Water Plan, would restrict or curtail freshwater inflow to the estuaries thereby altering natural gradients of both salinity and dissolved organics. This might affect the immigration of shrimp and other estuarine-dependent organisms to the estuaries.

Brown shrimp postlarval distributions in gradient tanks differed significantly according to the season of the year. Spring postlarvae

preferred higher salinities than those tested in the summer or fall. Field studies have shown that brown shrimp postlarvae in the spring are found in the estuaries in salinities considerably lower than those that would be expected from their distribution in laboratory gradient tanks. In contrast to findings for brown shrimp postlarvae, white shrimp postlarval distributions in gradient tanks differed seasonally only at low salinity levels.

During the summer, the average median salinity difference between brown and white postlarval distributions was only 3.2 ppt. This suggests that there is less difference in salinity preference between the two species at the postlarval stage than has been suggested for larger stages of the life cycle.

Experiments designed to determine whether the red illumination, acclimation salinity, and temperature influenced salinity preference were inconclusive. There was no evidence of any endogenous tidal rhythms for brown or white shrimp such as has been reported for postlarval pink shrimp.

Occasional striking variation was noted between experiments. Further work is required to recognize the causes of this presently unexplained variability in shrimp behavior.

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INTRODUCTION

The shrimp resource of the Gulf of Mexico is the most valuable fishery resource of the United States (Kutkuhn 1966). Gulf landings are composed primarily of three species--*Penaeus aztecus*, brown shrimp; *P. setiferus*, white shrimp; and *P. duorarum*, pink shrimp. All three species spend part of their life cycle in the estuaries. The shrimp fishery is but one of several commercial fisheries that is estuarine-dependent. Although the importance of the estuaries to commercial fisheries is recognized (Chapman 1966; Kutkuhn 1966), estuarine modification continues to occur along the Gulf Coast. This includes dredging, marsh reclamation, hurricane protection projects, and water diversion projects. Whereas the effects of dredging and marsh reclamation on the productivity of the estuaries have been investigated (Hutton et al. 1956; Odum 1963; Mock 1966; Taylor and Saloman 1968; Sykes and Hall 1970; Cronin, Gunter, and Hopkins 1971), the effects of restricting freshwater inflow to an estuary are not fully understood (Copeland 1966; Odum 1970). Obviously, salinities would rise as a direct result of less freshwater. Related to a decrease in flowrate would be a decrease in nutrient inflow, a probable reduction in turbidity, an alteration of circulatory currents within the system, and a modification of existing salinity gradients. How

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the above factors would affect the suitability of the estuary as a nursery ground is not known, but modifying the salinity gradient may have a direct effect on the natural influx of postlarval shrimp. The need to obtain answers to the above questions becomes apparent when one examines the projections of the Texas Water Plan, which proposes to dam every major river in Texas and divert water from the estuaries to agricultural and industrial usage (Chapman 1966).

STATUS OF THE PROBLEM

The general life history of the commercial penaeid shrimp found in the Gulf of Mexico has been reported by many authors (Broad 1965; Williams 1965; Baxter and Renfro 1967; Kutkuhn 1966; Trent 1966; Farfante 1969; Pullen and Trent 1969; Cook and Lindner 1970; Lindner and Cook 1970). Bibliographies on shrimp biology have been compiled by Chin and Allen (1959) and Allen and Costello (1969). The adult shrimp spawn in offshore waters. The eggs hatch after several hours into nauplii which pass through several molts, first into proto-zoaea, then mysis stages, and finally metamorphosing into postlarvae which approach the shoreline. The postlarvae enter estuarine waters and grow rapidly into juveniles. The shrimp then return to the open sea where they mature sexually.

Estuarine areas supply the proper conditions of salinity, temperature, substrate, food, and cover to enable postlarval shrimp to grow into juveniles (Broad 1965; Kutkuhn 1966). Summarizing field surveys, Pearse and Gunter (1957) stated that the early stages of shrimp apparently require oceanic water, but the older larvae must reach bay water or perish. Extensive field investigations have shown both brown and white shrimp to be present in waters both hypo- and hypersaline with respect to seawater (Simmons 1957; Joyce 1965). On the basis of field distribution data, Gunter (1961a) suggested that small shrimp (*P. setiferus*) are not killed or precluded by high salinity as if it were poison; they simply do not do well in it for unknown reasons. Laboratory studies (Zein-Eldin 1963) indicated that postlarval brown shrimp can both survive and grow over a salinity range of 2 to 40 ppt. Further studies (Zein-Eldin and Aldrich 1965; Zein-Eldin and Griffith 1969) show that combinations of low salinity and low temperature are detrimental to both white and brown postlarval shrimp. Wiesepape, Aldrich, and Strawn (1972) investigated the effects of temperature and salinity on thermal death in postlarval brown shrimp. They found that acclimation to 5 ppt provided near optimum thermal resistance at 5 ppt as well as at higher salinities up to 25 ppt. They concluded that living in low salinities permitted postlarval brown shrimp to resist high temperatures.

Laboratory studies indicate that juvenile and adult brown and white shrimp are physiologically adapted for somewhat different salinity regimes. McFarland and Lee (1963) found that white and brown shrimp could osmoregulate over a wide range of salinities; however, white shrimp were better adapted to tolerate low salinities, and brown shrimp were better adapted to higher salinities. Low temperatures decreased the ability of white and brown shrimp to osmoregulate at low salinities (Williams 1960; McFarland and Lee 1963).

Juvenile white and brown shrimp are often found in different areas of the estuarine nursery grounds. Generally, white shrimp penetrate further up the estuaries into less saline water than do brown shrimp. Gunter (1950) using minnow seines and otter trawls found the greatest abundance of white shrimp in South Texas within a salinity range of 10.0-14.9 ppt, while brown shrimp were most abundant in salinities from 15.0 to 19.9 ppt. Loesch (1962) reported that the greatest numbers of white shrimp in experimental trawl catches were taken in waters between 1 and 5 ppt during summer and fall months. During this same period, trawl catches of brown shrimp were most numerous in water having a salinity ranging from 10 to 15 ppt.

Field observations suggested to Gunter (1961b) that white shrimp have a greater tolerance to low salinities than brown shrimp. Correspondingly, the greatest production of white shrimp has always been from the vast estuarine area of the Louisiana coast, and the greater brown shrimp production has come from the drier Texas coast. Gunter and Hildebrand (1954) found a correlation between white shrimp production and rainfall. A later study demonstrated that the white shrimp catch in Texas was related to the annual rainfall of the previous 2 years (Gunter and Edwards 1969). They concluded that this correlation was apparently related to salinity per se or some other factor governed by salinity.

The manner in which the postlarval shrimp orient to the estuarine nursery grounds is not clearly understood. Several investigators have taken postlarvae mostly on incoming tides (Pearson 1939; Tabb, Dubrow, and Manning 1962; St. Amant, Broom, and Ford 1966; Caillouet, Fontenot, and Dugas 1968). Anderson, King, and Lindner (1949) postulated that white shrimp postlarvae need a favorable incoming current and are perhaps responsive to a salinity gradient. In laboratory experiments, Aldrich (unpublished results) found that postlarval brown shrimp, caught along the ocean beach, actively moved towards lower salinity waters in a salinity gradient tank. The salinity range preferred by the young shrimp seemed to be related to the past salinity history of the organism (Aldrich 1963). Joyce (1965) suggested that postlarval shrimp have the ability to choose a tide favorable for transport or to leave an unfavorable one. Hughes (1969a) tested the response of postlarval pink shrimp (*P. duorarum*) to tidal changes. Using laboratory experiments, he found that following a decrease in salinity, postlarval pink shrimp settled to the bottom; when salinity was increased, they became active in the water column. He hypothesized that in nature this response would allow postlarval shrimp to use incoming tides (high salinity) to penetrate the estuaries, but as the tide changed, the shrimp would settle to the bottom, thereby avoiding offshore displacement by the ebb tide (low salinity). Hughes did not explain how tidal influence could bring about salinity change within a water mass. In a later paper, Hughes (1969b) stated that further experimentation showed that a decrease in salinity was not invariably followed by a decrease in activity; frequently the shrimp remained active on or just above the substrate. Hughes reported on the response of postlarval pink shrimp to salinity discontinuity barriers. He found that postlarvae were able to perceive and respond to salinity differences of as little as

1 ppt. He proposed that this would enable postlarvae to discriminate between ebb and flood tides. On the basis of these experiments, Hughes concluded that postlarval pink shrimp have an "aversion" to penetrating waters of lower salinity, but that within a period of 1 week, this "aversion" is considerably reduced. Presumably within this period, the postlarvae would have reached the low salinity estuarine waters. The avoidance response, which initially prevented their following the low salinity ebb tide seaward, would no longer be needed. In his most recent experiments, Hughes (1972) subjected postlarval pink shrimp to a current of constant velocity and recorded their swimming direction. The results showed a pattern of up- and downstream swimming that appeared to be in phase with the tidal cycle in nature. Hughes proposed that the shrimp have an endogenous rhythm to synchronize their activity with the tidal cycle; however, the swimming direction observed in the laboratory was seaward--upstream at time of flood tide and downstream at time of ebb tide. This would not seem to facilitate shoreward movement of the organism. Hughes explained this discrepancy by hypothesizing that the postlarvae's presence or absence in the water column at the time of ebb or flood tide determines their displacement--not the actual swimming orientation of the organism.

The transport mechanism that initially brings the postlarvae into the estuaries remains unknown. Hughes' latest theory resulting from laboratory experiments with pink shrimp may explain certain aspects of shoreward movement, but depends on the presence of predictable tides. In Galveston Bay, wind direction and amplitude often override gravitational influences in determining tidal stage. One alternative possibility is that the animals display a more active role in determining their distribution through responses to natural salinity gradients existing in coastal waters adjoining estuaries. In recent preference experiments, brown shrimp postlarvae selected salinity levels lower than those occurring along the Gulf of Mexico beach where they were collected (Aldrich, unpublished results).

The objectives of this investigation are to determine if there is a seasonal variability in the salinity preference of postlarval shrimp, to test for responses of white shrimp to experimental salinity gradients, to determine if differences exist between salinity preferences of white and brown shrimp postlarvae, to investigate the effect of acclimation salinity on salinity preference, to investigate the relationship of temperature to salinity preference, to test for the effect of age on salinity preference, and to relate these findings to existing ecological knowledge of these species.

METHODS

The present apparatus evolved from earlier experimentation by Aldrich (1963). He established a continuous salinity gradient ranging from 1 to 70 ppt in a cylindrical 7-l, 1.2 m vertical column to study postlarval penaeid shrimp. This arrangement was not completely satisfactory because the crustacean larvae, having a higher specific gravity than seawater, tended to sink in the vertical column. This tendency required them to swim continuously to maintain their position in the column (abnormal behavior). The above problem encountered with Aldrich's (1963) vertical column was eliminated by making a resting place or "bottom" available to shrimp in the gradient (Keiser and Aldrich 1973). This was accomplished simply by slanting the gradient tank at an angle of 25°. The sloping tank permitted postlarval shrimp to rest at any level in the gradient, using as a "bottom" what was a vertical wall when the tank was upright. Another problem, the presence of "blind spots" in the cylindrical chambers, was eliminated through the use of square cross-sectional design.

Description of Apparatus

The apparatus consisted of two tanks, their supports, and lighting. The experimental tanks were constructed of 0.6 cm Plexiglas with inside dimensions 3.6 m x 10.2 cm wide x 10.2 cm high, open at one end. The tanks were constructed of these dimensions to maximize the use of available space and for ease of handling. The 3.6 m long sides were made by joining end-to-end two pieces of Plexiglas and overlapping the joints with 4-cm Plexiglas braces. The location of the joints was varied between adjoining walls to further strengthen the tank (Fig. 1A). The two tanks rested on wooden boards 1.8 x 22.8 cm ("1 x 10" in) and were stacked one on top of the other on a framework of 3.7 x 14.0 cm ("2 x 6" in) boards (Fig. 1B). All wooden supports were painted dull black to reduce light reflection. Six 122 cm (4 ft) 40-watt Rapid Start fluorescent fixtures were mounted on a 1.8 x 28.4 cm ("1 x 12" in) board in 2-3.6 m rows and positioned 43.3 cm behind the tanks. The distance between the back surface of each tank and the light was spanned by 0.6 cm plywood which directed the illumination. A 7.6 cm space between the board and the lamps allowed for dissipation of the heat generated by the bulbs. Initially, the apparatus had a plywood cover; however, experimentation showed that a lid was unnecessary in a darkened room. Lines parallel to the floor were affixed to the outside of the tanks at 5 cm intervals. This provided a grid with which to define the position of the animals in the tank.

Forty-watt red fluorescent lamps provided the only illumination during the experiments. Waterman (1961) noted that the few marine crustaceans which have been examined possess photopigments that would reduce their visual sensitivity to light of long wavelengths. This suggested that the use of red light might likewise minimize the sensitivity of penaeid shrimp to visual stimuli. The intensity of

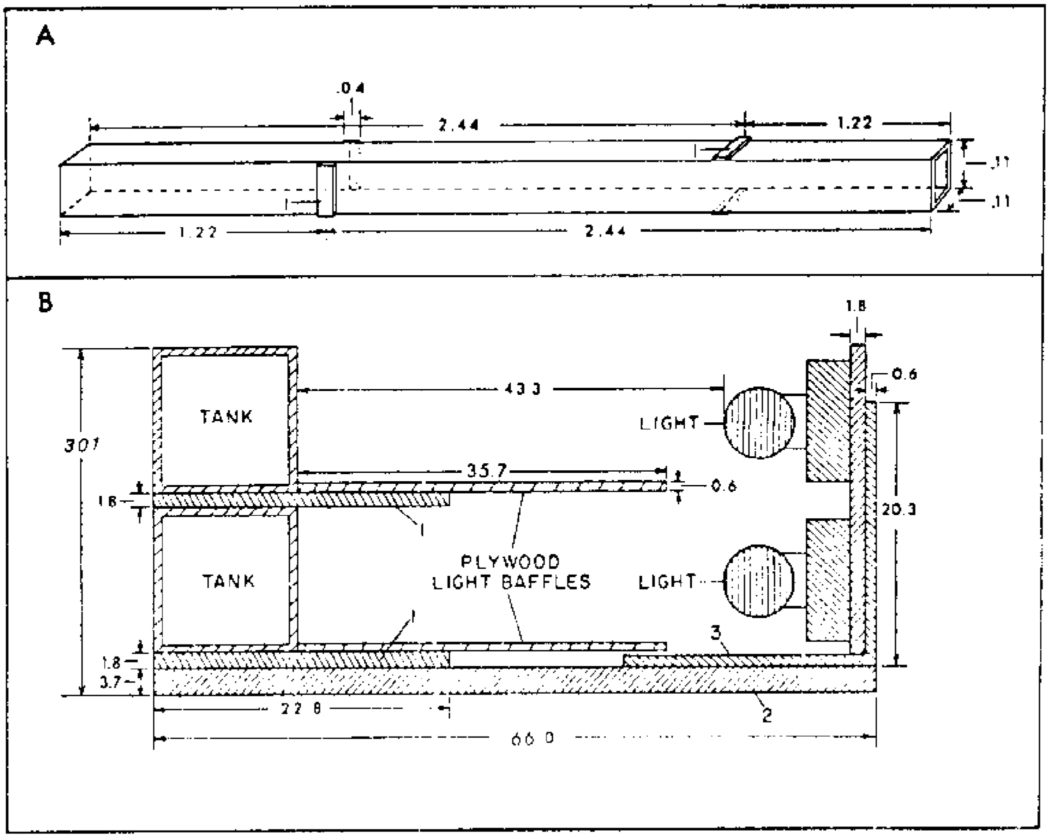

FIGURE 1. A. Diagram showing detail of tank. (1) external Plexiglas brace at joints. All dimensions in meters. B. Detailed cross-section of apparatus. (1) longitudinal supports, (2) transverse support, (3) angle iron brace. All dimensions in centimeters.

visual light emitted by fluorescent tubes decreased towards the ends and often differed among tubes. We used a photometer (model 250; Science and Mechanics, New York, N.Y.) to select tubes of similar illumination. Light illumination was measured at approximately the center of each 5 cm interval on the far outside wall of the water-filled tanks away from the light source. Illumination ranged from 10 ft candles at the ends of the bulbs to 20 ft candles at the middle of the bulbs. Figure 2 shows the typical distribution of light transmitted through an experimental tank. An examination of shrimp distribution in control and experimental tanks showed no pattern resembling that of the light illumination distribution.

Collection and Holding of Postlarvae

Postlarvae were collected at several locations along the Galveston beach front, in Bolivar Roads Pass, and in tidal ponds. Figure 3 indicates the location of the collection sites. The majority of the shrimp were collected at East Beach near the South Jetty (Table 1).

A hand-drawn beam trawl (Renfro 1963) was used to collect the postlarvae. The catch was transported to the laboratory in an insulated ice chest. During transfer, the water was aerated by a battery operated airpump. At the laboratory, the shrimp were separated from other organisms and debris in the catch and placed in Instant Ocean (Aquarium Systems, Eastlake, Ohio) seawater medium;

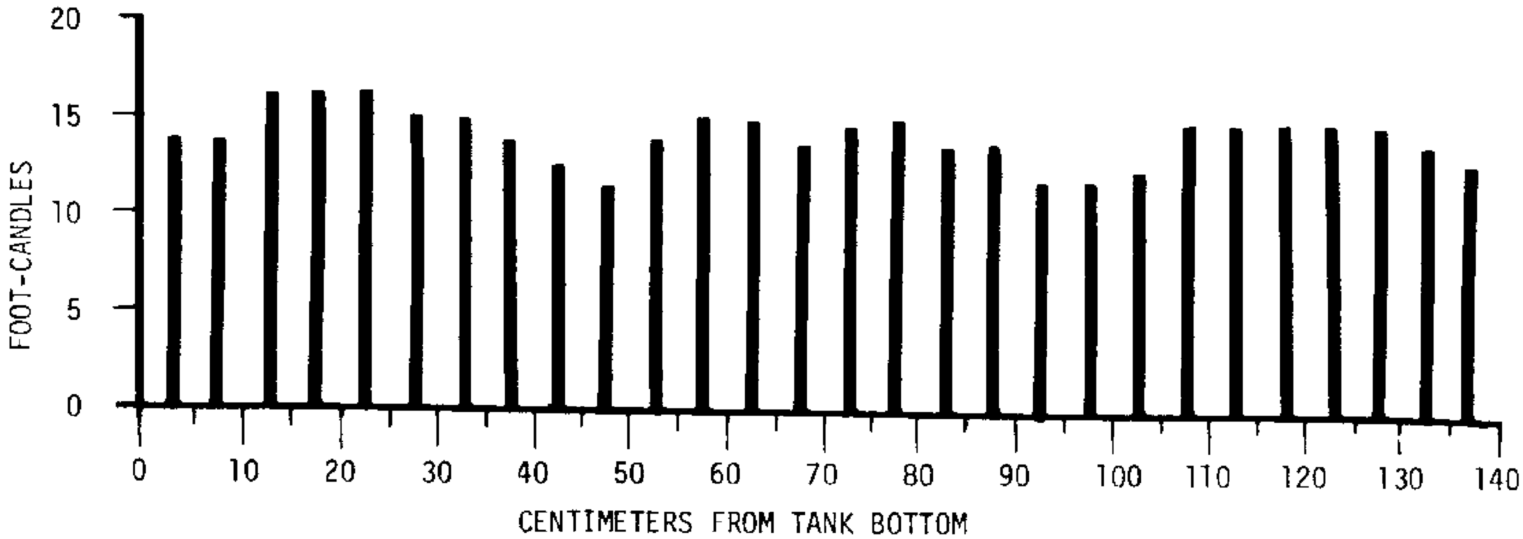

FIGURE 2.--Typical distribution of light transmitted through an experimental tank.

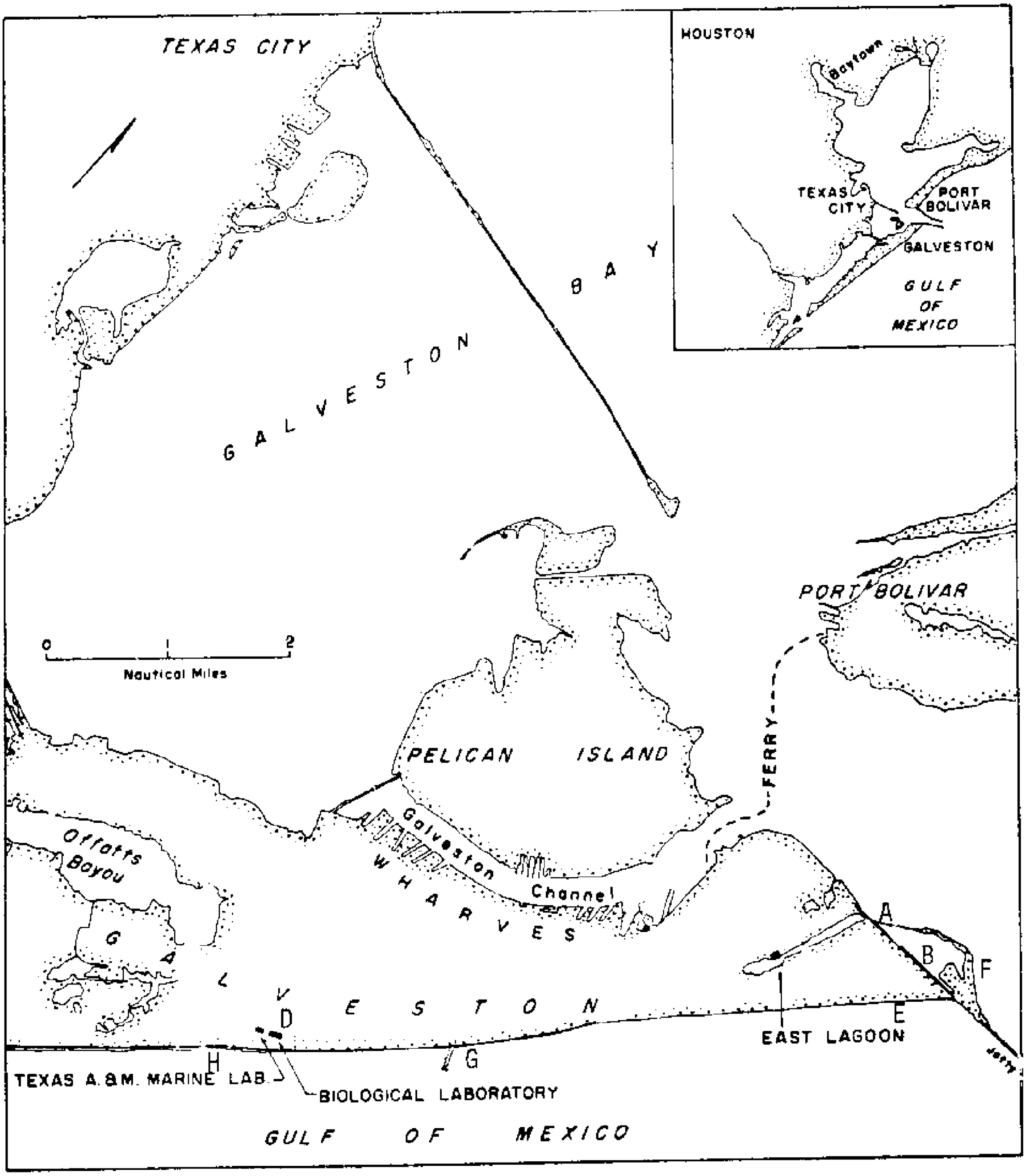

FIGURE 3.—Map showing the locations of the collecting stations. Letters indicate collection sites referred to in Table 1, p. 15. Tidal pond near 7-mile road (Site "C") located off map to the West.

TABLE 1.--Dates, sites, and field conditions for collections of postlarval shrimp tested in salinity gradient experiments

Experiment no.	Tank code	Shrimp species	Collection Conditions				
			Date	Time	Site*	Salinity (ppt)	Temperature (C)
1	A,B	*P. aztecus*	9/02/71	-	A	31	28
2	A,B	*P. setiferus*	9/14/71	-	A	27	27
3	A,B	*P. setiferus*	9/21/71	-	A/B	24	27
4	A,B	*P. setiferus*	9/21/71	-	A/B	28	27
5	Not run						
6	A,B	*P. setiferus*	11/16-17/71	-	C	29	22
7	A,B	*P. aztecus*	10/27/71	-	D	30	21
8	A,B	*P. aztecus*	2/25-26/72	-	B/E	25	17
9	A,B	*P. aztecus*	2/25-26/72	1000	B/E	25	17
10	A,B	*P. aztecus*	2/25-26/72	1000	B/E	25	17
11	Not run						
12	A,B	*P. aztecus*	3/13-14/72	1600	B	21	19
13	A,B	*P. aztecus*	4/02/72	1030	E	27	21
14	Not run						
15	A-D	*P. aztecus*	5/03/72	1030	E	23	26
16	A-D	*P. aztecus*	6/19/72	0800	E	22	28
17	A,B	*P. setiferus*	6/30/72	1000	E	34	30
17	C,D	*P. aztecus*	6/30/72	1000	E	34	30
18	A,B	*P. setiferus*	7/26/72	1115	E	24	30
18	C,D	*P. aztecus*	7/26/72	11-5	E	24	30
19	A-D	*P. aztecus*	8/24-25/72	1200	E	33	31
20	A-D	*P. aztecus*	8/24-25/72	1200	E	33	31
21	A,B	*P. aztecus*	8/24-25/72	1200	E	33	31
21	C,D	*P. aztecus*	9/08/72	1500	E	30	32
22	A-D	*P. setiferus*	9/14/72	-	F	24	29
23	A,B	*P. setiferus*	10/14/72	-	E	26	26
23	A,B	*P. aztecus*	10/14/72	-	E	26	24
24	A,B	*P. aztecus*	11/02/72	-	E	26	23
24	A,B	*P. setiferus*	11/02/72	-	E	26	23
25	A,B	*P. setiferus*	11/02/72	-	G	26	23
26	A-D	*P. setiferus*	10/14/72	1000	E	26	26
27	A-D	*P. aztecus*	11/18/72	-	D		
28	A-D	*P. aztecus*	11/18/72	-	D		
29	A-D	*P. aztecus*	11/18/72	-	D		
30	A-D	*P. aztecus*	3/03/73	1030	G	23	15
31	A-D	*P. aztecus*	3/17/73	1500	E	26	20
32	A,B	*P. aztecus*	3/17/73	1500	E	26	20
32	C,D	*P. aztecus*	3/03/73	1030	G	23	15
33	A-D	*P. aztecus*	4/01/73	1100	E	12	22
34	A,B	*P. aztecus*	5/08-09/73	1030	E	13	25

TABLE 1.--(continued)

Experiment no.	Tank code	Shrimp species	Collection Conditions: Date	Time	Site*	Salinity (ppt)	Temperature (C)
34	C,D	*P. setiferus*	5/08-09/73	1030	E	13	25
35	A-D	*P. aztecus*	5/18/73	0830	E	21	24
36	A-D	*P. aztecus*	5/25/73	1400	E	30	27
37	A,C	*P. setiferus*	5/27/73	-	E	27	27
37	B,D	*P. aztecus*	5/27/73	-	E	27	27
38	A-D	*P. aztecus*	5/28/73	-	D	30	25
39	A,B	*P. setiferus*	5/27/73	-	E	27	27
40	A-D	*P. aztecus*	5/28/73	-	D	30	25
41	A-D	*P. setiferus*	6/26/73	1245	E	12	30
42	A,C	*P. aztecus*	7/01/73	1030	E	27	20
42	B,D	*P. setiferus*	7/01/73	1030	E	27	20
43	A,B	*P. aztecus*	7/15/73	0830	E	33	28
43	C,D	*P. setiferus*	7/15/73	0830	E	33	28
44	A-D	*P. aztecus*	7/15/73	0830	E	33	28
45	A-D	*P. aztecus*	7/15/73	0830	E	33	28

*A - Entrance to East Lagoon
B - Tidal Slough, South Jetty
C - Tidal Pond near 7-mile road
D - NMFS Hatchery
E - Front Beach, South Jetty
F - Bolivar Roads Pass
G - Front Beach, 30th Street
H - Front Beach, 61st Street

the acclimation salinity varied depending on the salinity at collection and experimental design (Table 2). It was also necessary to distinguish the two species of *Penaeus* postlarvae. Size was one of several criteria used as brown shrimp were generally 3 to 4 mm longer than white shrimp postlarvae. The other criteria utilized were slight differences in body proportions between species. Initially, identification was confirmed by killing a sample of brown and white shrimp separated visually, and examining them microscopically for the presence or absence of dorsal carinal spines according to Zamora and Trent (1968). As less than 1% of the shrimp were found to be misidentified using the visual method, microscopic confirmation was discontinued after experiment 6. At the end of an experiment, the shrimp were identified to species using the method of Zamora and Trent. At that time they were measured to the nearest millimeter from the tip of the rostrum to the tip of the telson (total length).

Animals were held in the laboratory for 3 to 9 days. The reasons for holding the postlarvae were to allow time for acclimation to the artificial seawater medium and to salinities or temperatures different from those in the field, and to select only the hardiest individuals for testing; mortality caused by handling or other stress would occur during holding rather than during experimentation. The varying length of pre-experimental acclimation was the result of several factors. One of these was the availability of postlarvae. Postlarval distribution in the field is characterized by its irregularity. One day a 5-min tow might yield 1000 postlarvae

TABLE 2.--General features of experimental design

Experiment no.	Tank code	Shrimp species	Mean Total Length (mm) ± 1 std. dev.	Holding Conditions: Duration (days)	Holding Conditions: Salinity (ppt)	Holding Conditions: Temperature (C)	Experimental: Purpose*	Experimental: Initial date	Experimental: Duration (hr)	Experimental: Control tank salinity (ppt)	Experimental: Temperature (C)	Experimental: Light Regime**
1	A,B	*P. aztecus*	-	3	33	23	R	9/02/71	26.0	33	24	C
2	A,B	*P. setiferus*	-	3	33	23	R	9/17/71	26.0	33	24	C
3	A,B	*P. setiferus*	8.0 ± 0.4	4	33	23	SP	9/25/71	27.0	33	24	C
4	A,B	*P. setiferus*	12.3 ± 1.6	12	33	25	AS	10/03/71	26.0	33	25	C
5	Not run											
6	A,B	*P. setiferus*	7.5 ± 1.3	2-3	33	23	SP	11/19/71	68.8	33	23	C
7	A,B	*P. aztecus*	20.0 ± 2.4	53	33	24	SP	12/20/71	24.5	33	25	C
8	A,B	*P. aztecus*	13.4 ± 1.1	8-9	33	30	T	3/03/72	24.5	33	31	C
9	A,B	*P. aztecus*	15.0 ± 2.2	10-11	33	23	SP,T	3/05/72	25.5	33	23	C
10	A,B	*P. aztecus*	12.3 ± 0.9	12-13	33	18	T	3/07/72	26.0	33	19	C
11	Not run											
12	A,B	*P. aztecus*	11.8 ± 1.0	6-7	33	24	SP,T	3/20/72	30.5	33	25↑30↓19	C
13	A,B	*P. aztecus*	12.3 ± 1.3	4	33	19	SP,T	4/06/72	49.5	33	18↑24	C
14	Not run											
15	A-D	*P. aztecus*	12.4 ± 0.9	4	33	24	R,S,P,T	5/07/72	80.8	33	23↑30↓24	C
16	A-D	*P. aztecus*	11.8 ± 1.0	4	33	22	R,S,P,T	6/23/72	94.3	33	22↑30↓21	C
17	A,B	*P. setiferus*	6.6 ± 0.7	3	34	23	SP,T	7/03/72	87.3	33	23↑31↓24	C
17	C,D	*P. aztecus*	10.9 ± 0.9	3	34	23	SP,T	7/03/72	87.3	33	23↑31↓23	C
18	A,B	*P. setiferus*	7.5 ± 1.3	5	33	24	SP,T	7/31/72	57.2	33	23↑30↓23	C
18	C,D	*P. aztecus*	11.1 ± 0.8	5	33	24	SP,T	7/31/72	56.3	33	23↑30↓23	C
19	A-D	*P. aztecus*	10.7 ± 1.0	5-6	33	22	AS,R,SP,T	8/30/72	106.2	33	21↑30↓21	C
20	A-D	*P. aztecus*	11.6 ± 1.1	10-11	33	22	AS,R,T	8/30/72	72.9	33	21↑31↓22	C
21	A,B	*P. aztecus*	13.4 ± 1.6	18-19	33	22	AS,T	9/13/72	65.6	33	21↑31↓21	C
21	C,D	*P. aztecus*	10.8 ± 0.8	5	33	22	SP,T	9/13/72	44.2	33	24↑31↓21	C
22	A,B	*P. setiferus*	7.8 ± 0.7	6	30	24	SA,SP	9/20/72	58.3	30	25	C
22	C,D	*P. setiferus*	7.7 ± 0.9	5	15	24	SA,SP	9/20/72	58.6	15	25	C
23	A,B	*P. setiferus*	8.0 ± 0.9	9	33	22	AS,SP,T	10/23/72	64.5	33	23↑32↓23	C
23	C,D	*P. aztecus*	12.5 ± 1.2	9	33	22	SP,T	10/23/72	64.5	33	22↑32↓23	C
24	A,B	*P. aztecus*	12.0 ± 1.2	4	33	23	SP	11/06/72	66.0	33	23	C
24	A,B	*P. setiferus*	9.0 ± 1.5	4	33	23	SP	11/06/72	66.0	33	23	C
25	A,B	*P. setiferus*	9.0 ± 0.6	8	33	23	AS,SP	11/10/72	72.7	33	23	C
26	A,B	*P. setiferus*	22.8 ± 3.0	61	33	22	AS,SP	12/14/72	27.5	33	20	C
26	C,D	*P. setiferus*	15.6 ± 2.1	61	33	22	AS,SP	12/14/72	97.8	32	22	C
27	A,B	*P. aztecus*	12.0 ± 1.5	35	33	22	AS	12/23/72	44.7	32	24	C
27	C,D	*P. aztecus*	7.6 ± 0.7	35	33	22	AS	12/23/72	44.8	33	23	C

TABLE 2.--(continued)

Exper-iment no.	Tank code	Shrimp species	Mean Total Length (mm) ± 1 std.dev.	Holding Conditions: Dura-tion (days)	Holding Conditions: Salin-ity (ppt)	Holding Conditions: Tempera-ture (C)	Experimental: Purpose*	Experimental: Initial date	Experimental: Dura-tion (hr)	Experimental: Control tank salinity (ppt)	Experimental: Tempera-ture (C)	Experimental: Light Regime**
28	A,B	*P. aztecus*	13.1 ± 1.7	42	33	22	AS	12/30/72	98.8	33	24	C
28	C,D	*P. aztecus*	9.8 ± 0.9	42	33	22	AS	12/30/72	98.3	33	24	C
29	A,B	*P. aztecus*	18.2 ± 3.2	56	33	23	AS	1/13/73	63.3	33	24	C
29	C,D	*P. aztecus*	18.5 ± 3.0	56	33	23	AS	1/13/73	64.4	33	24	C
30	A,B	*P. aztecus*	12.2 ± 0.6	5	32	23	SA,SP,T	3/08/73	111.9	32	24→14→23	C
30	C,D	*P. aztecus*	12.5 ± 0.8	5	24	23	SA	3/08/73	113.3	24	22	C
31	A-D	*P. aztecus*	13.3 ± 0.9	4	26	23	AS,R,SP	3/21/73	50.7	26	23	C
32	A,B	*P. aztecus*	15.4 ± 1.3	19	26	23	AS	4/03/73	40.9	26	23	C
32	C,D	*P. aztecus*	18.1 ± 1.5	31	24	23	AS	4/03/73	39.9	32	23	C
33	A	*P. aztecus*	16.0 ± 1.3	8	24	30	SA,T	4/09/73	37.5	-	30	C
33	B	*P. aztecus*	15.8 ± 1.4	8	12	30	SA,T	4/09/73	37.5	-	30	C
33	C	*P. aztecus*	14.1 ± 1.0	8	24	23	SA,SP,T	4/09/73	37.1	-	23	C
33	D	*P. aztecus*	14.2 ± 1.0	8	12	23	SA,T	4/09/73	37.1	-	23	C
34	A,B	*P. aztecus*	11.7 ± 0.8	3-4	24	23	SP	5/11/73	28.8	14	24	C
34	C,D	*P. setiferus*	7.2 ± 0.5	3-4	24	23	SP	5/11/73	40.1	14	24	C
35	A	*P. aztecus*	11.9 ± 0.9	5	30	24	SA	5/23/73	118.2	-	24→32→23	C
35	B	*P. aztecus*	11.5 ± 1.1	5	20	24	SA,SP	5/23/73	118.2	-	24→31→23	C
35	C	*P. aztecus*	11.9 ± 0.9	5	30	24	SA	5/23/73	118.8	-	24	C
35	D	*P. aztecus*	11.5 ± 1.1	5	20	24	SA	5/23/73	118.8	-	24	C
36	A-D	*P. aztecus*	11.0 ± 0.8	4	30	24	R,SP	5/29/73	33.0	-	23	C
37	A	*P. setiferus*	7.6 ± 0.6	4	30	24	L,SP	5/31/73	69.9	-	24	I
37	B	*P. aztecus*	11.9 ± 0.9	4	30	24	L,SP	5/31/73	69.9	-	24	I
37	C	*P. setiferus*	7.6 ± 0.6	4	30	24	L,SP	5/31/73	26.7	30	24	I
37	D	*P. aztecus*	11.9 ± 0.9	4	30	24	L,SP	5/31/73	26.7	30	24	I
38	A-D	*P. aztecus*		4	30	25	AS	6/01/73		30	25	C
39	A	*P. setiferus*	10.1 ± 1.1	22	30	24	AS	6/18/73	45.0	-	25	C
39	B	*P. setiferus*	10.1 ± 1.1	22	30	24	AS	6/15/73	88.4	-	24	C
40	A-D	*P. aztecus*		25	30	25	AS	6/22/73		30	25	C
41	A,B	*P. setiferus*	7.5 ± 0.6	5	30	23	SA,SP	7/01/73	64.0	-	23	C

TABLE 2.--(continued)

Experiment no.	Tank code	Shrimp species	Mean Total Length (mm) ± 1 std. dev.	Holding Conditions: Duration (days)	Holding Conditions: Salinity (ppt)	Holding Conditions: Temperature (C)	Experimental: Purpose*	Experimental: Initial date	Experimental: Duration (hr)	Experimental: Control tank salinity (ppt)	Experimental: Temperature (C)	Experimental: Light Regime**
41	C,D	*P. setiferus*	7.5 ± 0.6	5	12	23	SA	7/01/73	63.4	12	23	C
42	A	*P. aztecus*	10.9 ± 0.7	8	30	23	L,SP	7/09/73	63.7	-	23	I
42	B	*P. setiferus*	7.3 ± 0.6	8	30	23	L,SP	7/09/73	63.7	-	23	I
42	C	*P. aztecus*	10.9 ± 0.7	8	30	23	L,SP	7/09/73	64.1	-	23	C
42	D	*P. setiferus*	7.3 ± 0.6	8	30	23	L,SP	7/09/73	64.1	-	23	C
43	A,B	*P. aztecus*	9.3 ± 0.6	4	33	26	AS,SA,SP	7/19/73	86.1	33	26	C
43	C,D	*P. setiferus*	7.5 ± 0.7	4	33	26	AS,SA,SP	7/19/73	85.9	33	26	C
44	A,B	*P. aztecus*	9.7 ± 0.6	11	33	15	T	7/26/73	49.0	33	16	C
44	C,D	*P. aztecus*	10.8 ± 1.3	11	33	23	AS,T	7/26/73	48.7	33	23	C
45	A,B	*P. aztecus*	12.6 ± 1.1	25	26	22	AS,SA	8/09/73	41.9	26	22	C
45	C,D	*P. aztecus*	12.2 ± 1.0	25	12	22	AS,SA	8/09/73	42.2	12	21	C

*AS - influence of age and size
L - influence of lighting
R - replicate experiment
SA - influence of salinity acclimation
SP - species comparison
T - influence of temperature

**C - continuous low-level red illumination
I - intermittent low-level red illumination

while on another day, collecting for 3 hr might yield only 10. Thus, to obtain sufficient numbers of postlarvae, it was often necessary to begin collecting for an experiment while another was in progress. If the postlarvae were all collected during the first day of an on-going experiment, they would necessarily be held for 4 to 5 days; however, if they were caught during the third day, they would probably be held for only 3 days. Another factor was the length of time required to drain the tanks from one experiment and refill them for the next. This procedure required a minimum of 1 day. Preparing the Instant Ocean is a 3-day process; 1 day for mixing and stirring; 1 day for settling and decanting to remove flocculant precipitate, and 1 day for aeration of stock solutions. Two experiments were delayed by a breakdown in the distilled water system. Although standardizing the holding time is desirable, it is often unfeasible in practice.

Gradient Preparation

Three stock solutions were used in each experiment. Two of these--the most saline water to be tested and the water to which the experimental animals had been acclimated--were prepared using distilled water and Instant Ocean; the third stock solution was distilled water. All were aerated for at least 24 hours before use to assure oxygen saturation. The most saline stock solution (50 or 70 ppt) and distilled water were used as the extremes in the gradient tank and were mixed to provide intermediate salinities. The control tank was filled with the acclimation solution. This tank was used to test the response of the animals to water pressure or other possible cues associated with the experimental apparatus. The experimental tank was identical to the control tank, except that it contained a salinity gradient ranging from the bottom to the top (70 to 0 ppt or 50 to 0 ppt). To construct a salinity gradient ranging from 70 to 0 ppt, the gradient tank was first filled to the 40 cm line with 70 ppt solution. The remaining solutions--63, 56, 49, 42, 35, 28, 21, 14, 7 and 0 ppt--were siphoned in that order into the tank using 4 mm i.d. plastic aquarium tubing. Each solution occupied a 10 cm (2.7 l) region of the tank. As each less dense solution was added, the flow rate was adjusted using a pinch clamp to confine mixing to the top 5 cm of the preceeding compartment. The mixing process was clearly visible with the back-lighted illumination of the apparatus. When filled to a level of 140 cm, each tank held 38 l. Constructing the broader salinity gradient of 50 to 0 ppt required a similar procedure. The first 30 cm was filled with 50 ppt solution, the 42, 35, 28, 21, 14, 7 and 0 ppt solutions were then siphoned in that order into the tank as above. All except the 0 ppt solution occupied a 15 cm segment of the tank; the 0 ppt solution filled the top 20 cm of the tank. Filling of the gradient and control tanks required approximately 6 hours. Most discontinuities were eliminated by gently stirring the column with a 3.6 m section of 2.1 cm o.d. PVC pipe fitted at one end with a #13 stopper.

Gradient Measurement and Adjustment

The gradient was then measured using a 3.6 m long siphon fashioned of 30 cm pieces of 3 mm i.d. rigid plastic and glass tubing joined by short sections of flexible aquarium tubing. Glass tubing was used at the lower end to provide weight, which facilitated introducing the siphon into the tank. Beginning at 20 cm from the tank bottom, salinity was measured with a precision of $\pm$ 0.5 ppt using a Goldberg refractometer (American Optical Co., Rochester, N.Y.) at 10 cm intervals. When each desired level was reached, a 70 ml sample was drawn through the siphon to flush out water from the previous depth (the volume of the siphon was less than 60 ml). The salinity of the new depth was then measured. The volume of water withdrawn during measurement (840 ml) was replaced at the surface by slowly siphoning in an equal amount of distilled water. After the tank was refilled to the 140 cm level, a surface sample was taken with an eyedropper. At the termination of the experiment, this procedure was repeated, beginning at 140 cm and ending at 20 cm.

During measurement of the gradient, a graph was made of salinity and depth. This relationship was usually quite linear. If salinity discontinuities caused the slope of this line to deviate from linearity, the gradient was adjusted by remixing the levels in question. This was accomplished by slowly pushing the 3.6 m rod, described above, to the level of the discontinuity. The discontinuity was "smoothed over" by a series of 15 cm to 30 cm long thrusts. The gradient was then remeasured beginning 10 cm below the adjusted region.

Temperature Regulation

The apparatus was housed in several temperature-controlled rooms which provided a combined temperature range of 12 to 40 C. Although the rooms were temperature controlled, there were differences in air temperature from the floor to the ceiling. The experimental tanks rested at an angle of 25° which placed the top of the tanks 1.5 to 1.8 m higher off the floor than the bottom. Consequently, temperature was measured at various levels in the water column to determine whether temperature gradients were present that might influence the distribution of shrimp in control and gradient tanks. In order to measure temperatures at various depths, thermometers were suspended in the water column and the indicated temperature read through the Plexiglas sides of the tank. Only slight differences in water temperature occurred between top and bottom levels of the same tank and between tanks at corresponding levels. Generally, these differences did not exceed 1 C. In several experiments, temperatures were raised or lowered to test the response of postlarvae to salinity over a range of temperatures. The length of time for tanks to reach a new equilibrium was determined to be 9 to 12 hours for tanks at 23 C raised to 30 C, and 15 to 20 hours for tanks at 30 C lowered to 23 C. After the equilibrium time was determined and vertical temperature gradients were found to be minimal, I measured water temperature only in the top 10 cm of the water column.

Introduction of Postlarvae Into Experimental Tanks

A releasing device (Fig. 4) was designed to avoid exposing the postlarvae to great salinity changes while introducing them into the tanks. It consisted of an outside cylinder (5.0 cm i.d. x 11.2 cm long) connected by a rubber stopper to Plexiglas tubing 1.6 m long and with 9 mm i.d. A Plexiglass rod 1.8 m long and 6 mm in diameter passed through the rigid tubing. To this rod were glued, 7 cm apart, a rubber stopper and a polyethylene-Plexiglas disc. Together they formed the releasing chamber. Pushing on the rod while holding the sleeve tubing opened the chamber; pulling the rod closed it. To load the releaser with animals it was inverted and opened approximately 2.5 cm. The postlarvae in about 75 cc of holding water were poured into the releaser. The chamber was then filled with more of the same water, closed, and lowered slowly, to avoid disturbing the gradient, into the tank to a depth corresponding to the salinity of the holding tank water. This depth was easily calculated from the salinity/depth graph. When the desired depth was reached, the chamber was opened, and the inside disc moved forward pushing the animals out. The releaser was closed and removed from the tank, withdrawing water of the same salinity and volume as was introduced with the animals. This procedure did not disturb the salinity

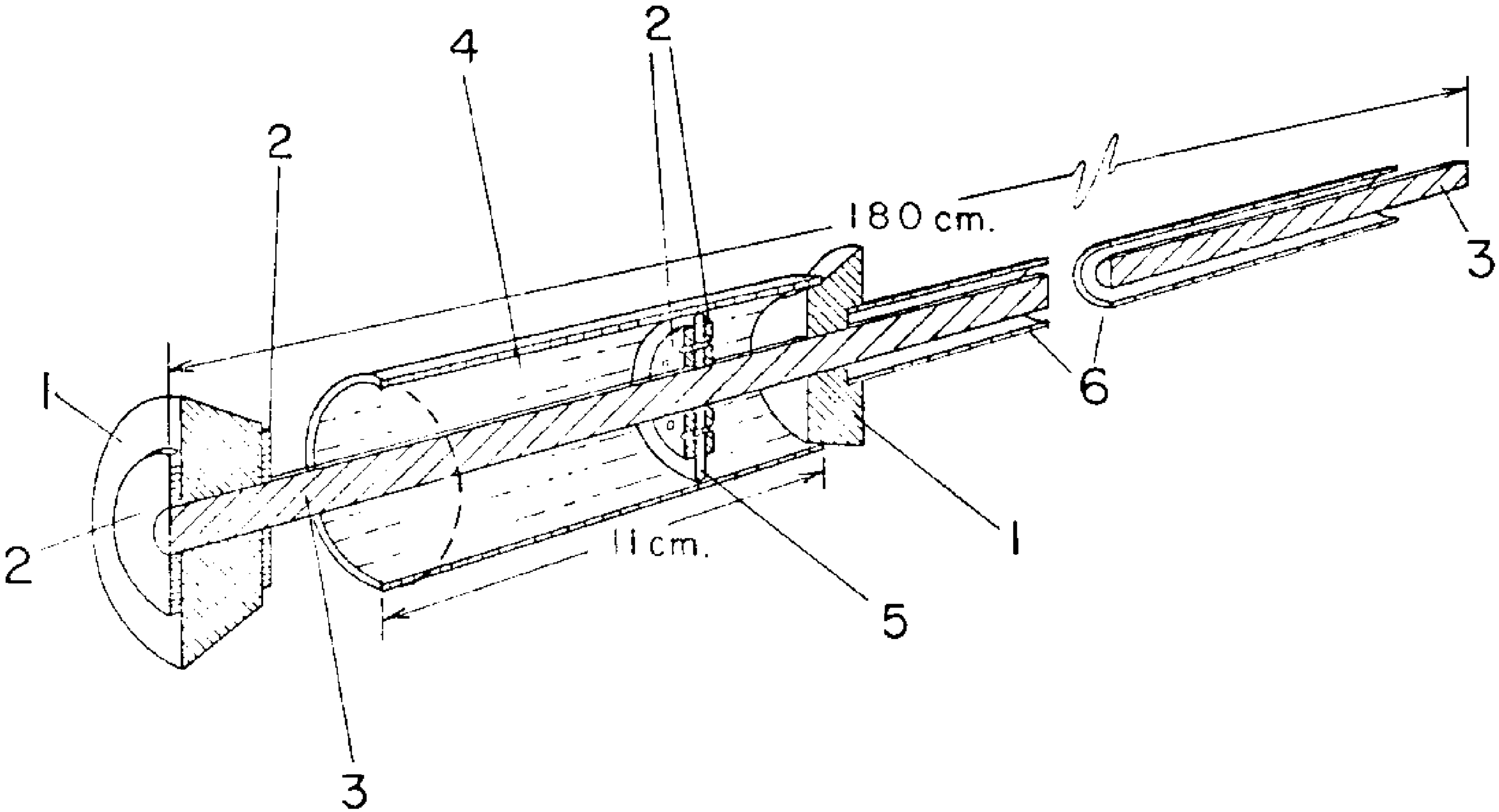

FIGURE 4.--Releasing device used to introduce animals into tanks. (1) no. 10 rubber stopper, (2) Plexiglas disc 4.0 x 0.6 cm, (3) Plexiglas rod 180 x 0.6 cm, (4) Plexiglas chamber 11.0 x 4.7 cm i.d., (5) polyethylene disc 4.7 x 0.3 cm, (6) Plexiglas tube 160 x 0.9 cm i.d.

gradient. Animals were similarly released in the control tank at the same depth as in the gradient tank.

Observation Procedure

In the preliminary experiments, the postlarvae were counted once hourly for 24 hours beginning 2 hours after introduction into the experimental tanks. I modified this procedure after experiment 6. From that time on, shrimp were counted every 6 hours for 5 to 7 times at 5-or 10-min intervals. This procedure was less fatiguing and obtained approximately the same amount of information--i.e., the total number of shrimp counted during an experiment remained the same. Both methods had their advantages and their disadvantages. The former method gave an hourly record of shrimp distributions throughout a 24-hr period while the latter method gave detailed information on shrimp movements within a narrower time frame, but little insight into shrimp movements in the 5-hr interval between observation periods.

For each experiment, an equal number of shrimp was counted out for introduction into the control and experimental tanks; however, there were differences in the total number of shrimp actually observed, these resulted primarily from counting errors. The small size of the postlarvae made them difficult to locate. At times, the postlarvae were resting permitting accurate counting. However, at other times, they were extremely active with as many as 10 to 14 swimming rapidly within a 5 cm region, making it impossible to count them accurately. Also, loading the shrimp into the releaser occasionally resulted in the loss of individuals. Very small shrimp (7 mm or less) had a tendency to get sucked behind the releasing chamber of the introducer during loading. When the shrimp were very active, occasionally some would jump out as they were transferred from the holding beaker to the releaser. In addition, some shrimp died during the experiment. The number of dead shrimp observed was recorded. Dead shrimp were not removed as this would have risked disturbing the experimental animals and the salinity gradient. Mortality was caused by injury during introduction, long-term exposure to lethal salinities, or starvation (long-term experiments only). All of the above factors explain why identical counts were usually not obtained in two tanks intended to contain equal numbers of postlarvae.

Duration of the Experiments

The duration of the salinity preference experiments was from 25.5 to 118.8 hr (Table 2, p. 18-20). The gradients were very stable throughout this time period. In general, at the termination of the experiment, only occasional salinities deviated as much as 3 ppt from initial values and most levels had changed 1 ppt or less. The least stable portion of the gradient was near the top of the column. The water in this region was of lower salinity and hence, was less viscous than the water near the bottom. This was the region most likely to change when larger (>15 mm), more active postlarvae were used.

Dissolved oxygen values at three different levels of control and experimental tanks were determined at the end of 48 hours. The

Modified Winkler Method (Amer. Public Health Assoc. 1971) was used to determine oxygen values. Oxygen values were approximately the same at all levels within control tanks (Table 3). The tank at 15 C had higher oxygen values than the one at 23.6 C as a result of the increased solubility of oxygen in water at lower temperatures. In the salinity gradient tanks, there was less oxygen at 0 cm than at 140 cm due to decreased oxygen solubilities with increasing salinities (Sverdrup, Johnson, and Fleming 1942). The lower oxygen concentration at 85 cm compared to those at 0 and 130 cm in the 23.6 C gradient tank was the result of a concentration of postlarvae between 80 and 90 cm. This pattern of oxygen distribution did not develop in the tank at 15.6 C where the animals were less active than those at 23.6 C. None of the oxygen levels found was believed low enough to influence the shrimp's salinity preference.

For the maximum time tested (118.8 hr), the salinity gradient was stable; we believe, however, that 48 hr should probably be the upper time limit for testing postlarval shrimp in this type of salinity gradient apparatus. The animals were not fed after introduction into the tank so that their condition probably decreased rapidly. In addition to mortality resulting from starvation, the bottom region of the tank was occasionally fouled by shrimp that succumbed to the trauma of introduction and shrimp which became disoriented, and consequently died, in regions of lethal salinities. Animal condition and water quality were more limiting than gradient stability in determining the maximum time an experiment could be conducted.

TABLE 3.--Shrimp distribution 49 hr after introduction and dissolved oxygen (ppm) at three levels in four tanks of experiment 44. Fifty shrimp were introduced into each tank.

Tank	Level of measurement (cm from tank bottom)	Temperature (C)	Oxygen (ppm)	Mean number of shrimp observed within $\pm$ 5 cm of level of oxygen measurement
A	0		4.24	0
(Gradient)	85		5.00	11
	130	15.6	7.40	0
B	0		6.08	7
(Control)	85		6.00	2
	130	15.6	6.01	3
C	0		4.60	0
(Gradient)	85		3.32	11
	130	23.6	6.48	1
D	0		4.96	5
(Control)	85		5.24	2
	130	23.6	5.40	4

Statistical Treatment of Data

Shrimp were not normally distributed in either the gradient or control tanks. To permit comparison of experimental results between and within experiments, the 5th, 25th, 50th (median), 75th, and 95th percentiles (P5, P25, P50, P75, and P95, respectively) were computed in centimeters; for the gradient tanks, these percentiles were converted to salinity. Avoidance levels were defined by P5 and P95 as they each represented boundaries crossed by 5% of the shrimp during an observation period. The percentiles were plotted for each observation period to facilitate visual comparison of shrimp distributions. To compare the distribution of shrimp in control and gradient tanks, summary histograms were prepared for approximately the first 24 hours of observations. These graphs are arranged by experiment in Appendix A (Figs. 1-100). Several experiments were designed to investigate the salinity preference of shrimp at different temperatures. For those experiments in which temperature changes occurred within the first 27 hours of the experiment, the histograms represent only those observations made at the initial temperature range.

The data consisted of successive observations made on the same animals over a period of time. Some experiments lasted for 119 hr, but only the first 21 to 27 hr of observations were used in the statistical analysis. Shrimp were counted five times during this 21 to 27 hr period. Time 1 started 1.5 to 4.0 hr after the shrimp were introduced and Time 5 began between 22.9 and 27.0 hr following introduction of shrimp. To investigate the possible influence of diel rhythms on shrimp distribution, these five time intervals were coded into "day" and "night" according to the Sunrise and Sunset Tables (U.S. Coast and Geodetic Survey 1970a; U.S. National Ocean Survey 1971a, 1972a).

Preliminary analysis of the data suggested seasonal differences in salinity preference of brown shrimp. In some experiments, shifts in shrimp distribution also occurred with time. Split-plot analysis of variance (Steel and Torrie 1960) was used to determine statistically the significance of these trends in both brown and white shrimp. The split-plot design enabled the testing of significance of shifts with time as well as overall seasonal differences. The five percentiles, interquartile range ($|P75-P25|$) and the "overall" range ($|P95-P5|$) were considered as observations for seven separate analyses. The data were also unbalanced in the sense that the same number of experiments were not run in each season. The regression procedure program (PROC REGR) of the Statistical Analysis System (Barr and Goodnight 1972) compensated for the above factor and occasional missing observations. The correct error terms were derived from the output according to Dr. Charles E. Gates, Institute of Statistics, Texas A&M University (personal communication).

A total of 28 gradient experiments (17 with brown shrimp and 11 with white shrimp) and 23 control experiments (13 with brown shrimp and 10 with white shrimp) were analyzed by the above procedure. There are several reasons why there were fewer "controls" than "gradients". In some experiments, all four tanks contained salinity gradients. In one instance, the experiment was designed to test for similarity in postlarval response to salinity gradients in all four tanks. Other experiments also consisted only of gradient tanks; in these, animals in one gradient tank had been held at standard testing conditions: 23 C, 30 to 33 ppt, while shrimp in the other gradient tanks had been acclimated to different salinities and temperatures. In these experiments, the shrimp in the gradient tank tested under the "standard conditions" defined above served as "controls".

Many experiments tested brown and white postlarvae at the same time or tested the influence of different acclimation conditions on postlarval distributions in gradient tanks. Since this procedure resulted in not all experimental tanks being replicated, a replicate term was not included in the statistical model described above. Data from the replicate experiments are analyzed in the following section.

The distributions of white and brown shrimp that had been collected together were compared statistically. The distributions were characterized by the average values of the five percentiles, interquartile range ($|P75-P25|$) and overall range ($|P95-P5|$). These values were compared using the sign test (Steel and Torrie 1960) to determine if one species consistently chose higher or lower salinities than the other. Similar analyses could not be performed on the control distribution data as there was an insufficient number of control tank distributions.

The variances of the five percentiles, interquartile and overall ranges of brown and white shrimp distributions were compared using the test of homogeneity of variance (Steel and Torrie 1960) to determine if one species responded more variably in the gradient and control tanks.

Replication

In several experiments, the variation in response exhibited by shrimp collected at the same time and held under the same acclimation conditions was examined. Initially, both experimental tanks were used as controls to test the similarity in response of brown and white shrimp (experiments 1 and 2). Acquisition of an additional pair of experimental tanks made it possible to test for similarity in response in both gradient and control tanks when sufficient numbers of postlarvae were available (experiments 15, 16, 19, and 20). In experiment 31, two groups of shrimp were tested in salinity gradients ranging from 0 to 70 ppt (tanks A & C) and one group in a gradient ranging from 0 to 50 ppt (tank B). The other tank was used as a control (tank D). In experiment 35, all tanks contained salinity gradients; two tested salinity response of shrimp acclimated to 20 ppt while the others tested salinity response of postlarvae acclimated to 30 ppt. In experiment 36, shrimp acclimated to 30 ppt were tested in four salinity gradients ranging from 0 to 70 ppt.

The shrimp tested in the control tanks had similar distributions (experiments 1, 2, 15, 16, 19, 20, and 31; Appendix A, Figs. 1, 2, 19-21, 22-24, 31-33, 34-36, 61-63, respectively, p. 115, 115, 137-

141, 142-146, 155-159, 160-162, 193-195). The shrimp in 5 of the 7 replicate gradient studies (experiments 15, 16, 20, 31, half of experiment 35: tanks B & D) had very similar distributions. The shrimp tested in experiment 31 (Appendix A, Fig. 61-63, p. 193-195) which utilized two different salinity gradients confirmed that the shrimp were responding to salinity and not to depth; there was virtually no difference in response to salinity between shrimp tested in the 0 to 50 ppt gradient and those tested in the 0 to 70 ppt gradients. In three experiments (19, 35: tanks A & C, and 36), there was poor replication. Through an oversight, the tanks in experiment 19 (Appendix A, Figs. 31-33, p. 155-159) were not cleaned before use, and the shrimp may have been responding to the presence of a thin and variable film of algae or bacteria on the four tank walls. After the tanks were cleaned, shrimp from the same holding tank as those tested in experiment 19 were used in experiment 20. There was good replication in both gradient (A & C) and control tanks (B & D) in this experiment suggesting that the presence of an algal or bacterial film did influence postlarval distributions in experiment 19. In experiment 35, the shrimp acclimated to 30 ppt did not respond similarly to salinity although other shrimp collected at the same time, but acclimated to 20 ppt, had similar distributions. I can offer no explanation for this difference in response between two groups of shrimp collected at the same time. The dissimilarity of distributions by shrimp in experiment 36 also cannot be explained.

The shrimp in four tanks all exhibited a similar cyclic pattern in their distribution (Appendix A, Fig. 74-75, p. 208-210); however, the shrimp in tank A exhibited a preference for higher salinities than did shrimp in tanks B, C, and D.

RESULTS

Distribution of Shrimp in Gradient and Control Tanks

The distribution of shrimp in the control and gradient tanks was strikingly different. In the control tanks, shrimp showed a tendency to congregate in the bottom and top regions of the tanks with generally more shrimp being present in the bottom 10 cm than at the top. In the other regions of the tanks, the shrimp were randomly distributed. In the gradient tanks, the use of salinity extremes (50 or 70 ppt at the bottom and 0 ppt at the top) resulted in markedly fewer shrimp being present at the tank ends than in the other regions of the tank. An examination of histograms of control and gradient tanks in all experiments (Appendix A) shows clearly that the animals responded differently to the two test situations. In experiments where two different salinity gradients (0 to 70 ppt and 0 to 50 ppt) were utilized, postlarvae sought similar salinities and not similar tank levels indicating that shrimp in the gradient tanks were responding to salinity.

Seasonal Trends in Experimental Shrimp Distributions

The average values of the five percentiles for 2 years of experimental data were plotted by month (Fig. 5). The graph suggests that the salinity preference of brown shrimp varies with the time of year. From March to early April, brown shrimp postlarval distributions

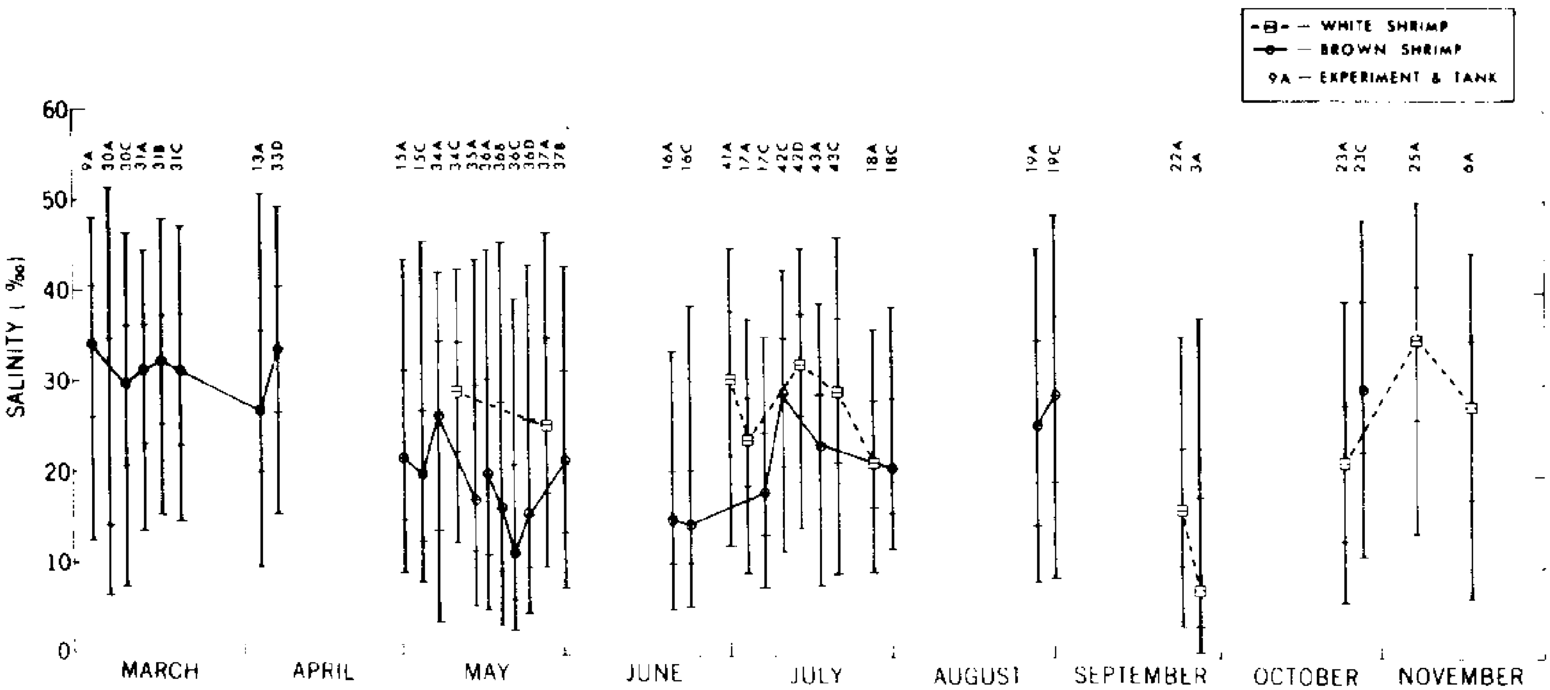

FIGURE 5.—Seasonal salinity preferences of brown and white postlarval shrimp (P. aztecus and P. setiferus). Vertical lines indicate distributions. Distributions are characterized by the average values, from top to bottom, of the 5th, 25th, 50th (median), 75th, and 95th percentiles. Lines connect medians.

showed a median salinity average of 29.9 ppt (Table 4). The distribution of those shrimp tested from May through July had a median salinity average of 20.6 ppt while the median salinity average for the remaining two groups of shrimp was 27.4 ppt. The temperature of the water at collection varied during the year ranging from 15 C in March to 22 C in April and continuing to rise from 24 C in May to 30 C in July. Water temperatures began to decrease at the end of August falling to 22 C in mid-November (Table 1, p. 15-16). Three seasons were arbitrarily defined--spring: March to early April; summer: May through July; and fall: end of August to November. Brown shrimp differed significantly in their seasonal response to salinity gradients at the 0.05 level for all percentiles with the 25th percentile and the median being significant at the 0.01 level (Table 5).

TABLE 4.--Average salinity value of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) of brown shrimp (*P. aztecus*) distributions in gradient tanks during spring, summer and fall

Season	Number of experiments	Salinity (ppt)						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}-P_{25}	P_{95}-P_5
Spring	6	49.1	38.1	29.9	21.9	11.4	16.2	37.7
Summer	9	41.4	28.9	20.6	13.9	7.2	15.0	34.2
Fall	2	47.3	36.0	27.4	19.2	10.0	16.8	37.3

White shrimp were collected and tested only during summer and fall. Except at low salinity extremes (P95), white shrimp did not

TABLE 5.--Split-plot analysis of variance for five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) of distributions of brown shrimp (*P. aztecus*) in gradient tanks during spring, summer and fall. "Time" consists of five observation periods during the first 24 hr of observations/experiment

Source	df	F-Statistics						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}-P_{25}	P_{95}-P_5
Season	2	5.09*	8.19**	7.13**	5.97*	4.50	0.30	0.64
Error a	14							
Time	4	0.45	0.19	0.53	4.27*	17.02**	2.30	1.71
Time x Season	8	0.16	2.56*	5.07**	4.48**	1.85	0.47	0.54
Error b	48							

*significant at 0.05 level
**significant at 0.01 level

exhibit seasonality in response (Table 6). In the fall, the average P95 for white shrimp was 5.8 ppt compared to 11.1 ppt in the summer (Table 7).

The data from the control tanks were analyzed in the same manner described for the gradient tanks. No seasonality was apparent in either the brown or white shrimp distributions (Tables 8 and 9). Average values of the percentiles and ranges are presented in Tables 10 and 11.

TABLE 6.--Split-plot analysis of variance for five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) of distributions of white shrimp (*P. setiferus*) in gradient tanks during summer and fall. "Time" consists of five observation periods during the first 24 hr of observations/experiment

Source	df	F-Statistics						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Season	1	0.88	2.16	2.17	3.78	5.83*	0.63	2.19
Error a	9							
Time	4	0.17	0.40	1.80	6.30**	7.43**	3.11	2.10
Time x Season	4	0.81	1.21	1.64	1.95	0.79	0.16	0.66
Error b	29							

*significant at 0.05 level
**significant at 0.01 level

TABLE 7.--Average salinity values of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) of white shrimp (*P. setiferus*) distributions in gradient tanks during summer and fall

Season	Number of experiments	Salinity (ppt)						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Summer	6	43.5	34.5	28.0	21.1	11.1	13.4	32.3
Fall	5	41.0	28.5	21.1	13.6	5.8	14.9	35.2

TABLE 8.--Split-plot analysis of variance for five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) of distributions of brown shrimp (*P. aztecus*) in control tanks during spring, summer and fall. "Time" consists of five observation periods during the first 24 hr of observations/experiment

Source	df	F-statistics						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}-P_{25}	P_{95}-P_5
Season	2	1.15	0.09	0.32	0.56	1.10	1.89	1.04
Error a	10							
Time	4	0.27	0.56	0.62	0.76	0.50	0.42	0.81
Season x Time	8	1.38	0.79	0.63	0.68	0.32	1.17	0.76
Error b	36							

*significant at 0.05 level

TABLE 9.--Split-plot analysis of variance for five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) of distributions of white shrimp (*P. setiferus*) in control tanks during summer and fall. "Time" consists of five observation periods during the first 24 hr of observations/experiment

Source	df	F-Statistics						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}-P_{25}	P_{95}-P_5
Season	1	2.00	0.65	0.00	0.85	1.34	4.91	2.87
Error a	8							
Time	4	0.55	0.49	0.16	0.25	0.76	0.29	0.51
Time x Season	4	0.84	1.64	2.20	3.03*	2.83*	1.50	2.02
Error b	27							

*significant at 0.05 level

TABLE 10.--Average centimeter values of the five percentiles, interquartile range (|P75-P25|), overall range (|P95-P5|) of brown shrimp (*P. aztecus*) distributions in control tanks during spring, summer and fall

Season	Number of experiments	Centimeters from tank bottom					Centimeters	
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}-P_{25}	P_{95}-P_5
Spring	5	4.1	26.0	58.7	98.6	132.8	72.7	128.7
Summer	6	5.2	26.7	64.3	105.3	135.0	78.5	129.8
Fall	2	3.5	21.3	56.0	102.0	135.0	80.7	131.5

TABLE 11.--Average centimeter values of five percentiles, interquartile range (|P75-P25|), overall range (|P95-P5|) of white shrimp (*P. setiferus*) distributions in control tanks during summer and fall

Season	Number of experiments	Centimeters from tank bottom					Centimeters	
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}-P_{25}	P_{95}-P_5
Summer	5	5.4	25.8	53.6	87.6	126.7	61.8	121.2
Fall	5	3.4	18.9	52.4	98.2	133.0	79.3	129.6

Variation in Shrimp Distributions within Experiments Related to Time

Temporal influence.--In some instances, shrimp exhibited a constant preference for salinity during an experiment, whereas at other times, obvious shifts in salinity preference occurred. The split-plot analysis of variance tested variation in shrimp response among the five observation periods (Times 1-5) made during the first day of observations. Shifts in brown shrimp distributions during the experiment were significant for the 75th and 95th percentiles and the interaction of Time x Season was significant for the 25th, 50th, and 75th percentiles (Table 5, p. 41). To aid in the interpretation of these results, the mean values of these percentiles for each observation period were plotted by season and for all seasons (Fig. 6). The seasonal graphs of the 25th percentile showed that preferred salinity tended to increase in the spring as the experiment proceeded, decrease in the summer, and remain fairly constant in the fall. An examination of the median, plotted by season, showed that in the spring, there was a trend for the shrimp to seek higher salinities after the second observation period. This contrasts with the response of shrimp tested in the summer which sought progressively lower salinities as the experiment proceeded. The medians calculated for experiments conducted in the fall (experiment 19, tank A; experiment 23, tank A) were approximately the same for all observation periods. The graph of the 75th and 95th percentiles averaged over all seasons (Fig. 6, p. 46) showed that both percentiles tended to decrease during experiments. The 75th percentile also differed significantly by season. Shrimp in the spring evidenced a variable response to salinity at the 75th percentile while those tested in the summer tended to move into less saline water as the experiment proceeded. Shrimp in the fall also tended to move into less saline water until the fifth observation period when they again moved into higher salinities. The interaction of Time x Season was not significant

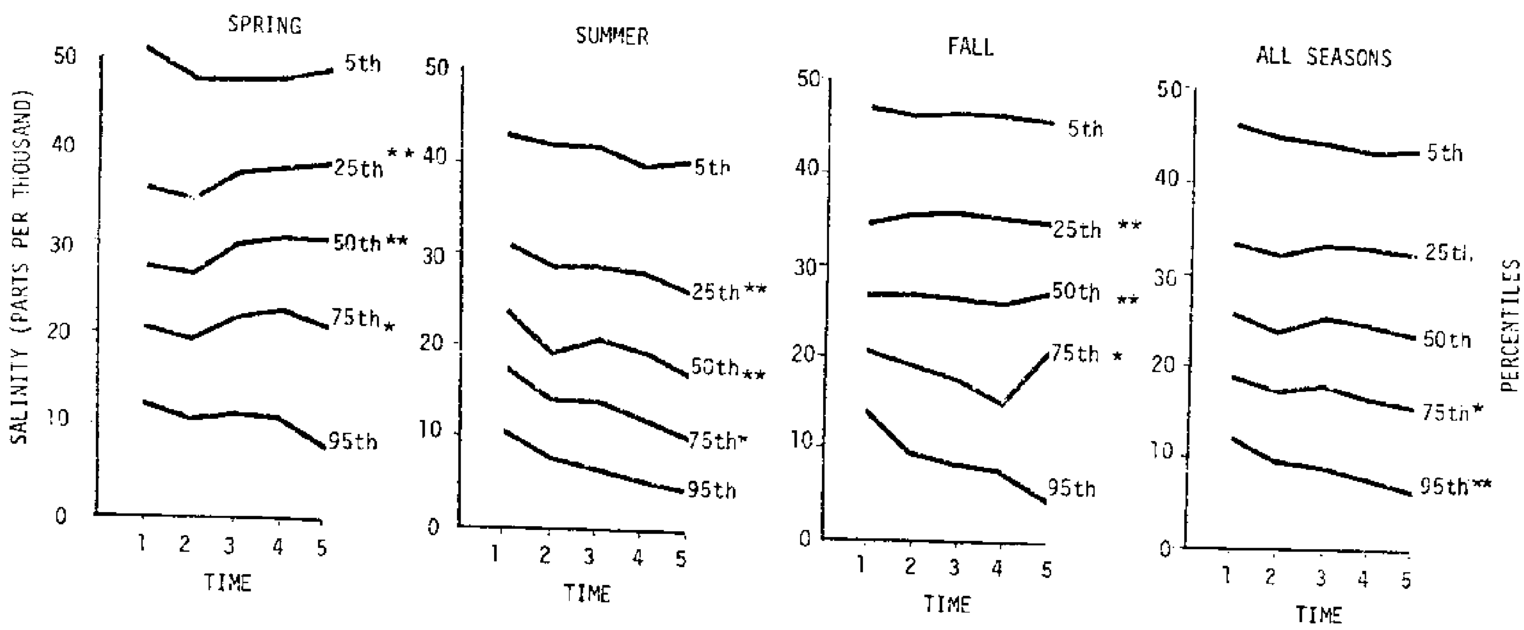

FIGURE 6.—Distribution of postlarval brown shrimp (P. aztecus) in salinity gradients by season and overall seasons. "Time" consists of five observation periods during the first 24-hr of observations/experiment. Distributions are characterized by the average values of the 5th, 25th, 50th (median), 75th, and 95th percentiles. * indicates that the distribution differs significantly between seasons or overall seasons for that percentile at the 0.05 level.

at the 95th percentile as the shrimp responded in a like manner among seasons (Fig. 6, p. 46).

White shrimp data were similarly analyzed. The 75th and 95th percentiles differed significantly (Table 6, p. 42 . Both of these percentiles showed a tendency to decrease from the beginning to the end of the experiment (Fig. 7) as noted previously for brown shrimp (Fig. 6, p. 46). There were no significant Time x Season interactions, as the shrimp distributions generally followed a similar pattern for both seasons (Fig. 7, p. 48).

Analysis of control tank distributions of both species (Tables 8-9, p.42-43) showed that there were no significant shifts among the observation periods averaged over all seasons. Only the 75th and 95th percentiles for white shrimp reveal signficant Time x Season interactions. The white shrimp tested in the summer tended to move towards the top of the tank during the experiment; however, those tested in the fall tended to seek lower levels (Fig. 8).

Day-night influence.--To investigate the possibility of diel periodicity in shrimp movements, the five time periods were coded into day and night. The analysis showed no significant day-night differences in brown and white shrimp distributions in either gradient or control tanks (Tables 12-15).

Tidal influence.--In certain experiments, there were pronounced shifts that suggested that the shrimp might be responding to tidal

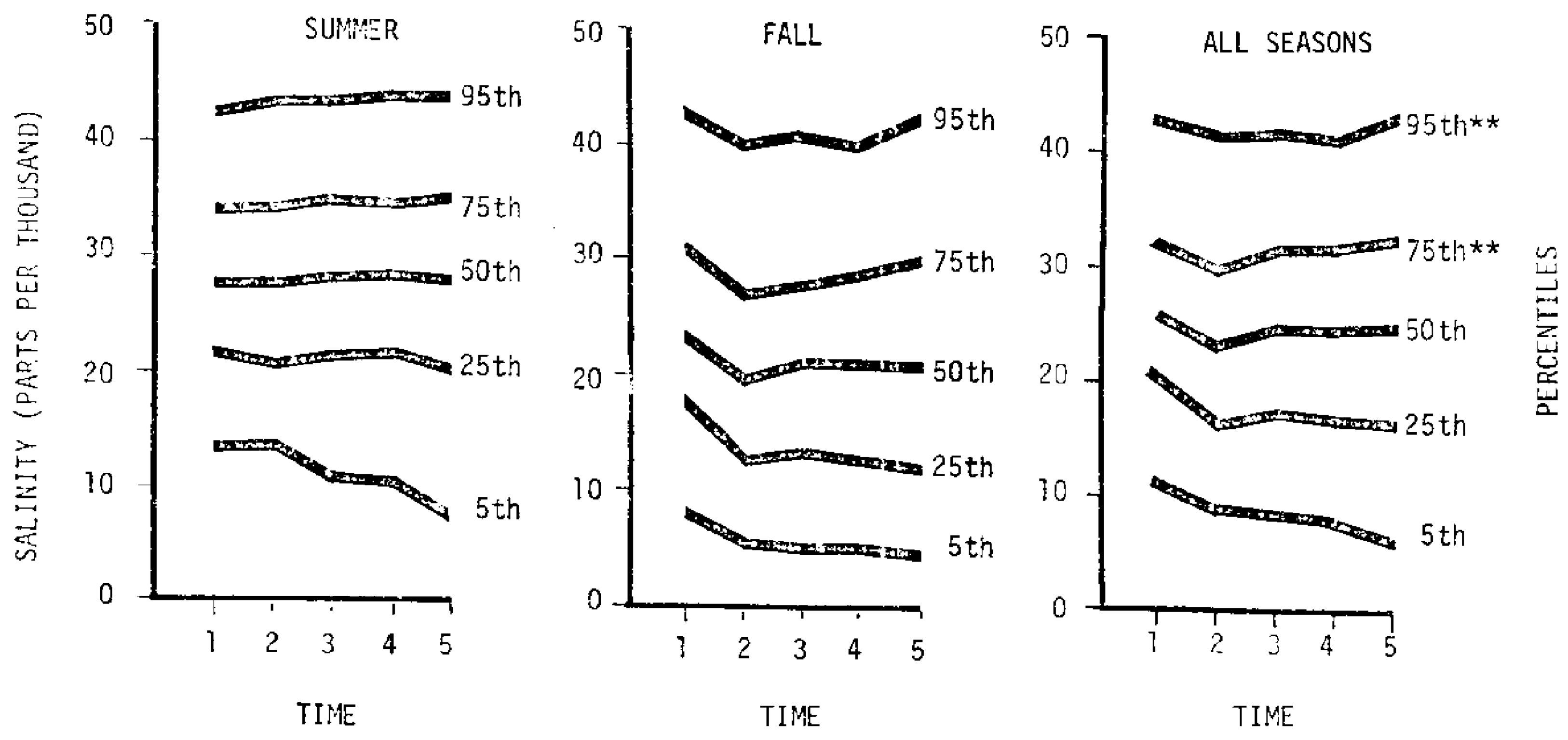

FIGURE 7.—Distribution of postlarval white shrimp (P. setiferus) in salinity gradients by season and overall seasons. "Time" consists of five observation periods during the first 24-hr of observations/experiment. Distributions are characterized by the average values of the 5th, 25th, 50th (median), 75th, and 95th percentiles. * indicates that the distribution differs significantly between seasons or overall seasons for that percentile at the 0.05 level.

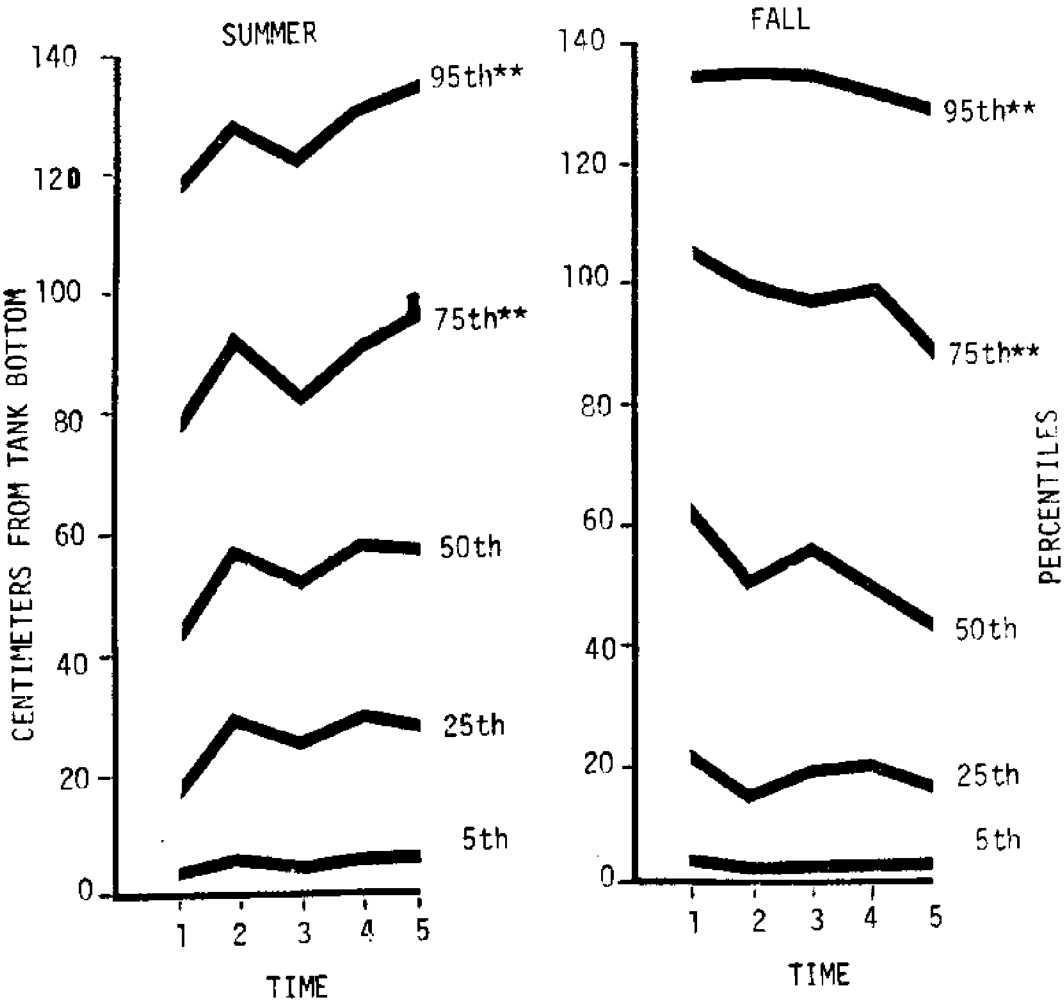

FIGURE 8.—Distribution of postlarval white shrimp (P. setiferus) in control tanks in the summer and fall. "Time" consists of five observation periods during the first 24-hr of observations/experiment. Distributions are characterized by the average values of the 5th, 25th, 50th (median), 75th, and 95th percentiles. ** indicates that the distribution differs significantly between seasons for that percentile at the 0.01 level.

TABLE 12.--Split-plot analysis of variance for five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) of brown shrimp (*P. aztecus*) distributions in gradient tanks during spring, summer and fall. The five observations taken during 24 hours of observations were coded into "day" and "night" for analysis

Source	df	F-Statistics						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}-P_{25}	P_{95}-P_5
Season	2	4.82*	8.41**	6.79**	5.72*	4.17*	0.47	0.69
Error a	14							
Day-Night	1	0.15	1.21	0.05	0.45	0.03	3.07	0.04
Day-Night x Season	2	0.00	0.16	0.18	0.76	0.08	0.94	0.06
Error b	57							

*significant at 0.05 level
**significant at 0.01 level

TABLE 13.--Split-plot analysis of variance for five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) of white shrimp (P. setiferus) distributions in gradient tanks during summer and fall. The five observations taken during 24 hours of observations were coded into "day" and "night" for analysis

Source	df	F-Statistics						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}-P_{25}	P_{95}-P_5
Season	1	0.80	1.90	1.80	3.20	4.70	0.42	1.45
Error a	9							
Day-Night	1	1.31	2.25	1.54	0.12	0.30	0.49	1.12
Day-Night x Season	1	1.29	0.07	0.56	1.60	0.91	1.53	0.00
Error b	35							

*significant at 0.05 level
**significant at 0.01 level

TABLE 14.--Split-plot analysis of variance for five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) of brown shrimp (*P. aztecus*) distributions in control tanks during the spring, summer and fall. The five observations taken during 24 hours of observations were coded into "day" and "night" for analysis

Source	df	F-Statistics						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}- P_{25}	P_{95}- P_5
Season	2	2.53	0.22	0.32	0.56	0.98	1.89	0.91
Error a	10							
Day-Night	1	3.07	0.34	1.47	1.39	0.99	0.79	0.11
Day-Night x Season	2	0.56	0.28	0.31	0.02	0.01	0.09	0.03
Error b	45							

*significant at 0.05 level
**significant at 0.01 level

TABLE 15.--Split-plot analysis of variance for five percentiles, interquartile range ($|P75-P25|$), and overall range ($|P95-P5|$) of white shrimp (*P. setiferus*) distributions in control tanks during the summer and fall. The five observations taken during 24 hours of observations were coded into "day" and "night" for analysis

Source	df	F-Statistics						
		P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Season	1	0.68	0.30	0.01	0.98	1.48	4.23	2.76
Error a	8							
Day-Night	1	3.36	0.36	0.73	0.33	0.11	1.25	0.00
Day-Night x Season	1	3.36	1.35	1.43	0.83	0.24	0.04	0.04
Error b	33							

*significant at 0.05 level
**significant at 0.01 level

rhythms. To test this possibility, tide levels (U.S. Geodetic Survey 1970a; U.S. National Ocean Survey 1971a, 1972a) and tidal currents (U.S. Geodetic Survey 1970b, U.S. National Ocean Survey 1971b, 1972b) were plotted for those gradient tank distributions that exhibited shifts as well as for several that did not (Appendix B, Figs. 1-13). No relationship was found between tidal stage and shrimp distribution for either white or brown shrimp postlarvae. Shifts in control tank distributions for the above experiments showed no relationship with tidal phase.

A Comparison of White and Brown Shrimp Salinity Preferences

Several times white and brown shrimp were collected together and tested several days later at the same time. The average values of the shrimp distributions and the interquartile and overall ranges from those experiments conducted during the summer were compared using the sign test. The chi-square value was significant at the 0.05 level for the median and 75th percentile (Table 16). Although these percentiles for white shrimp distributions corresponded to higher salinities than did those for brown shrimp distributions, the average salinity difference between the medians and the 75th percentiles was only 3.2 ppt and 3.9 ppt, respectively. In the one experiment conducted during the fall, all five percentiles of white shrimp distributions were lower than those for browns (Table 17).

TABLE 16.-- Sign test for average values of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) for brown (*P. aztecus*) and white (*P. setiferus*) shrimp distributions in gradient tanks during the summer. + indicates that for a particular percentile the salinity value for white shrimp is higher than that for brown shrimp or that the interquartile or overall range is larger for white shrimp; - indicates the opposite situation

Experiment	Salinity (ppt)																				
	P5			P25			P50			P75			P95			|P75-P25|			|P95-P5|		
	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign
17	35.7	38.4	+	24.3	28.4	+	18.4	23.9	+	13.5	18.9	+	7.9	9.4	+	10.8	9.5	-	27.2	29.0	+
18	38.8	35.1	-	28.4	28.5	+	21.0	21.7	+	16.0	16.4	+	11.5	8.4	-	12.4	12.1	-	27.3	26.7	-
34	42.2	42.3	+	34.6	34.2	-	26.1	28.9	+	13.6	22.3	+	3.7	12.6	+	21.0	11.9	-	38.5	29.6	-
37	52.7	46.2	-	33.7	34.6	+	22.8	25.3	+	15.3	17.3	+	8.0	10.7	+	18.4	17.3	-	44.7	35.5	-
42	42.4	44.7	+	34.6	37.3	+	28.6	31.7	+	22.0	26.9	+	11.7	14.8	+	12.6	10.4	-	30.7	30.0	-
43	36.4	45.8	+	29.2	36.5	+	23.2	28.4	+	16.7	20.8	+	8.6	9.3	+	12.5	15.7	+	29.9	36.1	+
	χ^2=0.17			χ^2=1.50			χ^2=3.84*			χ^2=3.84*			χ^2=1.50			χ^2=1.50			χ^2=0.17		

*significant at 0.05 level

TABLE 17.--Average salinity values of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) for brown (P. aztecus) and white (P. setiferus) shrimp distributions in gradient tanks during the fall in experiment 23

Species	Salinity (ppt)						
	P_5	P_{25}	P_{50}	P_{75}	P_{95}	P_{75}-P_{25}	P_{95}-P_5
P. aztecus	48.5	37.3	29.1	23.0	10.3	27.0	38.2
P. setiferus	39.0	28.0	21.1	13.0	10.3	15.0	34.6

The median values of the control tank distribution (Table 18) were not treated by the sign test as it requires a minimum of six pairs of observations to detect significant differences (Steel and Torrie 1960). Visual comparison shows that in the summer months, white shrimp were not consistently found in lower levels of the tanks than brown shrimp. In the fall, white shrimp were found at higher tank levels than the brown shrimp (Table 19).

The overall variance of the two species calculated during the analysis of variance was used as an index of species variability. The variance of the five percentiles, the interquartile range (|P75-P25|) and the overall range (|P95-P5|) of each species were compared using the F-test for homogeneity of variance. The results show that the variances of the two species did not differ significantly (Table 20).

The control tank percentiles were likewise compared for homogeneity of variance using the F-test. Calculated F values were

TABLE 18.--Average values of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) for brown (*P. aztecus*) and white (*P. setiferus*) shrimp distributions in control tanks. + indicates that for a particular percentile, the cm value for white shrimp was less than that for brown or that the interquartile or overall range is larger for white shrimp than for brown shrimp; - indicates the opposite situation

Experiment	Centimeters from tank bottom															Centimeters					
	P5			P25			P50			P75			P95			|P75-P25|			|P95-P5|		
	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign	Brown	White	Sign
17	5.1	7.4	-	26.7	34.1	-	64.6	71.8	-	112.3	106.9	+	137.1	135.9	+	85.6	72.8	-	132.0	128.2	-
13	4.6	5.1	-	35.9	27.0	+	78.3	58.2	+	113.6	103.0	+	137.2	135.2	+	[illegible]	76.0	-	132.6	130.1	-
34	2.5	2.0	+	15.4	9.4	+	41.7	21.8	+	89.1	47.8	+	132.4	104.6	+	73.7	38.4	-	129.9	102.7	-
37	5.4	6.6	-	25.3	41.3	-	60.4	73.5	-	95.1	105.1	-	130.3	132.7	-	69.2	63.8	-	124.9	126.0	+
43	5.3	5.7	-	28.7	26.8	+	69.7	59.2	+	107.0	94.2	+	136.9	130.6	+	78.3	67.3	-	131.2	124.9	-

significant for all percentiles indicating that the variance of white and brown shrimp differed significantly; white shrimp consistently had the higher variance (Table 21).

TABLE 19.--Average centimeter values of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) for brown (*P. aztecus*) and white (*P. setiferus*) shrimp distributions in control tanks during the fall in experiment 23

Species	Centimeters from tank bottom					Centimeters	
	P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
P. aztecus	2.6	15.5	50.0	99.0	133.9	84.4	131.3
P. setiferus	4.7	27.7	67.7	109.0	135.0	81.3	130.3

TABLE 20.--Test of homogeneity of variance of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) for brown (*P. aztecus*) and white (*P. setiferus*) shrimp distribution in gradient tanks

	Variance		F-Statistic
	Brown	White	
P_5	42.03	24.99	1.68 n.s.
P_{25}	40.76	50.52	1.24 n.s.
P_{50}	43.83	61.72	1.41 n.s.
P_{75}	37.21	52.61	1.41 n.s.
P_{95}	17.79	26.61	1.50 n.s.
$P_{75}-P_{25}$	17.83	14.69	1.21 n.s.
$P_{95}-P_5$	45.07	28.14	1.60 n.s.

TABLE 21.--Test of homogeneity of variance of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) for brown (*P. aztecus*) and white (*P. setiferus*) shrimp distributions in control tanks

	Variance		F-Statistic
	Brown	White	
P_5	3.50	6.71	1.92*
P_{25}	94.40	171.20	1.82*
P_{50}	203.69	427.88	2.10**
P_{75}	170.75	444.72	2.62**
P_{95}	20.27	138.70	6.84**
$P_{75}-P_{25}$	89.78	285.00	3.17**
$P_{95}-P_5$	3.50	6.71	7.44**

*significant at 0.05 level
**significant at 0.01 level

Effect of Age upon Salinity Preference

Field animals.--Studies were designed to determine whether salinity preferences of brown and white shrimp vary with size and age. Initially, postlarvae were introduced into the experimental tanks within 9 days of collection. Other individuals collected at the same time were tested 11 to 61 days after collection.

The data show that generally postlarvae held in the laboratory for 11 to 61 days were distributed at lower levels in both control and gradient tanks (Tables 22-25) than were postlarvae held for less than 9 days. The parallel movement of postlarvae in both control and gradient tanks suggests that some factor other than size or age alone influenced the response of shrimp in these studies.

TABLE 22.--Distribution in control tanks of brown shrimp (*P. aztecus*) held for varying periods in the laboratory. Average centimeter values of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) characterize shrimp distributions

Season	Age study no.	Mean size $\pm$ 1 std (mm)	Experiment no.	Days after collection	Centimeters from tank bottom					Centimeters	
					P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Fall	1	10.7±1.0	19	5	3.9	27.2	58.8	101.5	135.5	74.3	131.6
		11.6±1.1	20	11	4.5	22.2	54.6	91.7	129.1	69.5	124.6
		13.4±1.6	21	19	2.1	13.8	46.1	83.2	125.2	69.4	123.1
Spring	2	12.2±0.6	30	5	4.4	19.3	52.6	99.2	133.8	79.9	128.4
		18.1±1.5	32	31	2.3	9.9	39.7	78.3	135.2	68.4	132.9
Spring	3	13.3±0.9	31	4	5.6	38.4	70.6	108.5	136.0	70.1	130.4
		15.4±1.3	32	19	2.2	9.2	30.8	79.9	133.5	70.7	131.3
Summer	4	9.3±0.6	43	4	6.9	29.8	68.5	108.1	137.3	78.3	130.4
		10.8±1.3	44	11	2.6	12.4	46.0	92.2	135.4	79.8	132.8
		12.6±1.1	45	25	3.4	22.2	49.1	104.4	133.4		

TABLE 23.--Distribution in control tanks of white shrimp (*P. setiferus*) held for varying periods in the laboratory. Average centimeter values of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) characterize shrimp distributions

Season	Age study no.	Mean size $\pm$ 1 std (mm)	Experiment no.	Days after collection	Centimeters from tank bottom					Centimeters	
					P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Fall	1	8.0$\pm$0.9	23	9	3.7	25.4	63.8	107.4	135.3	82.0	131.6
		15.6$\pm$2.1	26	61	1.2	6.6	30.4	82.8	129.5	76.2	128.3
		22.8$\pm$3.0	26	61	11.5	35.8	59.6	91.4	128.4	55.6	116.9
Fall	2	7.6$\pm$0.6	37	4	6.6	41.3	73.5	105.1	132.7	63.8	126.1
		10.1$\pm$1.1	39	22	2.0	9.0	32.9	79.4	132.3	70.4	130.3

TABLE 24.--Distribution in gradient tanks of brown shrimp (*P. aztecus*) held for varying periods in the laboratory. Average salinity values of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) characterize shrimp distributions

Season	Age study no.	Mean size ± 1 std (mm)	Experiment no.	Days after collection	Salinity (ppt)						
					P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Fall	1	10.7±1.0	19	5	46.7	35.2	27.5	20.4	12.0	14.8	34.7
		11.6±1.1	20	11	49.5	41.3	33.0	24.3	14.0	17.0	25.2
		13.4±1.6	21	19	49.0	39.6	30.8	19.5	12.0	20.0	36.3
Spring	2	12.2±0.6	30	5	51.8	34.7	22.7	14.3	5.5	20.4	46.5
		18.1±1.5	32	31	48.0	42.0	34.8	25.0	18.1	17.0	29.9
Spring	3	13.3±0.9	31	4	46.7	37.3	31.3	23.7	14.3	13.6	34.7
		15.4±1.3	32	19	48.0	41.7	33.2	22.8	11.1	18.9	36.9
Summer	4	9.3±0.6	43	4	39.0	29.0	23.0	14.5	7.9	14.5	31.1
		10.8±1.3	44	11	45.4	34.5	26.9	18.1	9.0	16.4	36.4
		12.6±1.1	45	25	40.1	29.6	20.5	14.2	5.7	15.4	34.4

TABLE 25.--Distribution in gradient tanks of white shrimp (*P. setiferus*) held for varying periods in the laboratory. Average salinity values of five percentiles, interquartile range (|P75-P25|), and overall range (|P95-P5|) characterize shrimp distributions

Season	Age study no.	Mean size $\pm$ 1 std (mm)	Experiment no.	Days after collection	Salinity (ppt)						
					P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Fall	1	8.0 ± 0.9	23	9	39.0	28.0	21.1	13.0	5.4	15.0	33.6
		15.6 ± 2.1	26	61	60.1	47.6	37.8	26.1	12.1	21.5	48.0
		22.8 ± 3.0	26	61	52.8	41.2	29.3	18.7	10.5	22.5	42.3
Fall	2	7.6 ± 0.6	37	4	46.4	34.8	25.7	17.8	10.0	17.0	36.4
		10.1 ± 1.1	39	22	53.7	40.8	33.3	24.5	10.2	16.3	43.5

Hatchery animals.--Hatchery reared brown shrimp were obtained in December, 1972 from the National Marine Fisheries Service Laboratory (NMFS). They were not of uniform size and were separated by eye into two size groups. At the start of experimentation (experiment 27), the shrimp were 35 days old, at which time the two groups measured 7.6 and 11.7 mm, respectively. Figure 9 presents a summary of the salinity preference shown by each size group of shrimp tested from the November 18th hatch. It appears that the size of the shrimp was more important than age in determining salinity preference. The 7.6 mm shrimp preferred a median salinity approximately that of seawater while the 11.7 mm shrimp preferred salinities 6 ppt lower. Shrimp remaining in the holding tanks were tested at the age of 42 days (experiment 28). The smaller shrimp at this time measured 9.9 mm and the larger postlarvae, 12.4 mm. As previously, the smaller shrimp preferred a higher median salinity (29.5 ppt) than did the larger postlarvae (25 ppt). The overall ranges of the two groups of 42-day shrimp, however, were more similar than those of the two groups of 35-day postlarvae.

On January 8th another group of shrimp from the November hatch was obtained from the NMFS hatchery. These shrimp measured 18 mm and were more uniform in size than the first group. They were split into two groups for holding and then tested at 56 days of age. Unfortunately during this experiment (experiment 29), the salinity gradients in both experimental tanks changed. As the point in time when this salinity change occurred could not be determined, the

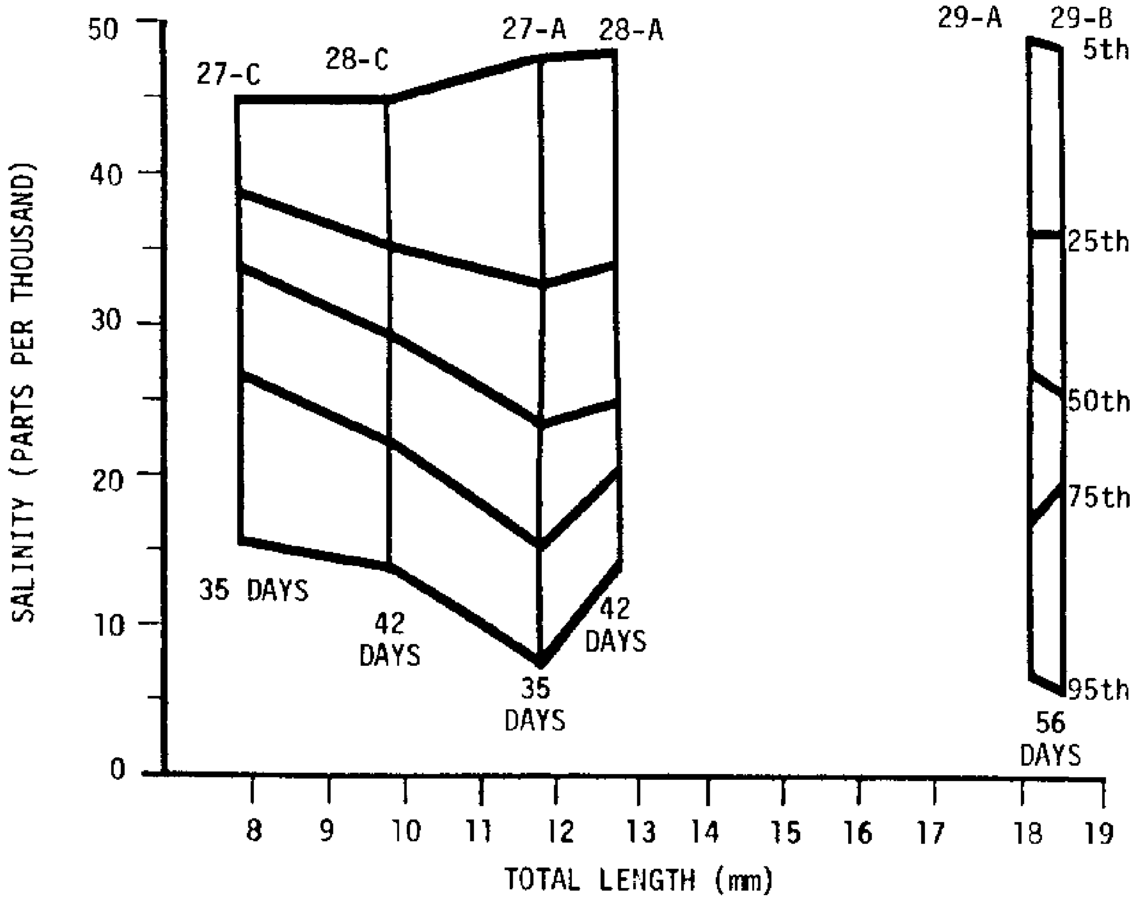

FIGURE 9.--Distribution of hatchery shrimp (P. aztecus) of different sizes and ages in salinity gradient tanks during experiments 27, 28, and 29. Distributions are characterized by the average values of the 5th, 25th, 50th (median), 75th, and 95th percentiles. Numbers and letters refer to experiment and tank, respectively.

initial salinity measurements were used to compute the salinity preference of the shrimp in the first two observation periods, and the final gradient measurements were used for the last observation period. The distribution data for shrimp at other observation times were not used. These shrimp appeared to prefer salinities similar to those selected by the 11.7 mm, 35-day shrimp and the 12.4 mm, 42-day shrimp.

Distribution of animals in the control tanks was fairly similar for all sizes and ages of shrimp (Appendix A, Figs. 51-54, 56-57, p. 179-184, 186-187). The 7.6 mm shrimp had the weakest bottom-seeking tendency with only 20% of the shrimp being found in the bottom 10 cm. This compares with 25 to 30% of the shrimp of other ages and sizes present in the bottom 10 cm region of the control tank.

Brown shrimp obtained in June, 1973 from the NMFS hatchery were tested (experiments 38 and 40) in an attempt to verify whether salinity preference is related to the size of the shrimp. Unfortunately, these shrimp were far less hardy than those obtained previously. They were also about 1 mm smaller than the smallest size group previously tested. Within 2 hours of introduction 33% of the shrimp had died in the gradient tanks. Eight hours later, the mortality had increased to 77%. Mortality was also higher than normal in the control tanks, 20% dying within 2 hours and 33% dying within 8 hours. Shrimp from this hatch were tested again 21 days later. High mortalities were still observed. Twenty-three hours after introduction, 48% had died in one gradient tank and 66%

of the postlarvae in the other. The majority of the deaths occurred in salinities greater than 58 ppt. Because of the high mortality, the results of these experiments are not presented.

Effect of Acclimation Salinity upon Salinity Preference

The effect of acclimation salinity upon salinity preference of brown shrimp seemed to be variable. In experiment 30, shrimp acclimated to 24 ppt were found in higher salinities (Appendix A, Fig. 58, p. 188) than those held at 32 ppt. In experiment 33, the median salinity of shrimp acclimated to 12 ppt was 24 ppt (Appendix A, Fig. 67, p. 199) compared to 33.5 ppt for those held at 24 ppt for the same period of time. Another group of shrimp was held for 23 days (experiment 45). At 20 hours after introduction, the distributions of shrimp acclimated to 12 and 26 ppt had similar medians and 75th and 95th percentiles (Appendix A, Fig. 98, p. 244); however, the P5 and P25 levels were 8 ppt higher for the shrimp acclimated to 26 ppt indicating that these shrimp frequented higher salinity extremes than those acclimated to 12 ppt.

Acclimation salinity seemed to have only a short-term effect on white shrimp. In both experiment 22 and 41 (Appendix A, Figs. 41 and 84, p. 167 and 221), there was an initial difference in salinity preference with those shrimp acclimated to the lower salinities selecting lower salinity levels than those acclimated to the higher salinity. By the end of 22 and 34 hr (experiments 22 and 41, respectively) the distribution of shrimp in each experiment was similar.

Brown shrimp in experiments 30 and 45 exhibited a variable response in the control tanks to acclimation salinity. Shrimp acclimated to 24 ppt for 5 days were generally found higher in the control tanks than those acclimated to 32 ppt at each observation period; however, the summary histograms were similar for the first 27 hr of observations (Appendix A, Fig. 60, p. 192). Brown shrimp acclimated to 26 ppt for 23 days were found higher in the control tanks than were those acclimated to 12 ppt (Appendix A, Fig. 100, p. 246).

White shrimp selected similar levels in the control tanks irrespective of their acclimation salinity (Appendix A, Figs. 42 and 85, p. 168 and 223).

Effect of Temperature on Salinity Preference

Two types of experiments were designed to determine the effects of temperature upon salinity preference. Postlarvae were either acclimated to different temperatures and tested in experimental tanks at their respective acclimation temperatures or acclimated to one temperature and tested at that temperature and then at higher or lower temperatures. In several experiments of the latter type, final observations were made at temperatures close to initial temperatures (Table 26).

The response of brown shrimp postlarvae to temperature was investigated using shrimp from 12 collections. No consistent differences in salinity preference were observed as temperature increased or decreased (Table 26, p. 69). In experiments where final and initial

TABLE 26.--Distribution of postlarval brown shrimp (*P. aztecus*) in salinity gradient tanks at different temperatures and seasons. Five percentiles, interquartile range (|P75-P25|) and overall range (|P95-P5|) characterize distributions

Season	Study	Experiment no.	Tank	Acclimation temperature (C)	Acclimation salinity (ppt)	Experimental temperature (C)	Salinity (ppt)						
							P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Spring	1	8	A	30	33	31	41.6	23.6	15.2	9.8	3.0	13.8	38.6
		9	A	23	33	23	48.7	40.5	33.6	25.6	12.4	14.9	36.3
		10	A	18	33	18	47.9	38.8	31.0	23.5	13.9	15.3	20.1
	2	12	A	23	33	25	50.4	42.7	34.0	23.1	11.1	19.6	39.3
						29	53.5	44.5	34.5	23.5	5.0	21.0	48.5
	3	13	A	18	33	18	46.5	35.6	26.4	19.9	9.5	15.7	37.0
						23	43.8	33.5	23.5	12.5	3.5	21.0	40.3
	4	30	A	23	33	23	51.8	34.7	22.7	14.3	5.5	20.4	46.3
						17	52.5	36.0	27.0	19.6	8.5	16.4	44.0
						19	56.9	34.1	24.9	18.4	10.0	15.7	46.9
	5	33	A	30	24	30	47.7	36.5	28.4	15.2	6.8	21.3	40.9
		33	B	30	12	30	40.0	31.0	18.5	12.0	12.0	19.0	28.0
		33	C	23	24	23	49.3	40.5	33.5	26.6	15.4	13.9	33.9
		33	D	23	12	23	45.7	31.4	22.4	12.8	6.1	18.6	39.6
Summer	1	15	A	23	33	23	49.5	29.5	20.7	13.3	8.0	16.2	41.5
						30	36.7	21.5	13.8	8.5	3.8	13.0	32.9
						24	35.0	23.0	14.5	9.0	3.5	14.0	31.5
	2	16	A	23	33	22	35.9	21.5	15.1	10.1	5.3	11.4	30.6
						30	32.5	22.0	14.5	8.8	3.2	13.2	29.3
						23	38.2	26.5	17.6	9.8	2.5	16.7	35.7

TABLE 26.--continued

Season	Study	Experiment no.	Tank	Acclimation temperature (C)	Acclimation salinity (ppt)	Experimental temperature (C)	Salinity (ppt)						
							P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
	3	17	C	23	33	23	34.7	24.4	18.2	13.5	7.8	10.9	23.8
						30	36.9	23.5	17.0	11.5	4.0	12.0	32.9
						23	37.2	23.2	17.3	11.5	6.2	11.7	31.0
	4	18	C	23	33	23	38.8	28.4	21.0	16.0	11.5	12.4	27.3
						30	35.1	23.3	17.7	12.6	6.4	10.7	28.7
						23	35.5	24.5	19.1	13.6	6.3	10.9	29.2
	5	35	A	24	30	24	43.8	30.1	17.5	10.3	4.0	19.8	39.8
						30	44.0	34.3	21.0	9.7	2.0	24.6	42.0
						23	37.0	29.0	18.0	10.0	0.0	19.0	37.0
		35	B	24	20	24	39.4	26.0	16.2	7.3	3.3	18.7	35.6
						30	40.7	26.0	11.5	4.5	1.7	21.5	39.0
						23	42.0	30.0	22.2	8.0	2.0	22.0	40.0
		35	C	24	30	24	47.5	34.3	26.3	17.5	5.6	23.3	42.1
		35	D	24	20	24	39.9	27.0	14.5	6.8	2.4	20.2	41.9
Fall	1	19	A	23	33	21	45.0	33.5	25.5	18.3	11.8	15.2	33.2
						30	49.2	37.5	15.5	6.2	1.8	31.3	47.4
						21	45.6	29.7	15.7	6.8	1.5	22.9	44.1
	2	23	C	23	33	23	48.5	37.3	29.1	23.0	10.3	14.3	38.2
						32	50.6	40.6	34.3	23.2	4.2	17.4	46.4
						23	45.9	37.0	26.1	14.8	4.7	22.2	41.2

temperatures were similar, final distributions of shrimp in the salinity gradients generally differed from initial distributions. Usually, the final distribution was characterized by lower values (experiments 15, 17-19, 23); however, in experiments 16 and 30, most of the final values were higher than initial values (Table 26, p.69). These results suggest that the length of time in the experimental tanks rather than temperature alone influences salinity preference. This possibility was investigated in experiment 35 by holding 2 of the 4 tanks at constant temperatures and varying the temperature in the other two tanks. The results of this experiment were inconclusive because the distributions of the 30 ppt-acclimated shrimp in the two tanks were not similar at the initial temperature (tank A & C; Table 26, p. 69, Appendix A, Fig. 73, p. 207). The distributions of 20 ppt- and 24 C-acclimated shrimp between 32.9 and 51.0 hr were determined at temperatures averaging near 30 C (tank B; Appendix A, Fig. 71, p. 205) and 24 C (tank D; Appendix A, Fig. 72, p. 206). The 25th and the 75th percentiles for the 30 C shrimp were nearly 7 ppt higher than for those tested at 24 C, whereas distributions differed by less than 2 ppt at the other percentiles.

The response of white shrimp postlarvae to temperature (Table 27) was investigated in three experiments. Shrimp tested in the summer appeared to seek lower salinities with increasing temperatures. This, however, was apparently more related to the length of time they had been in the experimental tank as when temperatures were again lowered, the median salinity remained the

TABLE 27.--Distribution of postlarval white shrimp (*P. setiferus*) in salinity gradient tanks at different temperatures and seasons. Five percentiles, interquartile range (|P75-P25|) and overall range (|P95-P5|) characterize distribution

Season	Study	Experiment no.	Acclimation temperature (C)	Acclimation salinity (ppt)	Experimental temperature (C)	Salinity (ppt)						
						P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Summer	1	17	23	33	23	38.4	28.4	23.9	18.9	10.4	9.5	28.0
				33	30	43.5	28.4	20.7	14.5	6.0	13.9	37.5
				33	23	40.2	27.4	21.2	14.5	8.0	12.9	32.2
	2	18	23	33	23	35.1	28.5	21.7	16.4	8.4	12.2	26.7
				33	30	37.8	26.6	18.8	11.1	4.0	15.5	33.8
				33	23	38.5	24.2	17.1	9.5	3.3	14.7	35.2
Fall	3	23	23	33	23	39.0	28.0	21.1	13.0	5.4	15.0	33.6
				33	30	50.4	39.2	30.2	16.7	3.7	22.5	46.7
				33	23	38.5	29.5	22.0	15.0	5.2	14.5	33.3

same or continued to decrease.

Distribution of white and brown shrimp in the control tanks seemed to be unrelated to temperature (Tables 28, 29). In some instances, lower median levels in the tank were associated with higher temperatures, but the opposite response was also observed.

Influence of Illumination upon Salinity Preference

Two experiments (37 and 42) were designed to determine whether the red illumination had an effect upon salinity preference of brown and white shrimp postlarvae. In experiment 37, the tanks were maintained in complete darkness except for half-hour periods of light every 6 hr. The distribution of shrimp was recorded within 1 min after the red lights were turned on behind the tanks. This first observation was considered to characterize the distribution of shrimp in darkness. Five observations made at 5-min intervals. beginning 10 min after illumination, formed the second group. The above classification will hereafter be referred to as "dark" and "light", respectively.

Light had a variable effect on shrimp distributions. In experiment 37, light had little influence on the salinity preference of brown shrimp. In the early part of this experiment, distributions were similar except at the 5th percentile, which indicated that some brown shrimp moved deeper into the tank into more saline waters in the light (Appendix A, Fig. 76-77, p. 211-212). Light had a pronounced effect on the distribution of white shrimp in

TABLE 28.--Distribution of brown shrimp in control tanks at different temperatures and seasons. Five percentiles, interquartile range ($|P75-P25|$) and overall range ($|P95-P5|$) characterize distributions

Season	Study	Experiment no.	Acclimation temperature (C)	Acclimation salinity (ppt)	Experimental temperature (C)	Centimeters from tank bottom					Centimeters	
						P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
Spring	1	8	30	33	30	2.8	13.3	43.5	83.5	128.3	75.2	125.5
		9	23	33	23	3.1	19.8	52.3	95.0	130.5	75.2	127.4
		10	18	33	18	2.1	20.0	64.6	112.5	135.5	92.5	133.4
	2	12	23	33	23	3.0	14.9	38.1	82.4	128.7	67.5	125.7
					30	2.1	10.5	41.5	96.5	131.7	86.0	133.8
	3	13	18	33	18	3.2	33.5	75.5	108.5	135.5	75.0	132.3
					23	6.0	41.0	78.4	111.0	136.5	70.0	130.5
	4	30	23	33	23	4.4	19.3	52.6	99.2	133.8	79.9	129.4
					16	2.3	15.4	36.6	69.6	127.7	54.2	125.4
					19	2.1	14.6	52.8	99.3	136.8	84.7	134.7
Summer	1	15	23	33	23	5.5	34.0	77.4	119.0	137.7	85.0	132.2
					30	2.7	22.0	63.9	97.0	136.5	75.0	133.8
					23	5.0	26.5	71.5	122.5	135.0	96.0	130.0
	2	16	23	33	23	6.1	27.7	67.3	107.4	135.6	79.7	129.5
					30	4.1	18.6	53.7	94.6	133.4	76.0	129.3
					24	2.5	16.5	45.0	88.0	134.6	71.5	132.1
	3	17	23	34	23	4.9	26.8	65.5	113.4	137.2	86.6	132.3
					30	4.2	25.3	68.1	112.9	137.8	87.6	133.8
					23	4.5	26.1	62.1	114.6	138.3	88.5	133.8
	4	18	23	33	23	4.6	35.9	78.3	118.6	137.2	82.7	132.6
					30	2.7	28.3	66.9	111.0	137.5	82.7	134.8
					23	7.7	25.0	59.2	109.0	134.0	84.0	126.3
Fall	1	19	23	33	20	3.9	27.2	58.8	101.5	135.5	74.3	131.6
					30	2.9	28.8	67.3	105.2	134.8	76.4	130.9
					23	4.0	31.5	73.6	107.5	137.0	76.0	133.0

TABLE 29.--Distribution of white shrimp in control tanks at different temperatures in summer. Five percentiles, interquartile range (|P75-P25|) and overall range (|P95-P5|) characterize distributions

Study	Experiment no.	Acclimation temperature (C)	Acclimation salinity (ppt)	Experimental temperature (C)	Centimeters from tank bottom					Centimeters	
					P_5	P_{25}	P_{50}	P_{75}	P_{95}	$P_{75}-P_{25}$	$P_{95}-P_5$
1	17	23	33	23	7.2	33.4	72.5	107.6	136.6	74.2	129.4
				30	5.4	36.3	77.8	117.1	137.6	80.8	132.2
				23	3.4	29.6	73.8	123.8	138.3	94.2	134.9
2	18	23	33	23	5.1	27.0	58.2	103.0	135.2	76.0	130.1
				30	4.0	26.8	75.3	114.9	136.7	88.1	132.7
				23	3.3	19.7	64.8	109.3	134.6	89.6	131.8

experiment 37. In the light period, distributions were lower at all percentiles than in the dark, indicating that the shrimp moved downward in the tanks in the light into more saline waters (Appendix A, Fig. 79 and 81, p. 215 and 217). The response of brown and white shrimp to dark and light conditions was variable in control tanks (Appendix A, Fig. 78, p. 214).

Another collection of brown and white shrimp was made 5 weeks later. Four salinity gradients were prepared (experiment 42), two of which had dark and light periods as in experiment 37, while the remaining two were continuously illuminated. Intermittent and continuous lighting had little influence on either postlarval brown or white shrimp distributions except at salinity extremes. Brown shrimp tended to be found at higher salinity extremes (P5) in the dark than during either periodic or continuous light (Appendix A, Fig. 87, p. 226). White shrimp distributions were similar in the dark and intermittent illumination; however, under continuous illumination, white shrimp occurred at lower salinity extremes (P95) (Appendix A, Fig. 88, p. 228).

DISCUSSION

Oceanic Phase of the Shrimp Life Cycle

The *Penaeus* life cycle encompasses both estuarine and oceanic phases. To evaluate the responses of postlarval shrimp to salinity gradients, it is necessary to review current knowledge of the oceanic phase of their life cycle and the forces or mechanisms that act to transport the postlarvae to the beachfront and from there into the estuaries.

The mechanisms by which postlarval shrimp find their way shoreward from spawning areas as far as 360 kilometers from land to the estuarine nursery grounds have not been clearly identified. Although laboratory studies have shown that low salinity is not essential for growth and survival of postlarval shrimp (Zein-Eldin and Aldrich 1965, Zein-Eldin and Griffith 1969), these shrimp generally utilize the low salinity estuarine areas as nursery grounds (Williams 1965).

It is not known whether the postlarvae are at the mercy of water currents alone or if they are capable of active shoreward movements, or if both factors are important. Since current velocity and direction may vary with depth, the delineation of differences in vertical distribution of larval stages is prerequisite to understanding the role of water currents in transport. In a series of cruises, Temple and Fischer (1965) found partial vertical separation of immature stages in the water column when a well-defined discontinuity layer was present and the water was exceptionally clear. Protozoeal and mysis stages were found more frequently in the deeper portions of the water column (18 and 34 m) while postlarval stages occurred more frequently near the surface. No differences in vertical distributions were found when the water column was isothermal and relatively turbid. When a discontinuity layer was present, immature stages migrated into surface waters as darkness approached and returned to deeper waters with dawn. There was no difference in day-night distributions when the water column was isothermal.

Jones et al. (1970) also found that the vertical distribution of pink shrimp (P. duorarum) larvae varied with age. At 15-fathom stations, postlarvae were generally more abundant at the surface and mid-depths than at the bottom. Significantly more protozoae and mysis were collected at the surface during the night than during the day. No significant difference was detected between the numbers of postlarvae caught at the surface during the day and during the night. They did not relate vertical distribution of shrimp to the presence or absence of thermal stratification.

Williams and Deubler (1968) tested the possibility that wind-generated onshore currents were important for transporting postlarvae shoreward into the gyres off the North Carolina coast and from there towards the inlets; however, their 10 years of data, obtained from collections made at flood tides in tidal passes and at estuarine stations, did not support this hypothesis. Wind direction, when postlarvae were present in collections, was nearly evenly divided between onshore and offshore showing that wind direction at time of catch had no effect on sampling success. There was also no relationship between the magnitude of currents and the number of postlarvae collected.

King (1971) found a positive correlation between wind direction and the number of postlarval brown shrimp caught on flood tides in a Texas tidal inlet. His results indicated that more postlarvae were captured when wind direction was offshore. His results are puzzling since he also observed that the greatest density of postlarval shrimp was at the surface. If wind-directed surface currents exist in the transport of postlarvae into the estuaries, one would expect immigration peaks to be positively correlated with onshore winds.

In the Northwestern Gulf of Mexico, the variation in surface currents is believed to be largely a function of prevailing winds. If northerlies are stronger than usual during the winter and their influence is apparent until late spring, then there is a delay in the establishment of onshore surface drift (Kimsey and Temple 1964). In a current study conducted off Galveston Island, 32% to 64% of the drift bottles recovered were found along the beaches of the Texas coast indicating that onshore surface currents were present (Baxter 1967). Further south, Watson and Behrens (1970), using drift bottles, concluded that currents on the shallow shelf can be generated by local winds. Nearshore current flowed in opposite directions during winter and summer just as did prevailing winds. Ringo (unpublished manuscript) found that the time of peak postlarval occurrence in Galveston Bay corresponded to south and southeasterly onshore winds. In view of these various findings, the role of currents in transporting postlarvae to the bays remains unclear.

Once in the vicinity of the tidal passes, postlarvae may utilize the tides to facilitate movement into the estuaries. Several investigators, sampling throughout tidal cycles, have caught postlarvae primarily on flood tides. St. Amant, Broom, and Ford (1966) collected a preponderance of brown postlarvae on incoming tides, and Baxter (1966) caught greater numbers of postlarval brown shrimp on flood tides than on ebb tides. On the basis of similar work, Caillouet, Fontenot, and Dugas (1968) and Caillouet, Perret, and Dugas (1970) concluded that postlarvae of both white and brown shrimp were carried shoreward by incoming tidal currents. King (1971), collecting only on flood tides, found that the rate of brown shrimp immigration was positively correlated with tidal amplitude. Tabb et al. (1962) caught the majority of pink shrimp on flood tides during the night. Eldred et al. (1965) caught most of the postlarval pink shrimp collected in their study during flood phases of full moon spring tides. Hughes (1969a) and Jones et al. (1970) also collected more postlarval pink shrimp on flood tides than on ebb. Jones et al. proposed that migration of shrimp may be facilitated by tidal currents, the larvae being carried by the flood currents, but clinging to the bottom during ebb flow.

The laboratory experiments reported here suggest that postlarval brown and white shrimp may utilize salinity gradients to orient to the estuaries. Brown and white postlarvae were observed to seek salinities lower than those usually found in the open Gulf of Mexico. Postlarvae could conceivably follow salinity gradients that extend from the estuary seaward. Aldrich (1966) showed that postlarvae are capable of extended swimming. He estimated that swimming alone could transport larvae 4.8 km per day. His laboratory estimate of the rate of postlarval movements is comparable to the observed rate of postlarval movement into the Galveston Bay System (Ringo, unpublished manuscript).

Our results are at variance with some of those reported by Hughes (1969b) who observed that postlarval pink shrimp (9.2 to 11.1 mm) had an aversion to penetrating waters of low salinity. There are two factors that may explain this discrepancy. Hughes exposed postlarvae to salinity discontinuities, whereas tested the response of postlarvae to continuous salinity gradients. It is also possible that pink shrimp have salinity responses which differ from those of brown and white shrimp.

From further laboratory experiments, Hughes (1972) proposed that postlarval pink shrimp had an endogenous rhythm which synchronized their activity with the tidal cycle. He suggested that this would result in the postlarvae present in the water column being carried shoreward at the time of flood tide. During ebb tides, they could settle to the bottom. Results of Hughes' study appear contradictory. In current-chamber studies, he found that postlarvae swam upstream at time of flood tide and downstream at time of ebb; thus, the shrimp swam "seaward" at a time when they might be transported "landward". If endogenous rhythms assist shrimp in synchronizing their position in the water column with tidal cycle, one might expect postlarvae to express these rhythms in the salinity gradient and control tanks by regularly shifting their distribution in accordance with tidal stage. Although shifts in shrimp distribution occasionally occurred in the experimental tanks, these shifts were not regular and could not be related either to changes in tidal stage or to magnitude of tidal currents (Appendix B).

Several factors may explain the lack of tidal synchrony in variations of postlarval distributions in the apparatus used in our study. Laboratory studies which have elicited behavioral responses of postlarvae to tidal stages have employed currents. Hughes (1969 a, b, c and 1972) simulated tides by reducing salinity in a cylindrical current-chamber, whereas the salinity gradient apparatus we used was a static system. Perhaps the response of postlarvae to tide is governed by moving water as well as by changes in salinity.

Hughes' (1969c) experiments with juvenile pink shrimp suggest that entrainment by the tidal cycle may also affect behavior of postlarvae; juvenile shrimp captured at different tidal stages responded differently to his current-tank apparatus.

The persistence of tidal rhythms of shrimp held in the laboratory has not been demonstrated. It is possible that tidal rhythms require reinforcement, and in the absence of environmental cues, would not persist. The postlarvae tested in these experiments were held for a minimum of 3 days under constant conditions of illumination and temperature in calm water stirred only by currents produced by gentle aeration.

Shrimp may utilize environmental cues to respond to tide which were not provided in the salinity gradient and control tanks. Aldrich (unpublished data) tested postlarvae in experimental tanks within 1 day of capture and found no evidence of tidal rhythmicity. In other experiments, swimming behavior of animals recently collected at the beach were observed in standing water aquaria. The number of postlarvae swimming in the water column was recorded at regular intervals over a period of several days. If, as Hughes (1972) proposed, postlarvae have an endogenous rhythm that results in their being present in the water column at flood tide and close to the bottom at ebb, one would expect more shrimp to be present in the water column during flood than during ebb tide. This was not the case, however, for postlarvae did not vary their swimming activity with tidal stage (Aldrich unpublished data).

It is possible that an endogenous response to tide is not the whole mechanism of postlarval transport. Galveston Bay is a shallow, well-mixed estuary. Accordingly, the water column does not usually exhibit vertical differences in salinity. Tidal rise and fall is less than a meter and, as a result of dominant wind effects, the tide is frequently irregular in cycles. An endogenous response to tide would not appear to have as much transport value on the Texas coast as it might elsewhere.

Several investigators have proposed that other marine organisms respond to tidal cycles and utilize the tides for transport. Verwey (1958) reported that large numbers of a swimming crab, *Portunus holsatus*, were present at the surface during ebb tide, but were not observed during flood tide. He also reported on an earlier paper by Peters and Panning (1933) who found that the megalops of the Chinese crab, *Eriocheir sinensis*, travel up the River Elbe during the flood tide and avoid seaward displacement by seeking the bottom during the ebb. Creutzberg (1958) caught 3 to 10 times more eel elvers during flood than during ebb tide. Carriker (1951), from his field investigations, observed that changing salinity apparently stimulated oyster larvae to swim up from the bottom on flood tide. Bousfield (1955) observed that vertical movements enabled estuarine barnacle larvae to escape from the seaward-moving surface layers. He found that the larval stages were carried seaward by surface water currents. As the larvae matured, they sought deeper waters resulting in their being transported back up the bay. Bousfield also observed that cyprids migrated vertically to take advantage of flood tides. He proposed that the stimulus to migrate upwards on flood tide need not be salinity, but mere mechanical stirring of the bottom.

In order to utilize tidal currents effectively, animals must be able to distinguish tidal stages; however, the manner by which animals distinguish these stages is largely unknown. Creutzberg (1961) found that elvers responded not to differences in salinity, but to the presence or absence of "scent" of inland waters. In his initial investigations, he found that the elvers did not respond to artificial ebb and flood tides simulated by changes in salinity. Later when the tidal cycle was simulated by the addition and later dilution of inland waters, the elvers left the bottom and rode the "flood tide" current. During "ebb tide", they remained close to the bottom and headed into the current. Creutzberg was unable to determine how elvers could determine the end of flood tide when they were in higher water levels; nevertheless, in his experiments, the elvers returned to the bottom at the end of the flood tide.

Haafter and Verwey (1960) tested the response of nudibranchs to water containing the scent of a prey species. They found that in the absence of a scent, the slugs generally swam with the current; however, when water containing scent was introduced, the animals headed into the current. Haafter and Verwey concluded that currents take over the role of orienting the animal so that it will be led to the place of scent origin. Scent has not been studied in post-larval shrimp, but such a study would provide useful information on possible orientation mechanisms utilized by them.

Field surveys disagree as to whether postlarval shrimp exhibit diel rhythms. Various researchers have investigated diel periodicity in postlarvae by taking samples in tidal pass entrances at regular intervals during 24-hr periods. Tabb et al. (1962) found immigrating pink postlarvae almost exclusively in the water column during hours of darkness. They believed light to be a negative stimulus, as they caught almost as many postlarvae during a flood tide on a dark, cloudy day as they did after dark on a flooding tide on the same day. Eldred et al. (1965), however, caught approximately the same number of postlarval pink shrimp in the daytime as at night. Young of other genera caught during their studies revealed much more pronounced nocturnal rhythms--98% of _Trachypenaeus_ postlarvae and 88% of _Sicyonia_ postlarvae were caught at nighttime during the study. Baxter and Furr (1964) estimated that 70% of the postlarval brown shrimp in their samples at the Bolivar Roads entrance to Galveston Bay were caught between 9 PM and 6 AM, but a similar study done at nearby Rollover Pass showed no relationship between time of day and number of postlarvae caught (Berry and Baxter 1969). Copeland and Truitt (1966) found that brown shrimp postlarvae were generally found near the surface at night; whereas they detected no difference in vertical distribution during the day. Williams and Deubler (1968) also reported that generally more grooved postlarval shrimp were present in surface plankton tows at night than during the day; furthermore, a bright light at night in the vicinity of their collection station drastically reduced their catch. In addition, they found that higher catches were made at times of new moon than at full moon. St. Amant et al. (1966) found no significant differences between numbers of brown shrimp caught during the day and the number caught at night. Caillouet et al. (1970), sampling every 2 hr over a 98-hr period, found no significant differences between numbers of postlarval brown shrimp in day and night catches. Caillouet et al. (1968) investigated the diel rhythms of white shrimp using the sampling program described above for brown shrimp. They reported that peak catches of white shrimp occurred at night 2 to 4 hr after high water and at the lowest water temperatures during each of the four 24-hour periods. During their study, however, tides were diurnal with flood tide occurring near midnight and ebb tide occurring near noon. They did not discuss whether time of day had a greater influence on postlarval abundance than tidal stage. King (1971) found no relationship between rate of immigration and time of day for either brown or white shrimp.

Our experimental work produced no evidence for diel cycles in shrimp distribution relative to depth or to salinity. Perhaps the lack of a suitable substrate or other factors associated with the apparatus or experimental conditions prevented the expression of diel cycles. Hagerman (1970) investigating diel behavior of *Crangon vulgaris* found it was necessary to provide the proper substratum for the animals to exhibit diel locomotory activity in the laboratory. In the absence of sandy substratum, *Crangon* had a very high constant level of swimming activity. When substrate was provided, the animals exhibited typical patterns of a single activity peak and a pronounced difference between day and night activity.

Hughes (1972) found no evidence of diel periodicity in pink shrimp postlarvae tested under continuous red light illumination. He concluded that the observed confining of pink shrimp activity in nature to nighttime is a direct response to prevailing light intensities. Only in one experiment (#37) did we observe postlarvae responding to light. In this experiment, the tanks were maintained in complete darkness except for observation periods. Light was apparently the stimulus that elicited the response of shrimp in the gradient tank. Our attempt to duplicate the results of this experiment (#42) was unsuccessful; little difference was observed between "light" and "dark" distributions. The variance in response to red light observed in the laboratory and the irregularity in diel activity reported from the field may indicate that postlarval shrimp have a variable response to light in nature.

Estuarine Phase of the Shrimp Life Cycle

The major influxes of postlarval brown and white shrimp occur at different times of the year. The peak immigration of brown shrimp usually occurs during March or April, and in some years there is a minor peak in late summer. White shrimp do not appear in the estuaries until May. Seasonal distribution of white shrimp postlarvae suggests that two peaks of abundance may occur each summer (Baxter and Renfro 1967).

There is a paucity of information on field distribution of postlarval shrimp. Investigations by Truesdale (1970), Conte (1971), and Caillouet et al. (1971, personal interpretation of raw data) suggest that salinity _per se_ (except for salinities less than 1 ppt) does not influence spacial distribution of postlarval white and brown shrimp in the estuary.

Our data show that the salinity preference of brown shrimp differed significantly according to the season of the year. From March to early April, brown shrimp postlarval distributions showed a median salinity average of 30 ppt, 9 ppt greater than that found for brown shrimp tested in the summer. This striking difference in response between spring and summer brown shrimp postlarvae is difficult to explain. One possible explanation is the different age of the shrimp being tested. As a result of prolonged slow growth at low temperatures offshore, shrimp entering the estuaries in the spring are larger and apparently older than shrimp entering in the summer (Aldrich, Wood, and Baxter 1968; Temple and Fischer 1968).

Field studies show that in the spring, brown shrimp postlarvae are distributed in the estuaries in salinities considerably lower than would be expected from their distribution in laboratory salinity gradient tanks. Truesdale (1970) concluded that salinity _per se_ had no effect on postlarval distribution and abundance in a portion of Trinity Bay near the Trinity River except during periods of high river discharge. During these times, the salinity of large expanses of his study area decreased to 0 ppt, and the postlarvae disappeared from the collecting areas. He concluded that the shrimp either perished or were swept away. Conte (1971) caught numbers of postlarval brown shrimp in the shallow waters (1 to 1.5 m) of two marsh embayments near West Bay of the Galveston Bay System. These areas were characterized by salinities ranging from 11 to 22 ppt. He noted no relationship between salinity and the distribution of postlarval shrimp in his study area.

Other field studies suggest that salinity may affect survival of postlarvae in the estuaries. St. Amant et al. (1966) suggested that salinities greater than 15 ppt appeared to enhance survival and growth of postlarvae. Gaidry and White (1973) reported that commercial catches of brown shrimp were poor in those years when salinities were less than 15 ppt at the time postlarvae were present in the estuaries. Correspondingly, years of high production were always associated with salinities greater than 15 ppt. The relationship between salinity and production was not clearly defined since years of low salinity were also characterized by low temperature.

Parker (1970) found that salinity apparently did not influence the distribution of juvenile brown shrimp in Galveston Bay. In the spring, they were encountered in areas where bottom salinity ranged from 0.9 to 36.5 ppt. He reported that juvenile shrimp were most abundant in salinities less than 5 ppt during 1 year and in salinities of less than 10 ppt the next.

Laboratory studies showed that juvenile brown shrimp have the ability to osmoregulate over a wide range of salinities, but there was some indication that brown shrimp were adapted to regulate in a salinity range of approximately 23 to 43 ppt (McFarland and Lee 1963).

There is no evidence to suggest that brown shrimp postlarvae are adapted to specific salinities. In laboratory experiments at non-limiting temperatures, salinities ranging from 2 to 40 ppt did not affect the growth rate of postlarval brown shrimp (Zein-Eldin 1963, Zein-Eldin and Aldrich 1965). Zein-Eldin and Griffith (1969) reported that extremes tolerated by 80% of brown shrimp postlarvae were salinities greater than 40 ppt and less than 5 ppt.

Temperature is apparently more important than salinity to postlarval growth and survival. In the laboratory, postlarval brown shrimp demonstrated a decreased tolerance to low salinities at temperatures lower than 15 C (Zein-Eldin and Aldrich 1965). Field studies indicate that low temperatures in the spring may be detrimental to postlarvae. Gaidry and White (1973) found that years of low commercial landings of brown shrimp were associated with prolonged estuarine temperatures of less than 20 C at the time of postlarval immigration to the estuary. Other studies indicate that estuarine temperature may determine when postlarvae enter the estuaries. St. Amant et al. (1963) stated that ". . . maximal postlarval densities do not appear in Louisiana until water temperatures remain above 20°C." Similarly, more than half the shrimp collected at the entrance to Galveston Bay, Texas, in the spring were collected at water temperatures of 18 to 22 C (Aldrich, Wood, and Baxter 1968). Laboratory experiments showed that temperature is important to postlarval survival at low salinities (Zein-Eldin and Aldrich 1965). Their experiments suggest that postlarvae would have a hard time surviving in the peripheral marshes since these areas in the spring are of low salinity and are subject to rapid cooling. Other laboratory experiments (Aldrich, Wood, and Baxter 1968) suggest that postlarval shrimp in nature reduce the degree of temperature change to which they are exposed by burrowing into the substrate at the onset of cool temperatures. This adaptive response would enable them to utilize large areas of the peripheral marsh in the spring.

In contrast to the marked seasonal differences in salinity preference exhibited by brown shrimp postlarvae, there was no significant difference in the salinity preference of white shrimp postlarvae tested in summer and fall except at the 95th percentile (the low salinity region of shrimp distribution). In the summer, brown and white shrimp postlarvae did not exhibit markedly different preferences for salinity. Only the median and 75th percentile were significantly higher for white than for brown postlarval distributions, and the average salinity difference between the medians was only 3.2 ppt. This suggests that there is less difference in salinity preference between the two species at the postlarval stage than has been suggested for larger stages of the life cycle.

Laboratory studies indicate that juvenile and adult brown and white shrimp are physiologically adapted for somewhat different salinity regimes. McFarland and Lee (1963) found that white and brown shrimp could osmoregulate over a wide range of salinities; however, white shrimp were better adapted to tolerate low salinities, whereas brown shrimp were better adapted to higher salinities. On the other hand, there is no evidence to indicate that postlarvae of the two species have different salinity optima. Zein-Eldin and Griffith (1969) reported that salinity extremes tolerated by 80% of the shrimp were very similar. At non-limiting temperatures, the extremes defined for brown shrimp postlarvae were salinities greater than 40 ppt and less than 5 ppt and for white shrimp postlarvae, 40 to 45 ppt and 4 ppt. In laboratory studies, salinity _per se_ did not affect the growth rate of postlarval shrimp (Zein-Eldin and Aldrich 1965, Zein-Eldin and Griffith 1969).

Some studies suggest that different size shrimp may utilize different areas of the estuary. Joyce (1965) observed that smaller brown and white shrimp occupied shallower waters than larger individuals. St. Amant et al. (1966) and Parker (1970) mention that the shrimp move from the periphery to deeper waters as they increase in size, but they did not indicate whether the shrimp were also moving into more saline water. Lindner and Anderson (1956) observed that there was a general progression from inside to outside waters in the size of trawl-caught white shrimp. The largest shrimp were collected in the outside waters where salinity was greatest. They found that the distribution of shrimp was not related to specific salinities, but with locality. Parker (1966) reported that generally the smaller brown shrimp were concentrated in the areas of lower salinity of the estuary and,as they grew, migrated into the higher salinity environment. Schmidt (1972) found that the mean size of brown and white shrimp increased as distance offshore and distance downbay increased. Our data are inconclusive as to whether shrimp differing in age and size have different salinity preferences.

Some investigators have shown an apparent relationship between distribution of juvenile brown and white shrimp and salinity. Williams (1955) reported that populations of juvenile white shrimp occurred in nursery areas of low salinity. In areas where white shrimp were abundant, few juvenile brown shrimp were present. Gunter, Christmas, and Killebrew (1964) reported that white shrimp juveniles were more abundant in salinities less than 10 ppt while brown shrimp juveniles were more abundant in salinities between 10.0 ppt and 19.9 ppt. They pointed out that most white shrimp are taken off Louisiana where the inside waters are relatively fresh while the greatest concentration of brown shrimp is off Texas where bay salinities are generally higher than in Louisiana. Gunter and Hildebrand (1954) found a correlation between rainfall and commercial catches of white shrimp off Texas. They proposed that increased rainfall and dilution of coastal waters might be favorable to white shrimp in Texas. Gunter and Edwards (1969) found no correlation of brown shrimp production with rainfall, but suggested that a longer time series of data may show a negative correlation. Although the above studies suggest that brown and white shrimp may exhibit distinct salinity preferences in nature, an examination of shrimp distributions shows that some juveniles are present over a wide range of salinities. Brown shrimp have been collected in salinity extremes of 0.1 ppt (Williams and Deubler 1968) to 69.0 ppt (Simmons 1957) and white shrimp have been collected in extremes of 0.22 ppt (Gunter and Hall 1963) to 47.96 ppt (Hildebrand, personal communication cited by Lindner and Cook 1970).

Competition between brown and white shrimp.--The information available suggests that postlarvae of both species utilize *Spartina* marshes as nursery areas for the first few weeks after they arrive in the estuary (Mock 1966, Truesdale 1970, Conte 1971). Competition on the nursery grounds is reduced by temporal isolation during the period of major abundance on the estuarine nursery grounds since the major influxes of brown and white postlarvae occur at different times (Baxter and Renfro 1967). When the white shrimp are entering the estuaries as postlarvae, the brown shrimp have moved to deeper waters in the estuary or have emigrated to the sea. During the summer, both species are present on the nursery grounds in lesser numbers. At this time, it is possible that the species actively compete for the available shelter in the marshes.

On the basis of laboratory experiments, Giles and Zamora (1973) suggested that competition for grass beds may occur between white and brown shrimp juveniles. They found that when brown and white shrimp were tested separately, both preferred the planted area of the tank. When the two species were tested together, however, the majority of the brown shrimp were found in the planted half of the tank, while the majority of the white shrimp were in the unplanted half. The authors suggested that should such competition take place in nature, brown shrimp would displace white shrimp. It would be useful to determine whether postlarval shrimp likewise show a preference for grassy areas and whether species competition plays a role in distributing them throughout estuaries.

Competition might be studied in gradient tanks. In one experiment (#24), we attempted to test the salinity preferences of brown and white shrimp together in one tank; however, under these experimental conditions, we were unable to distinguish between the species using only size and other gross morphological characteristics. To test both species concurrently in gradients, one would have to mark the postlarvae to enable accurate species determination.

It is possible that the two species are present in the same nursery areas, but do not utilize the same food. Karim (1969) showed that white shrimp postlarvae were more selective of food than were brown shrimp postlarvae. He suggested that food may be less limiting to the distribution, survival, and multiplication of brown shrimp than it might be for white shrimp.

Variation in Experimental Results

The salinity gradient apparatus was designed to test the response of organisms to salinity under controlled conditions. To achieve this goal, animals were acclimated under constant conditions of temperature and salinity, and temperature was controlled during the experiments. In addition, the tanks were housed in light-tight rooms so that the only source of illumination was red fluorescent bulbs. Control tanks were utilized to detect any inherent component of the experimental apparatus that might also elicit responses from postlarval shrimp. In spite of these precautions, postlarvae, at times, exhibited variations in distributions that could not be explained.

The response of shrimp in gradient tanks may have been influenced by constant holding conditions in the laboratory, as, in the field the shrimp would have been exposed to a wide range of salinities and temperatures. The temperature preference investigations by Norris (1963) suggested that prolonged acclimation to uniform temperatures can produce qualitative changes in the type of response. He reported that the normal responses of a fish, *Girella nigrans*, which had been acclimated for 21 days, seemed dulled, and the fish would often stop in temperatures which it normally would never enter. His results suggest that holding animals in the laboratory under constant conditions may modify their responses to environmental stimuli. Uniform holding conditions, therefore, may also have an effect on the salinity preference of postlarval shrimp.

Variations between experiments was striking. The distributions of shrimp collected together and tested at the same time were generally more similar than those of shrimp collected at different times and held for equivalent periods before testing. In one experiment (#3), the average median salinity of white shrimp distributions was more than 8 ppt lower than that of any other group of white shrimp tested during the 2 years of investigations. Shrimp also responded variably to acclimation salinities and to type of illumination (periodic vs. continuous).

One source of variability between experiments may be differences in the ages of the postlarvae being tested. Presently there is no way of determining the age of postlarval shrimp collected at the beachfront. Size cannot be used as an index of age. For example, shrimp collected in the spring are similar in size yet they probably hatched at different times during the winter months (Aldrich, Wood, and Baxter 1968; Temple and Fischer 1968). Shrimp taken at the beachfront could differ in age from a few days to a month or more depending on the season. Variation in age may be minimized by using hatchery animals since records of the spawning dates are available; however, NMFS personnel have noted variation between groups of laboratory spawned shrimp. Shrimp spawned in the laboratory differed in survival between larval stages, in their rate of growth, and in their response to selected environmental conditions (Anon. 1972). The variability in survival of hatchery-reared postlarvae was also observed in my salinity gradient experiments. Survival ranged from 23% (experiments 38 and 40) to 100% (experiments 27 and 28). The above responses may be related to the lack of selection in hatchery populations of shrimp.

The shrimp may be responding to some factor other than salinity which is at present unrecognized. Further evidence of this unexplained variation are the shifts that occurred during the experiments. These shifts could not be related to either temperature, time of day, tidal phase, or to oxygen depletion. The results of the homogeneity of variance tests (Tables 19 and 20, p.58) are also difficult to interpret. It is possible that the presence of a salinity gradient may have been a sufficient stimulus to override the variability that was exhibited by the white shrimp in the absence of a salinity gradient in the control tank. We can offer no explanation for the fact that white shrimp exhibited greater variability than browns.

The preceding discussion indicates the presence of unexplained variability in results of experiments with postlarval shrimp. Variability of response may be an adaptive characteristic of postlarval shrimp populations that allows shrimp to successfully utilize the widely fluctuating conditions present in the estuaries. In some cases, the observed variability may represent an intrinsic variation within the shrimp population. In others, the shrimp may be responding to a factor other than salinity which is at present, unrecognized. Further study will be required to recognize the causes of this presently unexplained variability in shrimp behavior.

The Importance of Freshwater Inflow to the Estuaries

The relationship of estuaries to commercial fisheries is well established (Chapman 1966, Gunter 1967, McHugh 1967). Chapman estimated that 98% of the commercial catch of Texas, by weight, was composed of estuarine-dependent species. Freshwater inflow is an integral part of an estuarine system. This is implicit in the definition of an estuary by Pritchard (1967): ". . . an estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with freshwater derived from land drainage." Because of the major role freshwater plays in the estuaries, one should view with concern the proposed Texas Water Plan which would divert large amounts of freshwater from estuaries to agriculture and industry. The total effect of the planned Texas Water Plan would be to reduce freshwater inflow to the estuaries from a 1941-1957 average of 19.8 million hectare-meters per year to an average of 10.5 million hectare-meters per year. Moreover during very dry years, total discharge possibly would not exceed 3 million hectare-meters per year (Chapman 1966). This is less than the amount of discharge during the worst years of Texas droughts. The implementation of the Texas Water Plan could reduce the nursery areas of the estuaries. Truesdale (1970) stated that the proposed Wallisville Reservoir on the Trinity River would destroy 30,880 hectares of nursery areas by converting present marshland upstream of the dam into a freshwater lake.

Freshwater may have another important role in estuaries. Results of the present study suggest that postlarval shrimp utilize salinity gradients for orientation to the estuarine nursery grounds. Odum (1970) proposed that estuarine organisms may use gradients of dissolved organics as "roadmaps" to orient themselves to the estuaries. The sharp curtailment of inflow and the subsequent decrease in the seaward extent of these gradients could affect the immigration of estuarine-dependent organisms into their nursery areas.

CONCLUSIONS

1. Postlarvae tested in artificial salinity gradients selected salinities lower than those generally present in the open Gulf of Mexico. In the field, postlarvae may use natural salinity gradients which extend from the estuary seaward to orient themselves to the estuarine nursery grounds.
2. Brown shrimp exhibited a seasonal difference in salinity preference. Shrimp tested in the spring preferred higher salinities than those tested in the summer and fall. The probable older age of spring postlarvae may explain their differences in salinity preference.
3. White shrimp postlarvae, in contrast to brown shrimp postlarvae, showed a seasonal difference in salinity preference only at the low salinity portion of the shrimp distribution.
4. In the summer, the distribution of white and brown shrimp postlarvae, which were tested at the same time in gradient tanks, did not differ greatly. Information on the distribution of postlarvae in the estuaries is sparse; however, those studies that have been conducted also indicated that salinity *per se* does not influence the distribution of white and brown shrimp postlarvae.
5. Illumination, acclimation salinity and temperature had a variable influence on postlarval distribution in salinity gradient tanks.

6. Occasionally, shifts occurred in shrimp distributions during an experiment that could not be related to time of day or tidal stage. At these times, shrimp were apparently responding to some factor other than salinity which is presently unrecognized. Further study will be needed to determine the cause of these unexplained shifts.
7. The interruption of freshwater inflow to the estuaries by water diversion projects such as the Texas Water Plan would affect natural gradients of both salinity and dissolved organics. In view of the results presented here, alteration of these gradients could affect the immigration of shrimp as well as of other estuarine-dependent organisms.

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APPENDICES

A - Distribution of postlarval brown and white shrimp (*P. aztecus* and *P. setiferus*) in experimental tanks
Figures 1 through 100

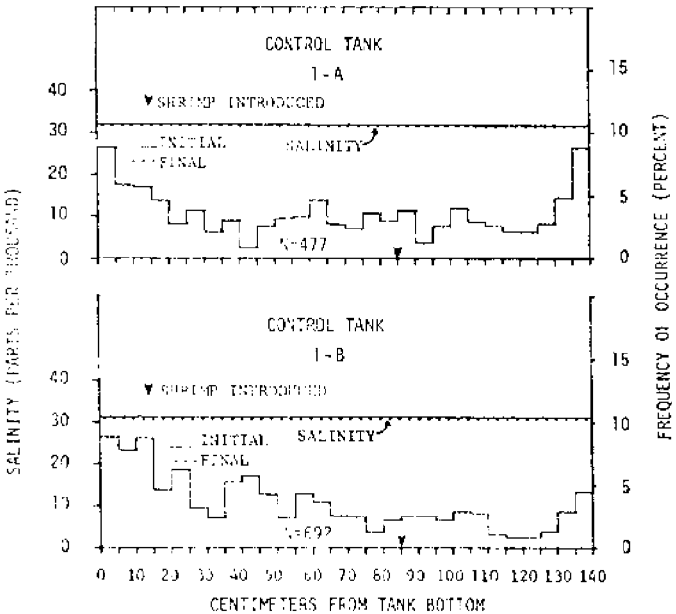


FIGURE 1.—Distribution of postlarval brown shrimp (P. aztecus) in control tanks A & B (replicates) in experiment 1 during observations made from 2.0 to 26.0 hours after shrimp were introduced. Temperature approximated 23 C. Number of shrimp introduced into tank A = 28, tank B = 38.

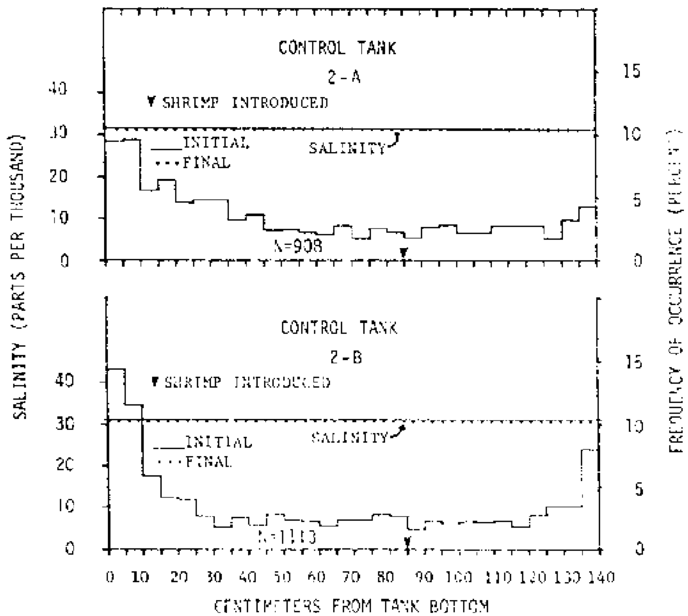
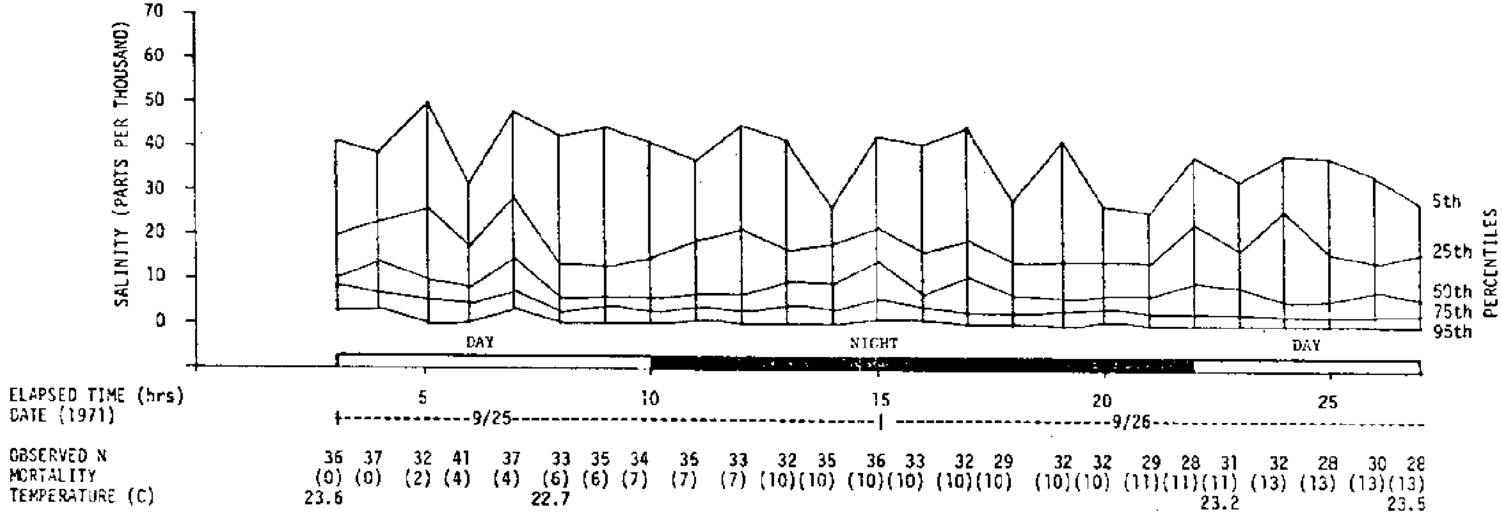


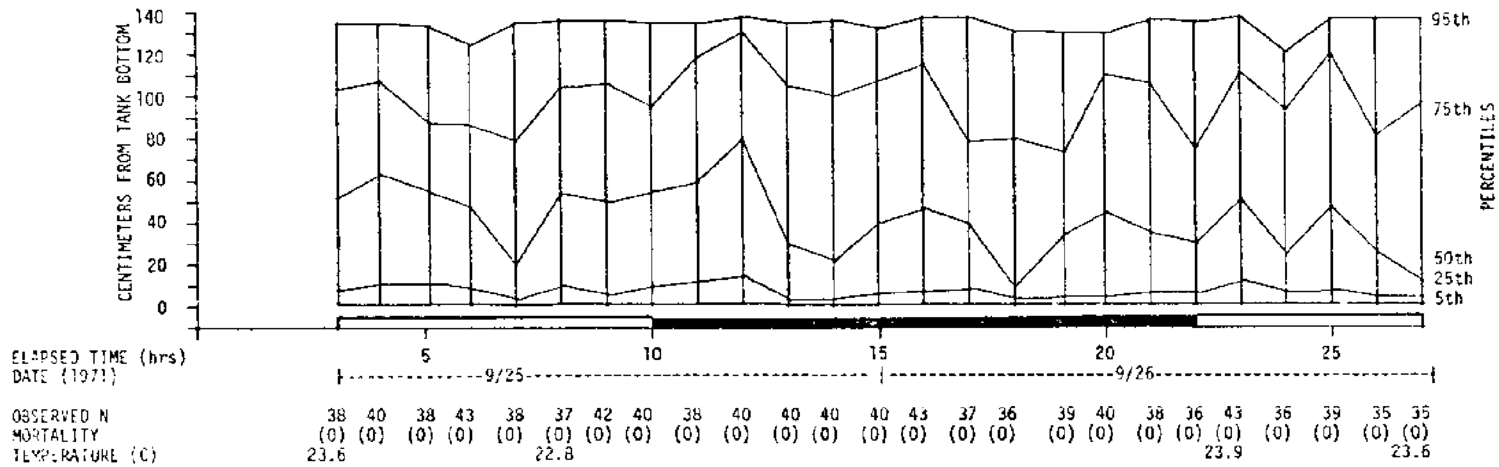
FIGURE 2.—Distribution of postlarval white shrimp (P. setiferus) in control tanks A & B (replicates) in experiment 2 during observations made from 2.0 to 26.0 hours after shrimp were introduced. Temperature approximated 23 C. Number of shrimp introduced into tank A = 38, tank B = 46.

FIGURE 3.—Distribution of postlarval white shrimp (*P. setiferus*) under continuous low level red illumination in experiment 3, tanks A & B. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles are oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

GRADIENT TANK 3-A



CONTROL TANK 3-B



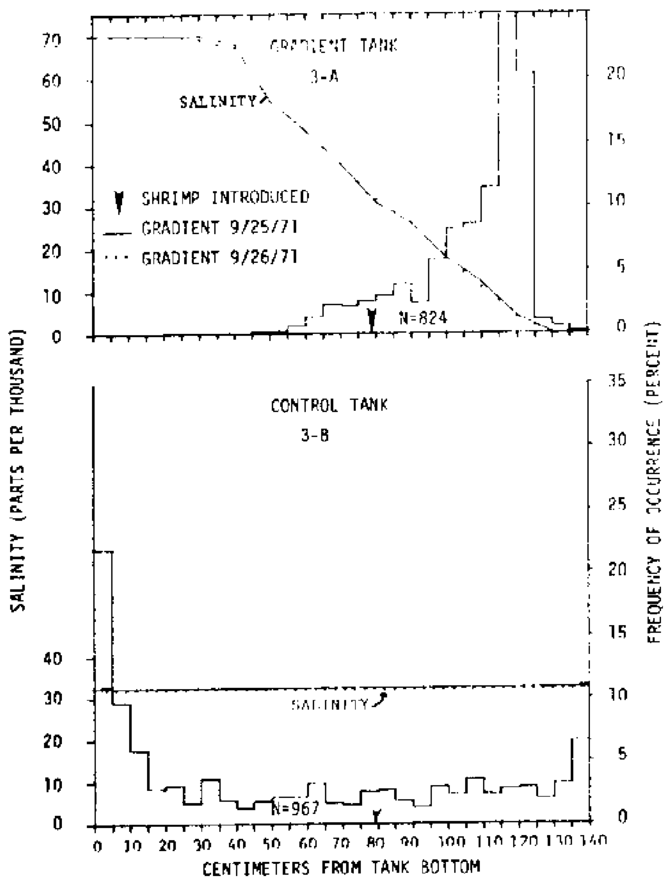
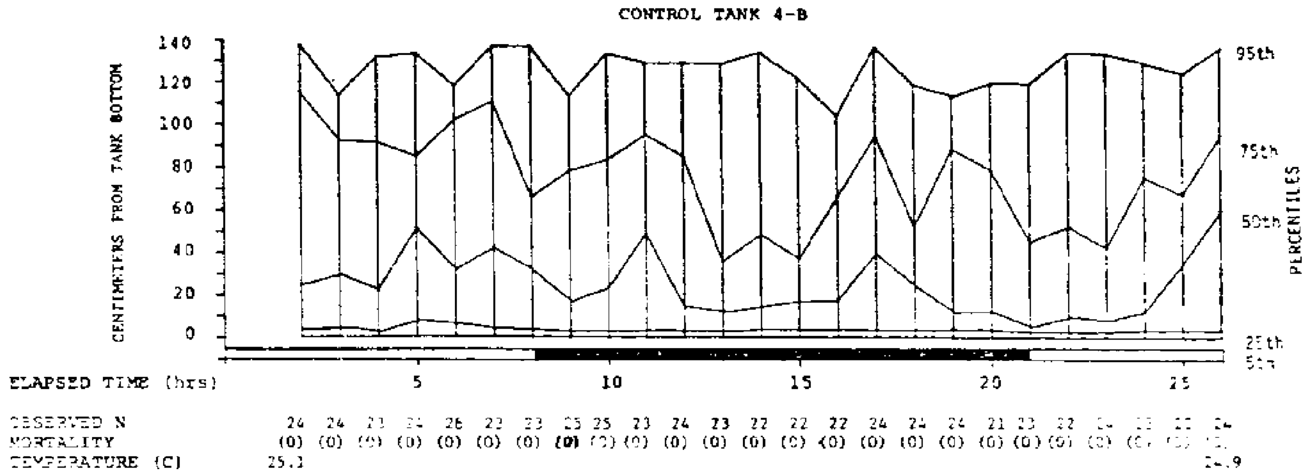
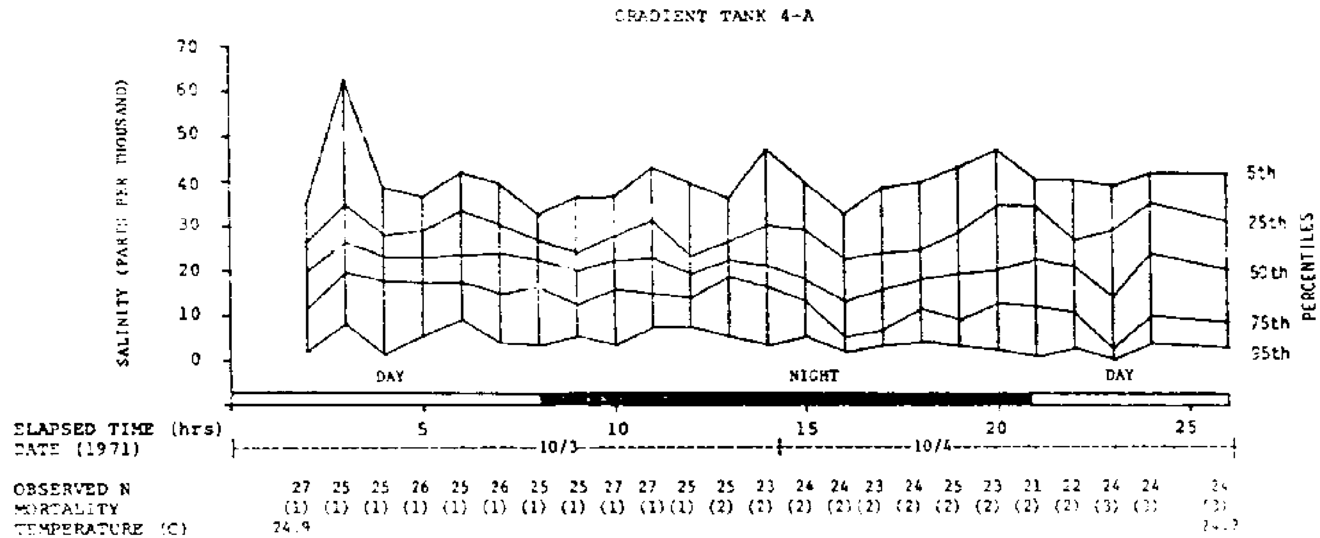


FIGURE 4.—Distribution of postlarval white shrimp (P. setiferus) and salinity in experiment 3, tanks A & B, during observations made from 3.1 to 27.0 hours after shrimp were introduced. Temperature approximated 23 C. Number of shrimp introduced into tank A = 48, tank B =48. N = total number of shrimp counted in a series of observations.

FIGURE 5.—Distribution of postlarval white shrimp (*P. setiferus*) under continuous low level red illumination in experiment 4, tanks A & B. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles are oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp made during an observation period; dead shrimp not removed.


CONTROL TANK 4-B
CENTIMETERS FROM TANK BOTTOM
140
120
100
80
60
40
20
0
95th
75th
50th
25th
5th
PERCENTILES
ELAPSED TIME (hrs)
5
10
15
20
25
OBSERVED N
MORTALITY
TEMPERATURE (C)
25.3


GRADIENT TANK 4-A
SALINITY (PARTS PER THOUSAND)
70
60
50
40
30
20
10
0
5th
25th
50th
75th
95th
PERCENTILES
DAY
NIGHT
DAY
ELAPSED TIME (hrs)
5
10
15
20
25
DATE (1971)
10/3
10/4
OBSERVED N
MORTALITY
TEMPERATURE (C)
24.9

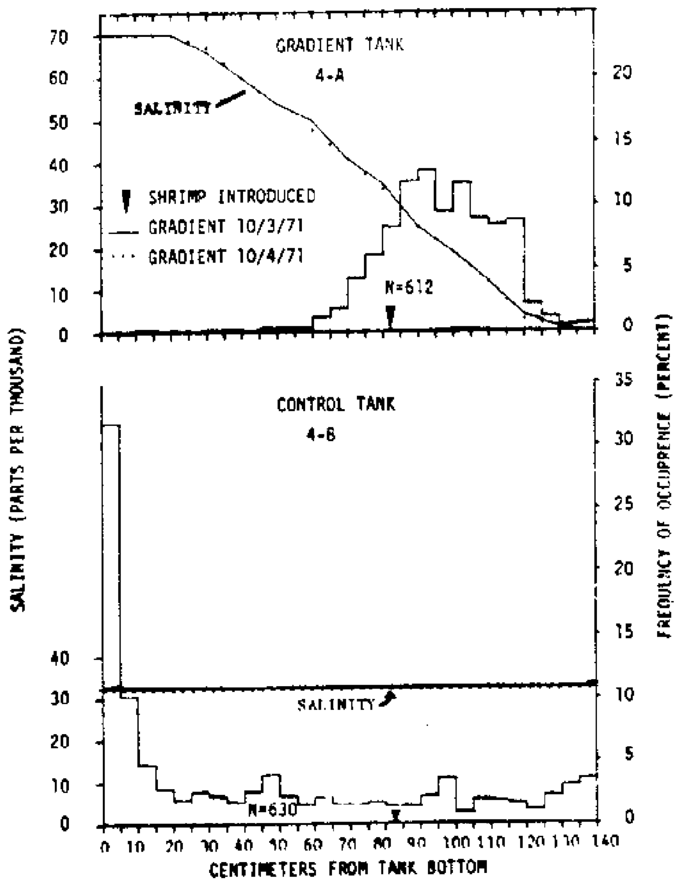
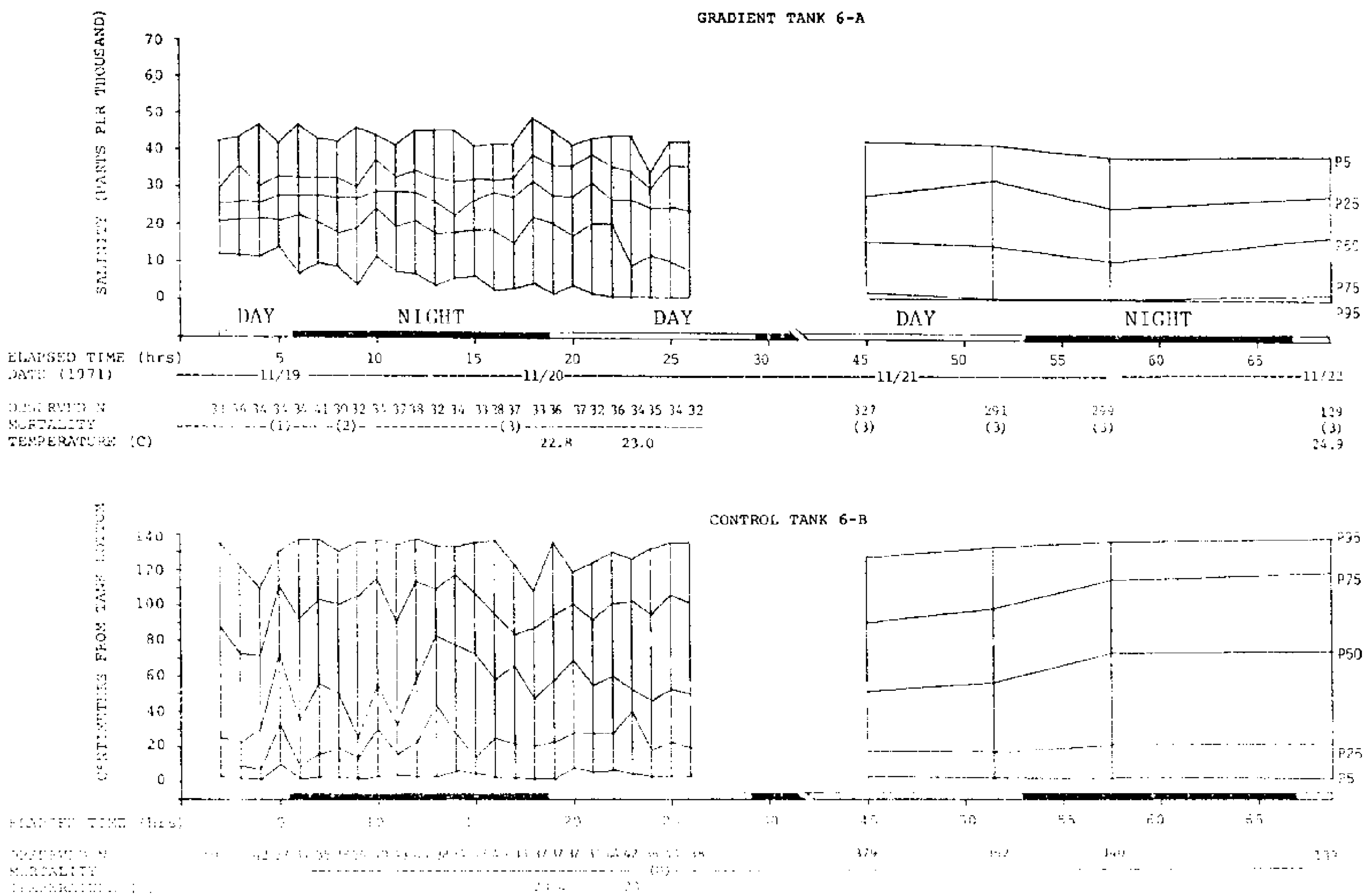


FIGURE 6.—Distribution of postlarval white shrimp (P. setiferus) and salinity in experiment 4, tanks A & B, during observations made from 2.0 to 26.0 hours after shrimp were introduced. Temerature approximated 25.0 C. Number of shrimp introduced into tank A = 27, tank B = 27. N = total number of shrimp counted in a series of observations.

FIGURE 7.—Distribution of postlarval white shrimp (*P. setiferus*) under continuous low level red illumination in experiment 6, tanks A & B. Vertical lines indicate distributions. Midline represents medians (P50) and the other four lines show the 5th, 25th, 75th and 95th percentiles (P5, P25, P75 and P95, respectively); percentiles are oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.


GRADIENT TANK 6-A
SALINITY (PARTS PER THOUSAND)
DAY
NIGHT
DAY
DAY
NIGHT
P5
P25
P75
ELAPSED TIME (hrs)
TEMPERATURE (C)
22.8
23.0
CONTROL TANK 6-B
P95
P75
P50

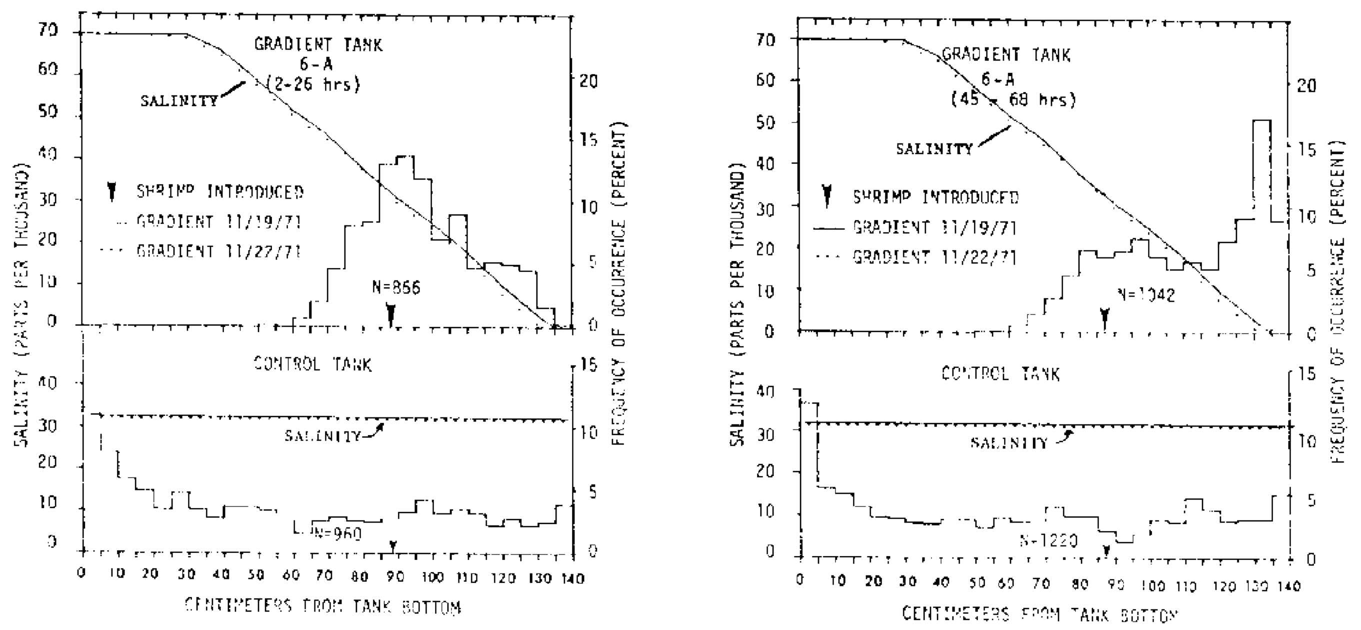


FIGURE 8.—Distribution of postlarval white shrimp (P. setiferus) and salinity in experiment 6 during observations made from 2.0 to 26.0 hours and from 45.0 to 68.8 hours after shrimp were introduced. Temperature approximated 23 C. Number of shrimp introduced into tank A = 37 and tank B = 44. N = total number of shrimp counted in a series of observations.

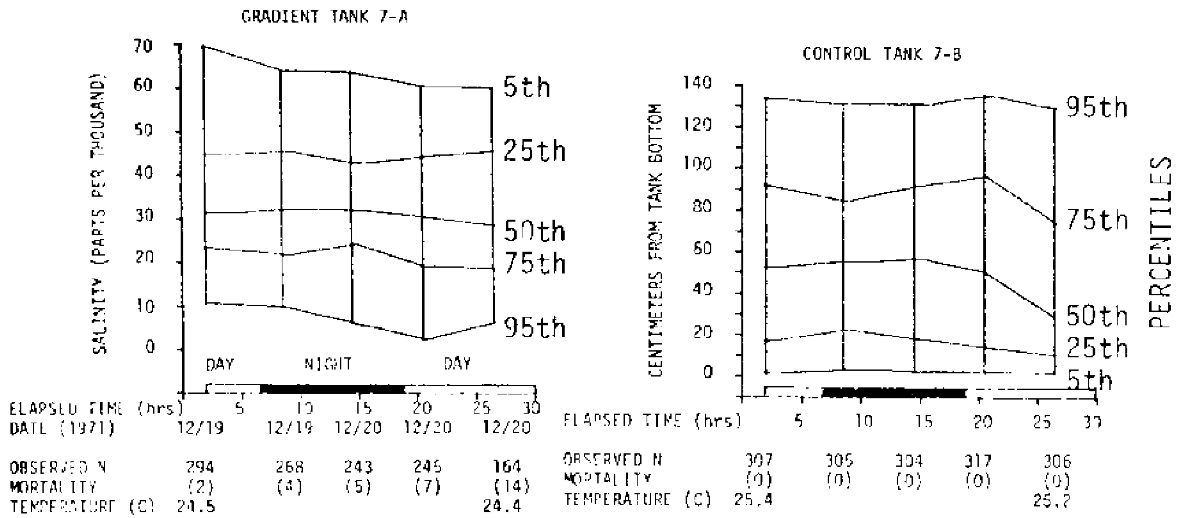


FIGURE 9.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 7, tanks A & B. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles are oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

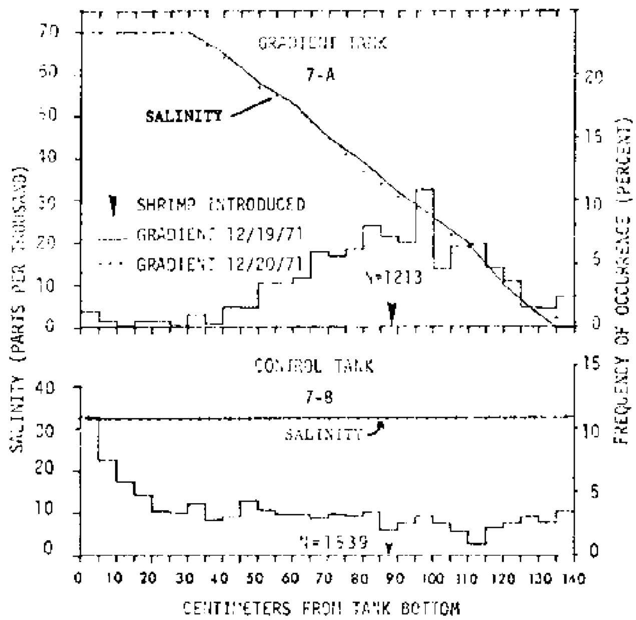
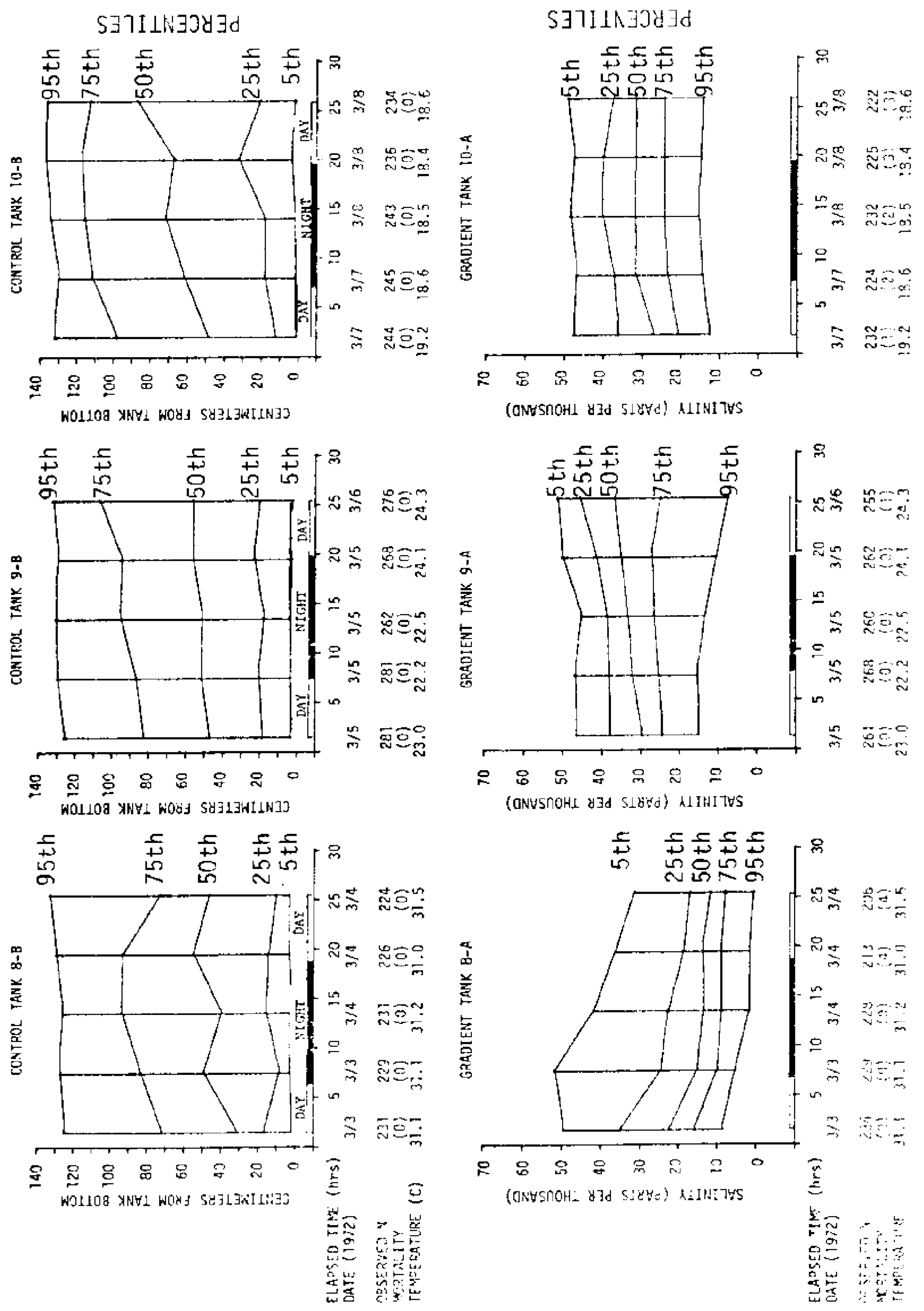


FIGURE 10.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 7, tanks A & B, during observations made from 2.0 to 26.5 hours after shrimp were introduced. Temperature approximated 25 C. Number of shrimp introduced into tank A = 25, tank B = 25. N = total number of shrimp counted in a series of observations.

FIGURE 11.—Distribution of postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiments 8, 9 and 10. Postlarvae were collected between 2/25/72 and 2/26/72 and acclimated to 30 C, 23 C and 18 C (experiments 8, 9 and 10, respectively). Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles are oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 11


CONTROL TANK 10-B
CONTROL TANK 9-B
CONTROL TANK 8-B
GRADIENT TANK 10-A
GRADIENT TANK 9-A
GRADIENT TANK 8-A
PERCENTILES
95th
75th
50th
25th
5th
CENTIMETERS FROM TANK BOTTOM
SALINITY (PARTS PER THOUSAND)
DAY
NIGHT
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)

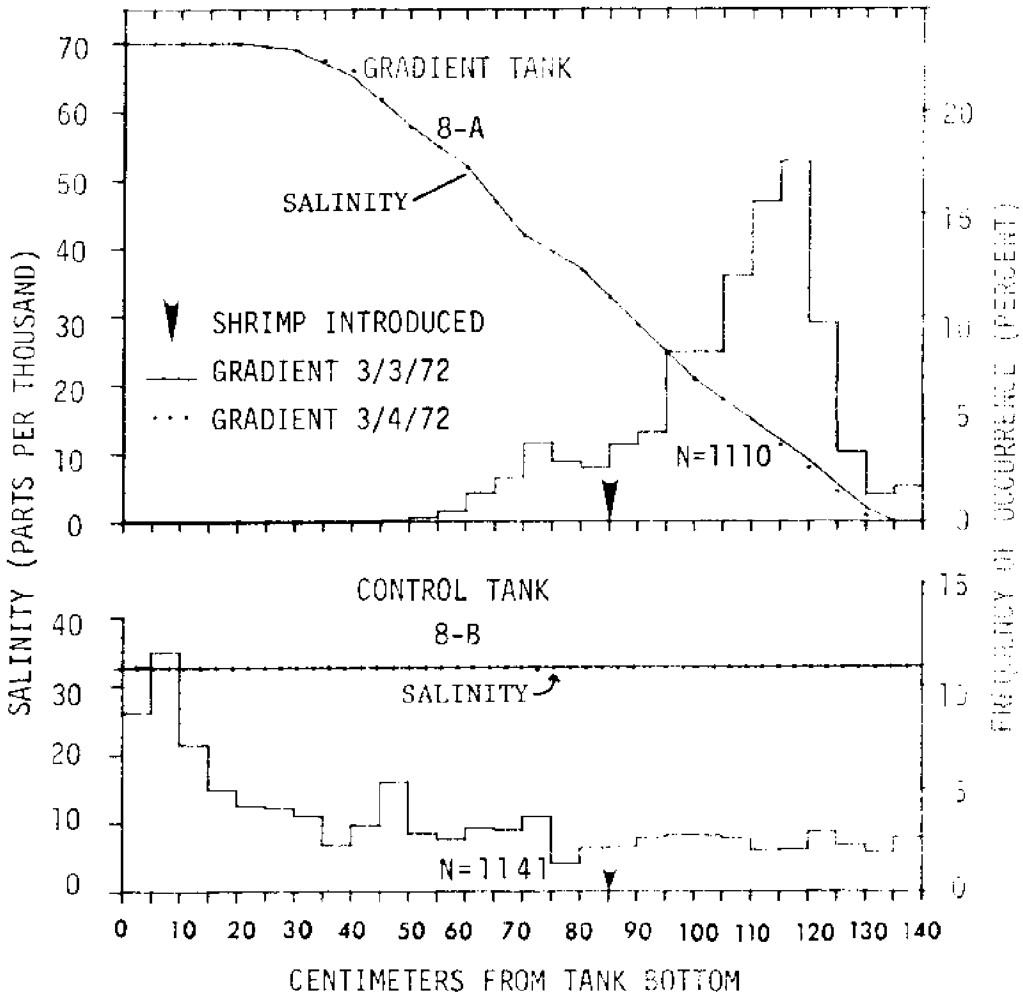


FIGURE 12.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 8, tanks A & B, during observations made from 1.5 to 25.5 hours after shrimp were introduced. Postlarvae were collected between 2/25/72 and 2/26/72 and acclimated for 9 days to 30 C. Temperature approximated 31 C during experiment. Number of shrimp introduced into tank A = 34, tank B = 34. N = total number of shrimp counted in a series of observations.

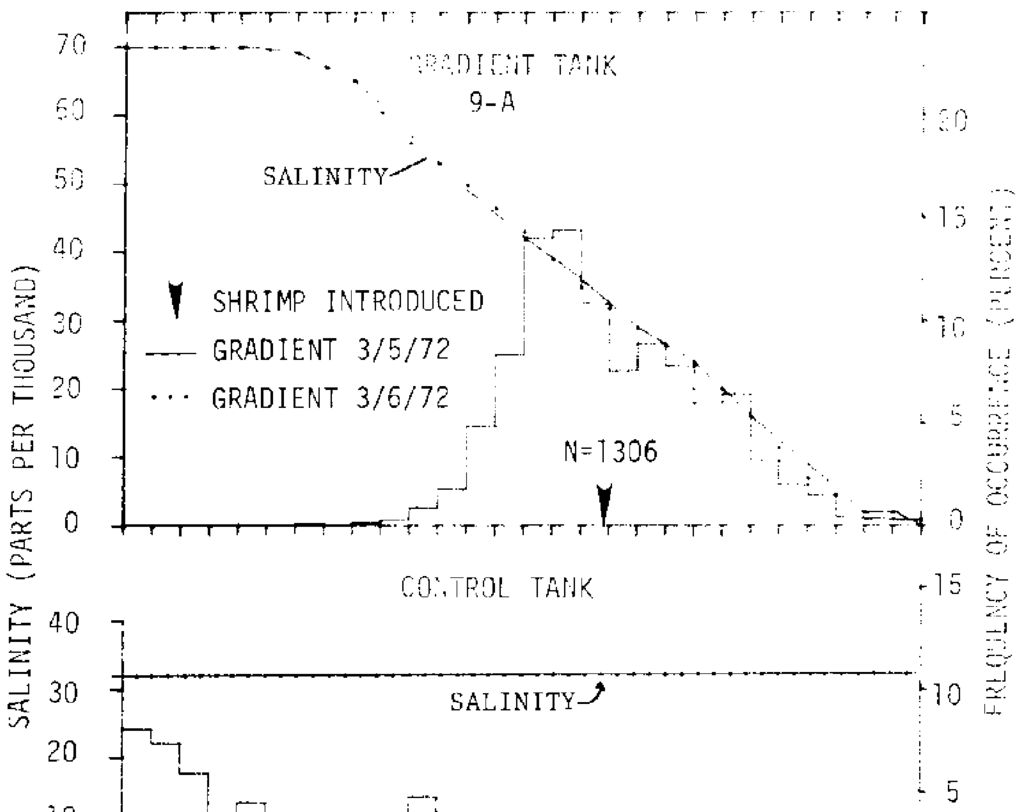


FIGURE 13.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 9, tanks A & B, during observations made from 1.5 to 25.5 hours after shrimp were introduced. Postlarvae were collected between 2/25/72 and 2/26/72 and acclimated for 11 days to 23 C. Temperature approximated 22 C during the experiment. Number of shrimp introduced into tank A = 36, tank B = 36. N = total number of shrimp counted during a series of observations.

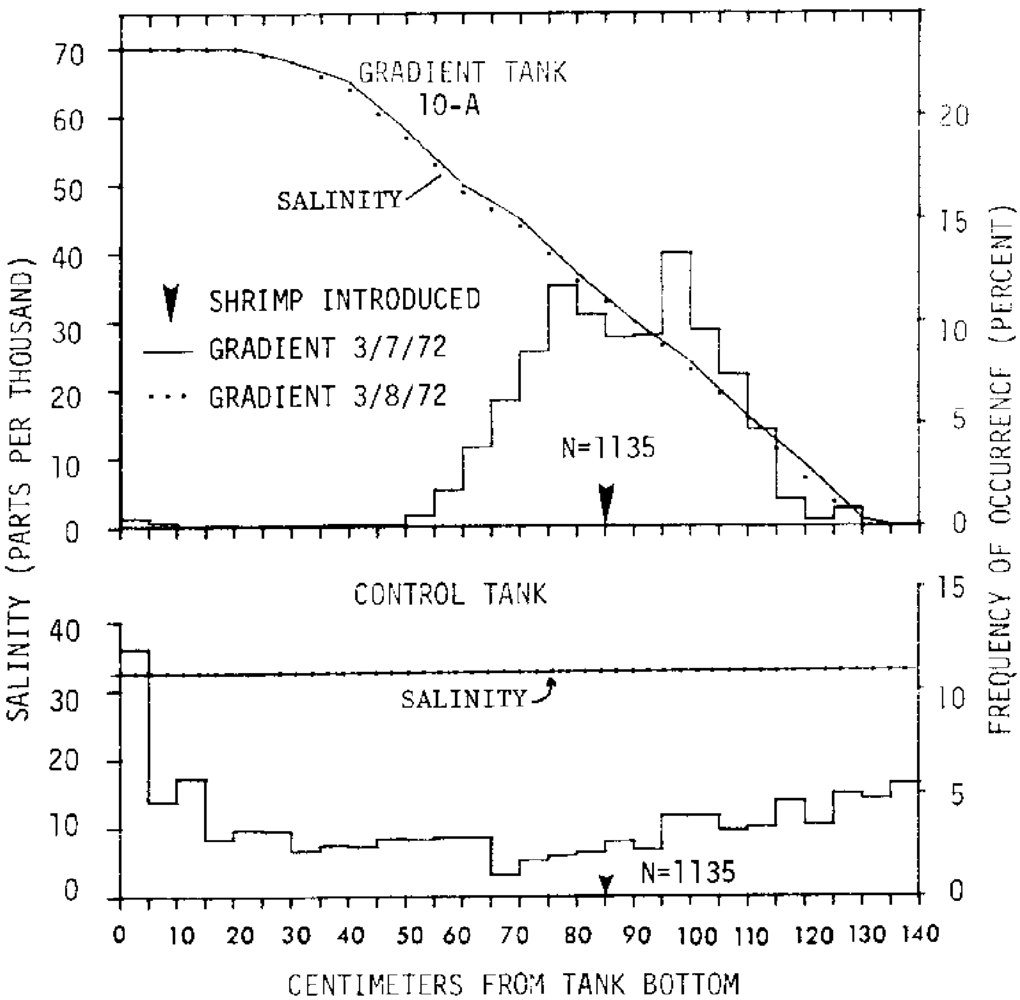
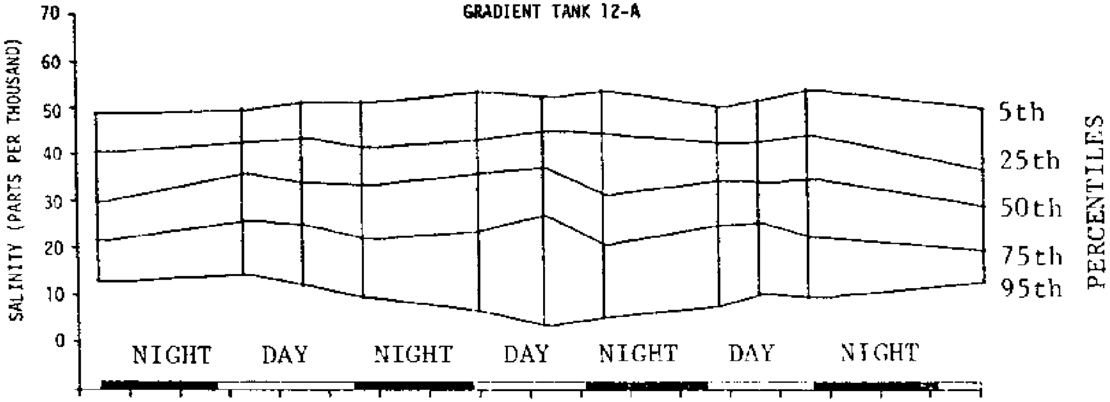


FIGURE 14.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 10, tanks A & B, during observations made from 2.0 to 26.0 hours after shrimp were introduced. Postlarvae were collected between 2/25/72 and 2/26/72 and acclimated for 13 days to 18 C. Temperature approximated 18.5 C during experiment. Number of shrimp introduced into tank A = 35, tank B = 35. N = total number of shrimp counted during a series of observations.

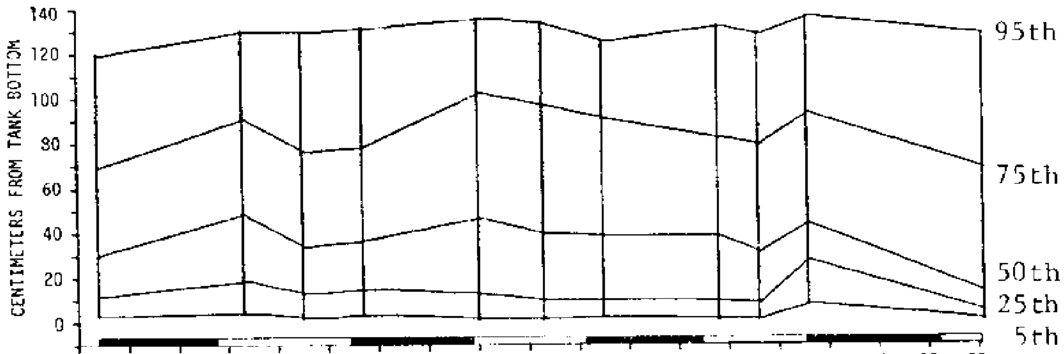
FIGURE 15.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level illumination in experiment 12, tanks A & B. Vertical lines indicate distributions. Midline represents medians (50th percentile) and the other four lines show the 5th, 25th, 75th, and 95th percentiles; percentiles are oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

GRADIENT TANK 12-A



DATE (1972)	OBSERVED N	MORTALITY	TEMPERATURE (C)
3/20	182	(2)	25.0
3/21	257	(2)	25.3
3/21	247	(2)	25.0
3/21	248	(2)	26.0
3/22	143	(2)	28.8
3/22	140	(2)	28.8
3/22	251	(2)	28.8
3/23	211	(2)	28.5
3/23	243	(4)	24.5
3/23	66	(5)	21.7
3/24	26	(14)	18.3

CONTROL TANK 12-B



DATE (1972)	OBSERVED N	MORTALITY	TEMPERATURE (C)
3/20	137	(0)	25.6
3/21	242	(0)	25.5
3/21	243	(0)	25.5
3/21	245	(0)	26.3
3/22	128	(0)	29.6
3/22	238	(0)	29.5
3/22	240	(0)	29.4
3/23	205	(0)	29.3
3/23	240	(0)	25.1
3/23	68	(0)	21.7
3/24	62	(0)	18.6

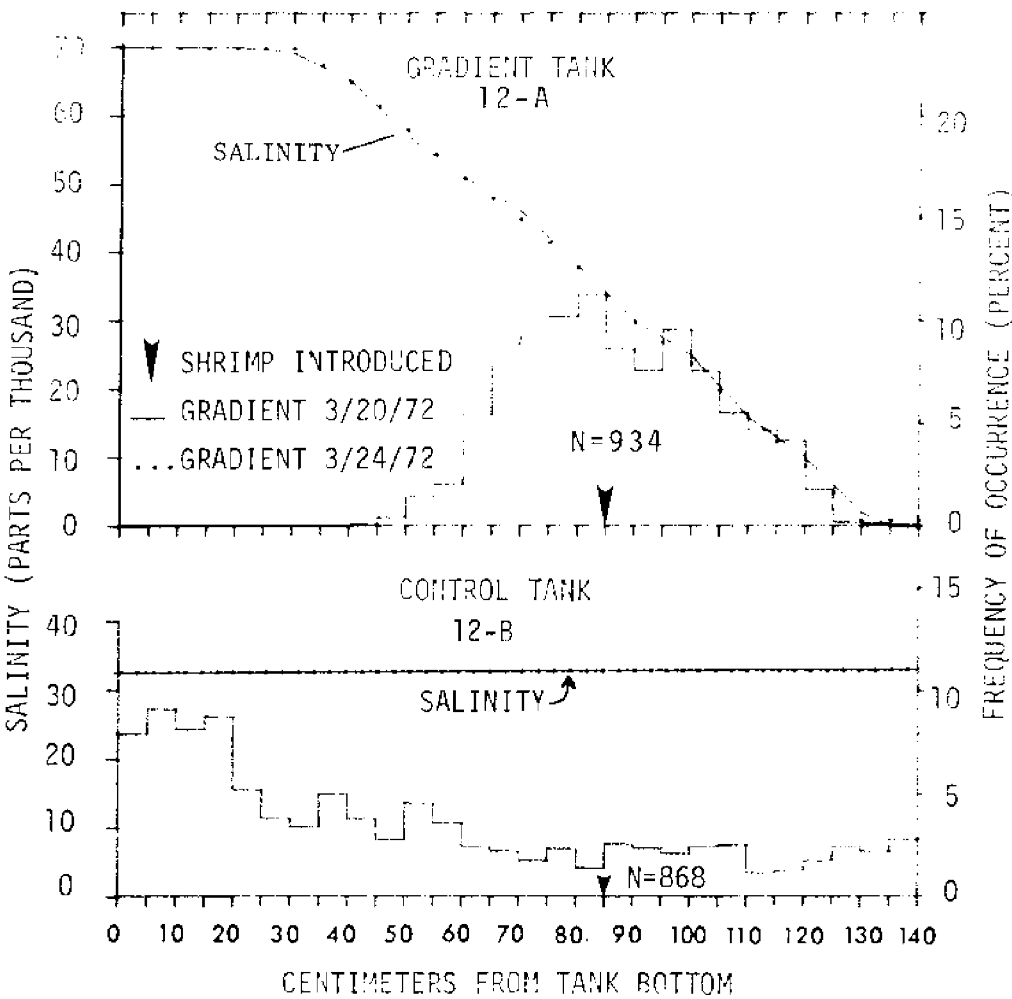


FIGURE 16.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 12, tanks A & B, during observations made from 2.0 to 28.5 hours after shrimp were introduced. Temperature approximated 25.5 C during the experiment. Number of shrimp introduced into tank A = 40, tank B = 40. N = total number of shrimp counted in a series of observations.

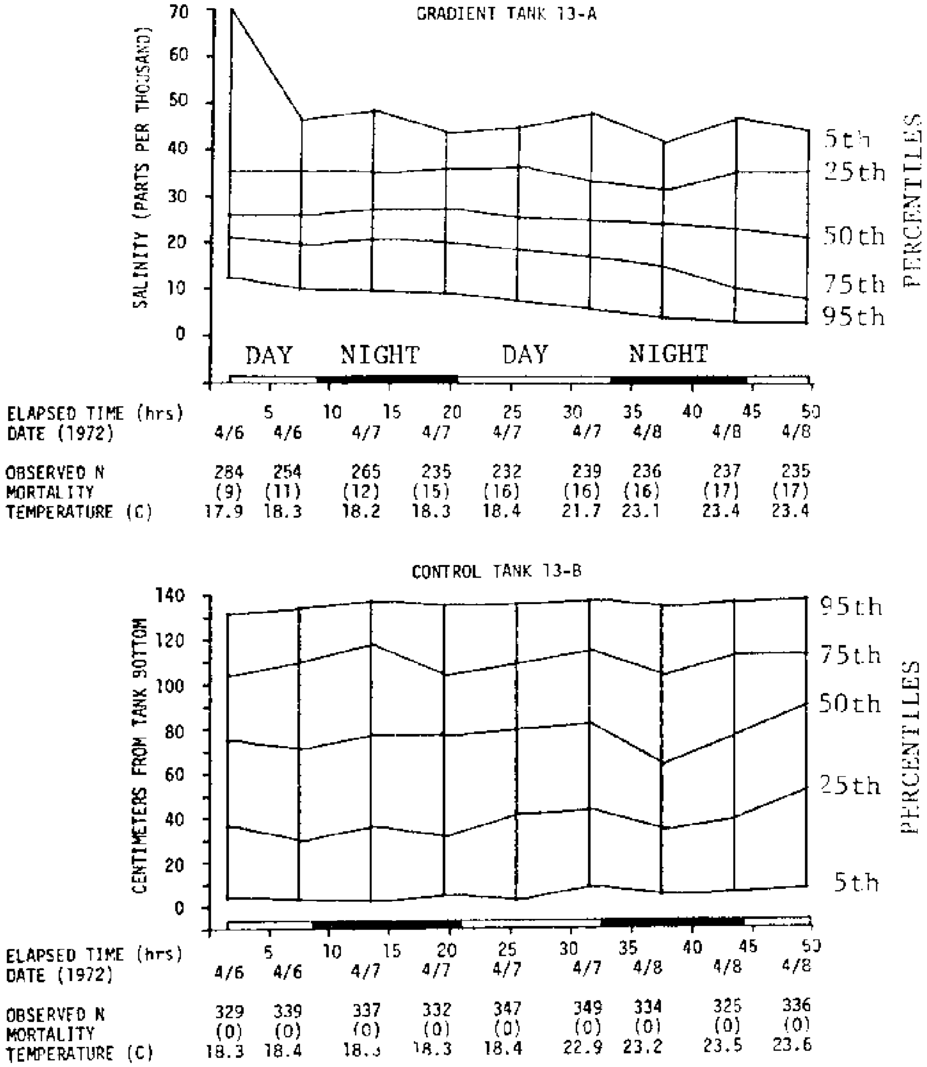


FIGURE 17.—Distribution of postlarval brown shrimp (P. aztecus) under low level red illumination in experiment 12, tanks A & B. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles are oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

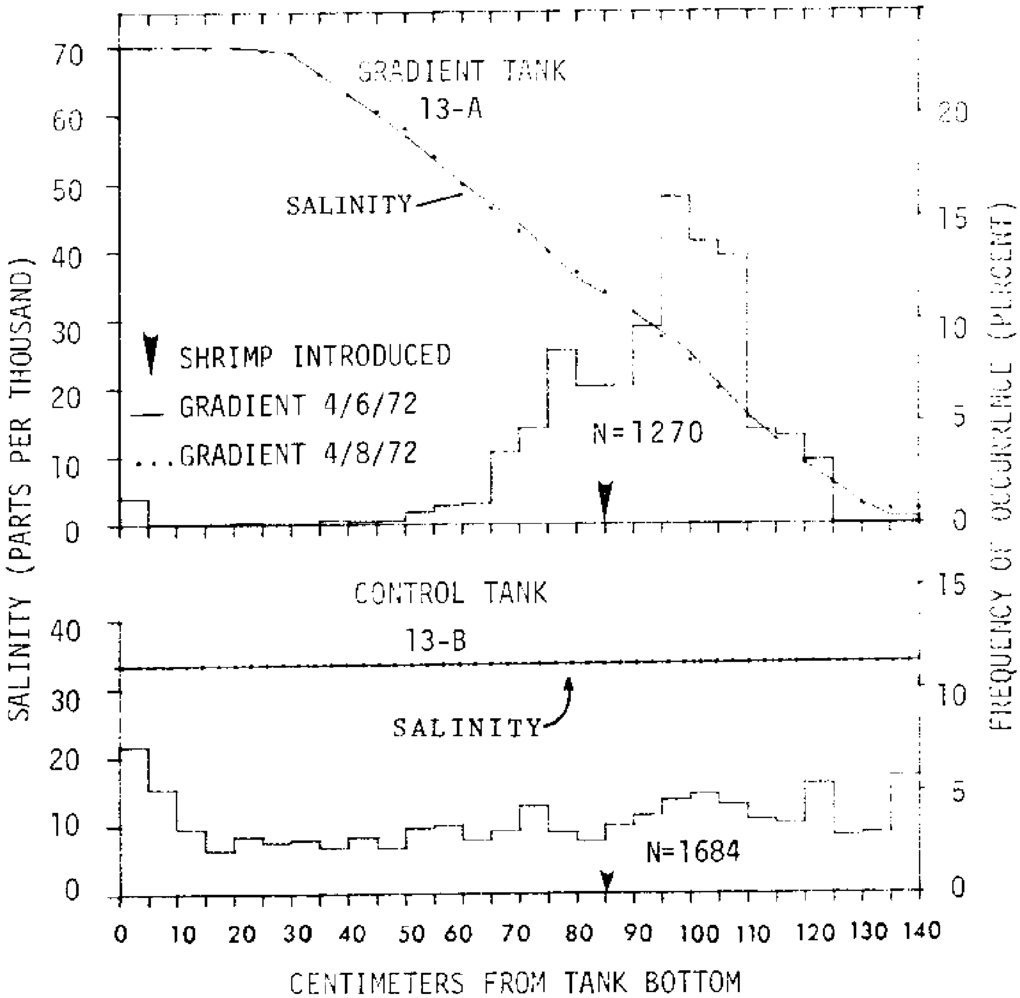


FIGURE 18.—Distribution of postlarval brown shrimp (*P. aztecus*) and salinity in experiment 13, tanks A & B, during observations made from 1.5 to 25.5 hours after shrimp were introduced. Temperature approximated 18 C during this time interval. Number of shrimp introduced into tank A = 50, tank B = 50. N = total number of shrimp counted during an observation period.

FIGURE 19.—Distribution of postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiment 15, tanks A & C (replicates). Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 19

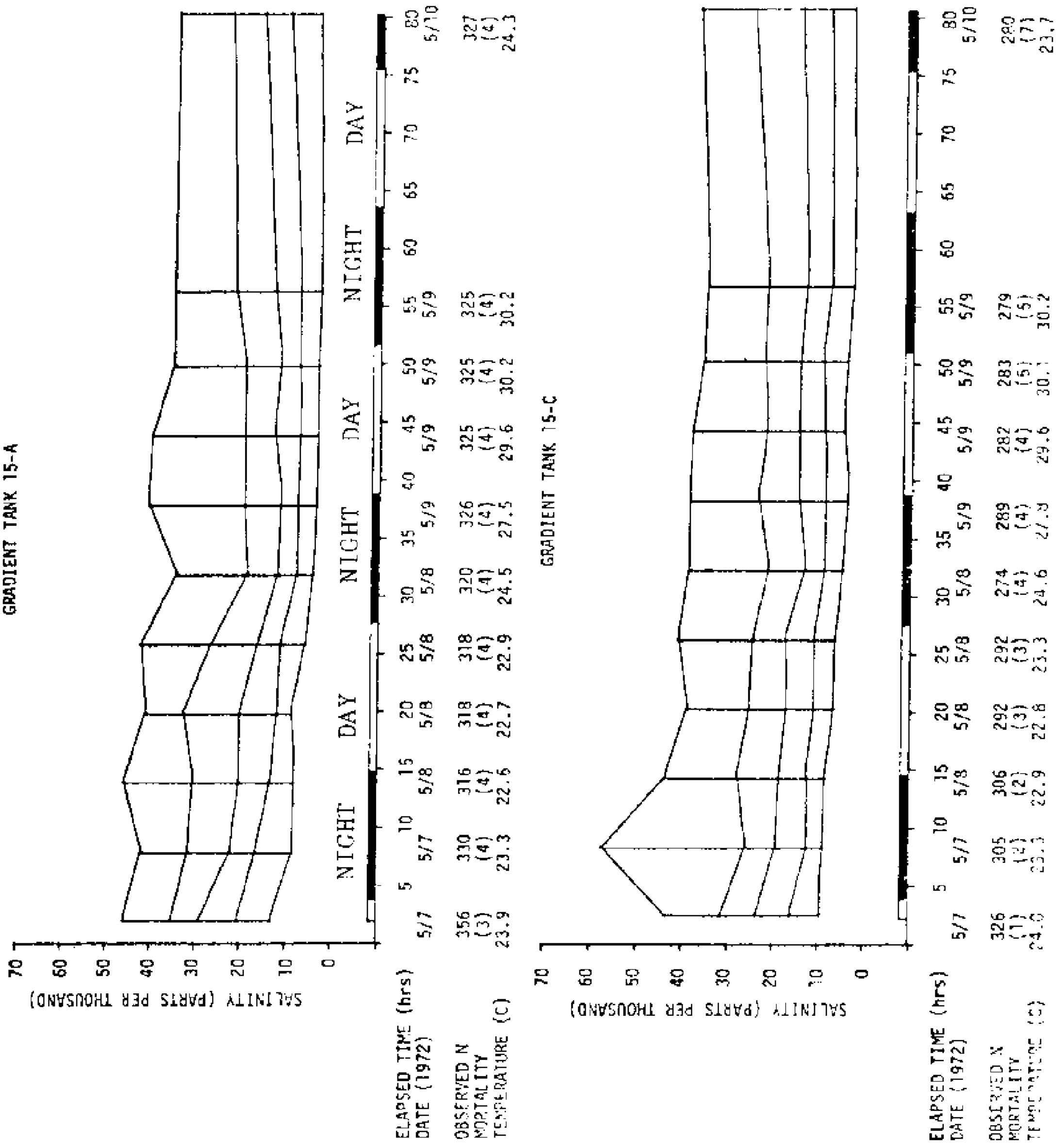
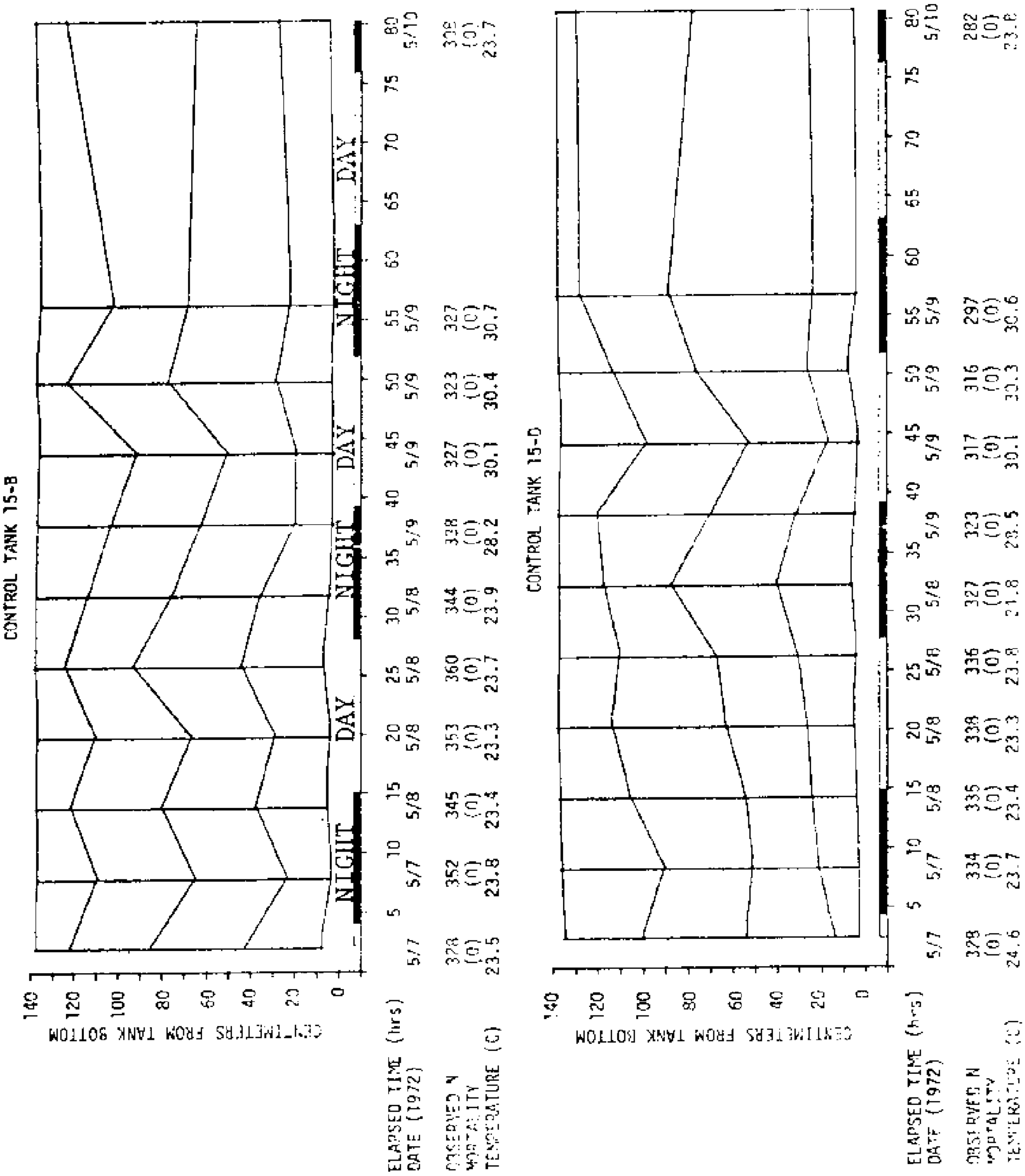

GRADIENT TANK 15-A
SALINITY (PARTS PER THOUSAND)
NIGHT
DAY
NIGHT
DAY
NIGHT
DAY
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)
GRADIENT TANK 15-C
SALINITY (PARTS PER THOUSAND)
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)

FIGURE 20.—Distribution of postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiment 15, tanks B & D (replicates). Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th, and 5th percentiles. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 20


CONTROL TANK 15-B
NIGHT
DAY
NIGHT
DAY
NIGHT
DAY
CENTIMETERS FROM TANK BOTTOM
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)
CONTROL TANK 15-D
CENTIMETERS FROM TANK BOTTOM
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)

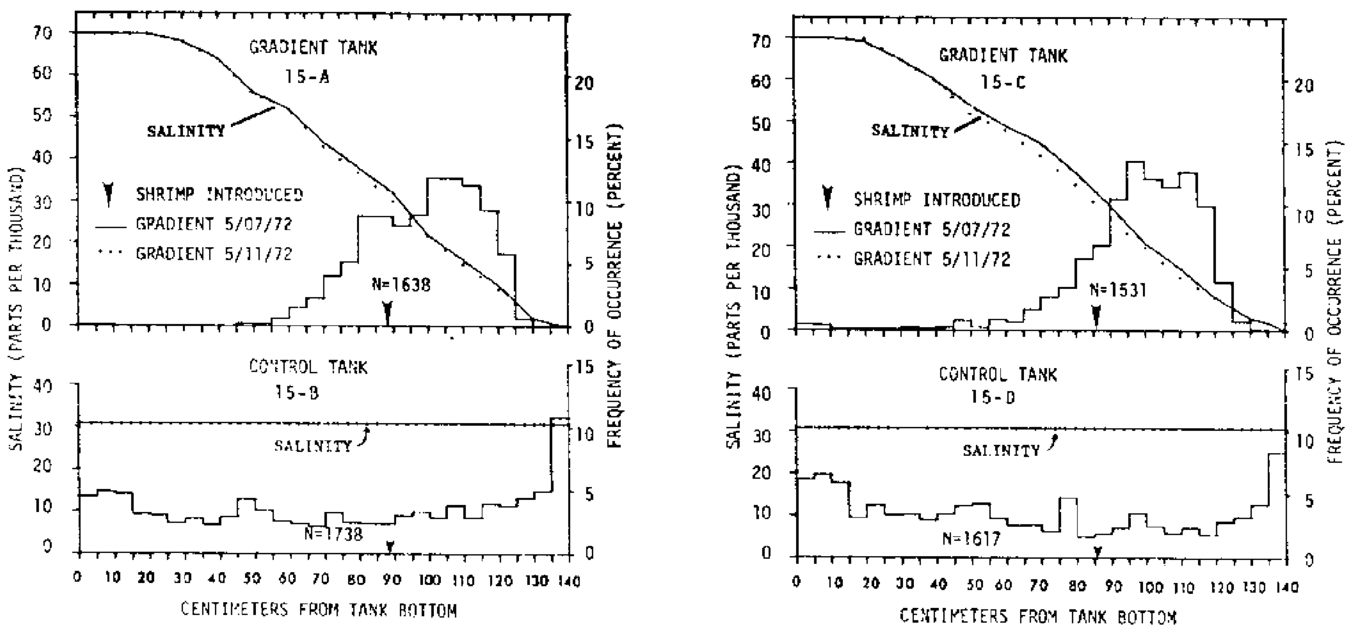
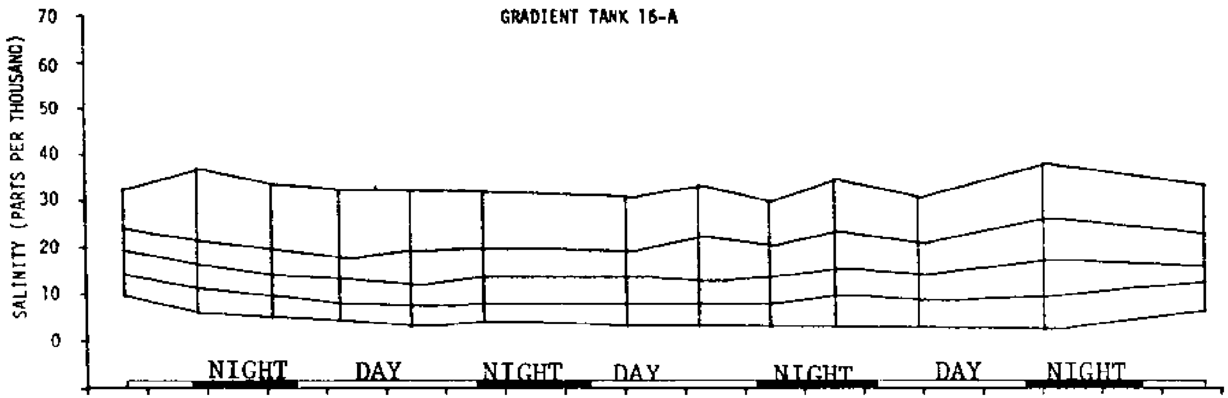
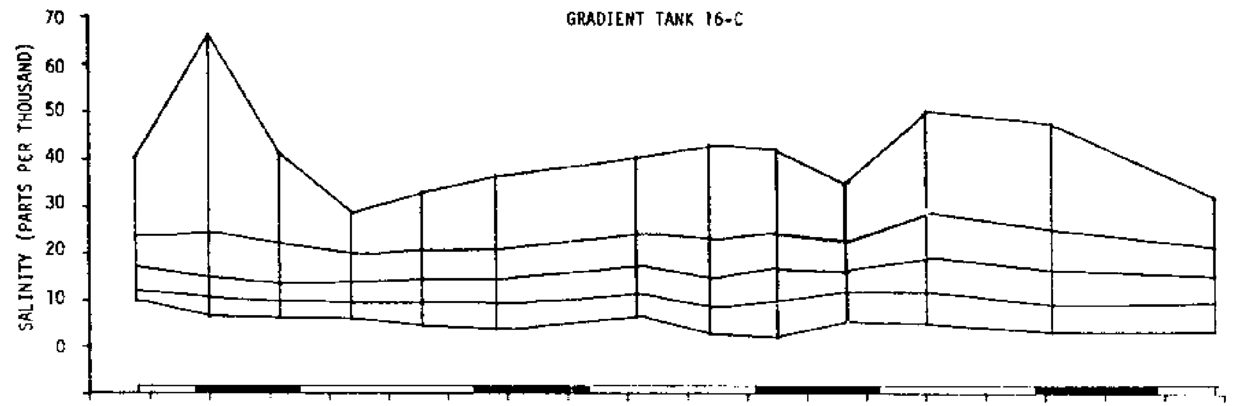


FIGURE 21.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 15 during observations made from 2.5 to 26.3 hours after shrimp were introduced. Temperature approximated 23 C during this time interval. Tanks A & C are replicates. Number of shrimp introduced into tank A = 50, tank B = 50, tank C = 50, tank D = 50. N = total number of shrimp counted in a series of observations.

FIGURE 22.—Distribution of postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiment 16, tanks A & C (replicates). Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortalitiy = number of observations of dead shrimp during an observation period; dead shrimp not removed.



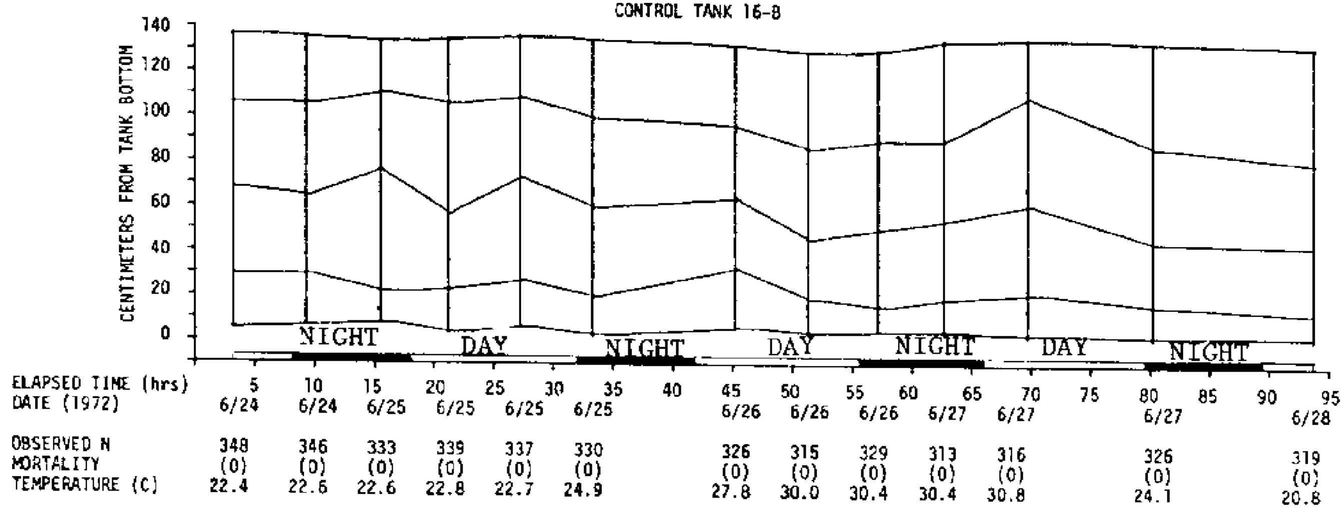
DATE (1972)	6/24	6/24	6/25	6/25	6/25	6/25	6/26	6/26	6/26	6/27	6/27	6/27	6/28
OBSERVED N	289	279	283	286	292	281	290	290	273	269	255	250	249
MORTALITY	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1)	(4)	(4)	(4)	(4)
TEMPERATURE (C)	22.2	22.4	22.3	22.7	22.4	24.6	27.8	29.7	30.3	30.2	30.3	23.3	20.2



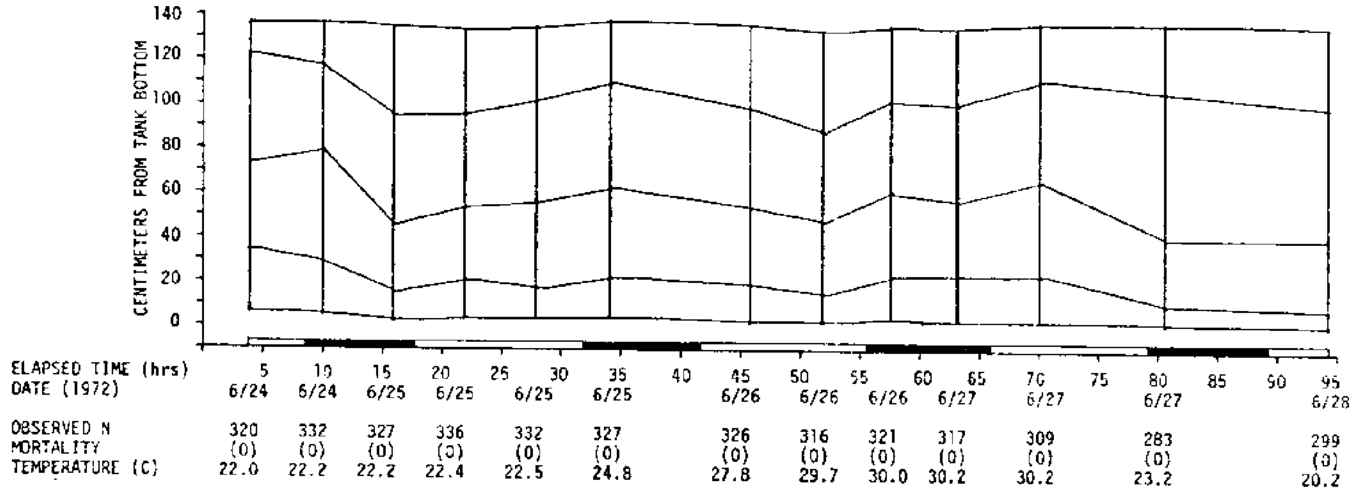
DATE (1972)	6/24	6/24	6/25	6/25	6/25	6/25	6/26	6/26	6/26	6/27	6/27	6/27	6/28
OBSERVED N	306	306	311	297	311	306	308	294	307	294	287	273	287
MORTALITY	(4)	(4)	(4)	(4)	(4)	(5)	(6)	(4)	(6)	(8)	(8)	(10)	(9)
TEMPERATURE (C)	22.0	22.0	21.7	22.2	22.3	24.5	27.8	29.2	29.6	29.6	29.7	22.6	19.8

FIGURE 23.—Distribution of postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiment 16, tanks B & D (replicates). Vertical lines indicate distributions. Midline represents medians and the other four lines show the 95th, 75th, 25th and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

CONTROL TANK 16-B



CONTROL TANK 16-D



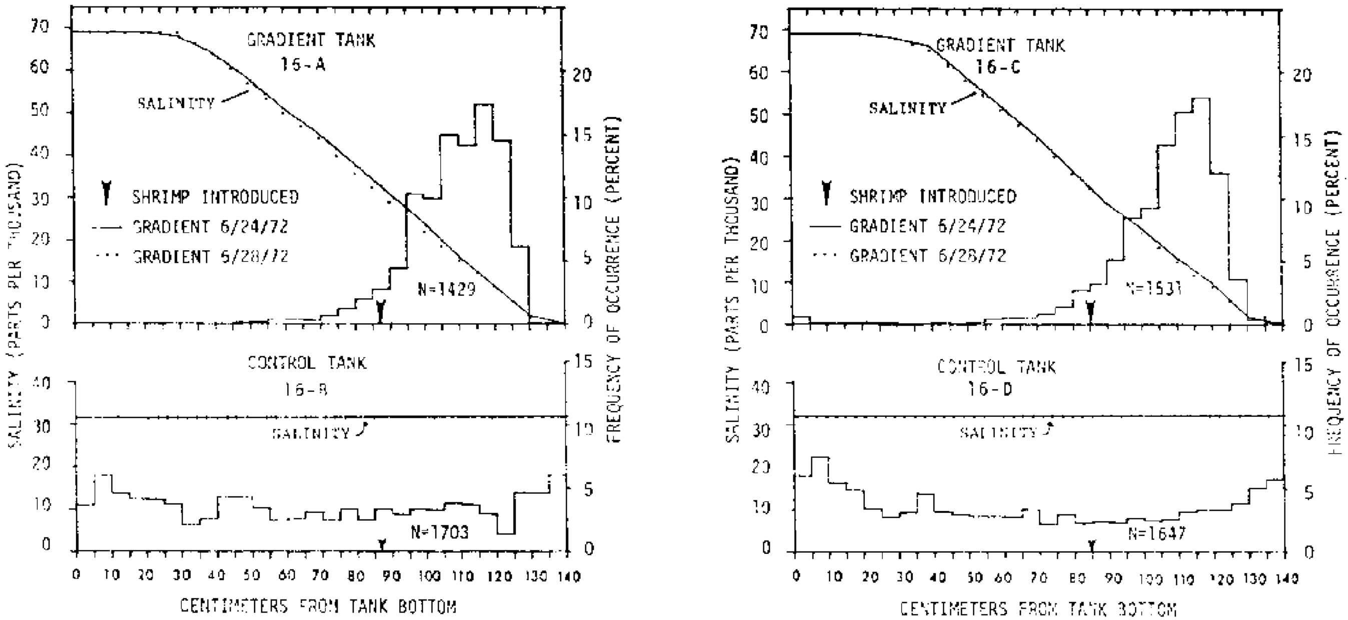
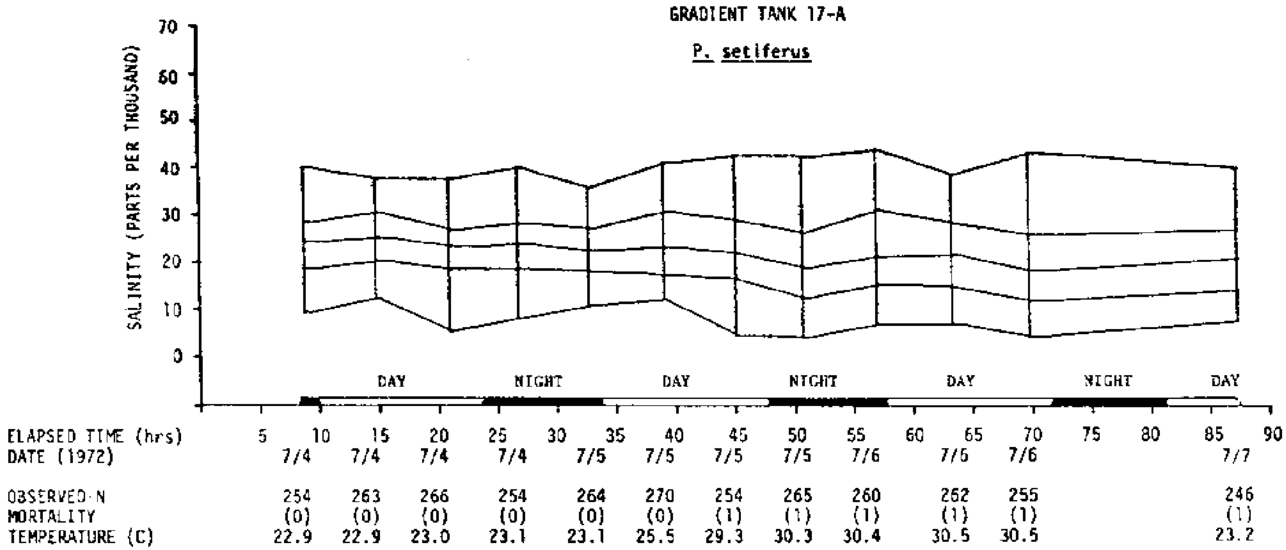


FIGURE 24.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 16 during observations made from 3.2 to 27.2 hours after shrimp were introduced. Temperature approximated 22.5 C during this time interval. Tanks A & C and tanks B & D are replicates. Number of shrimp introduced into tank A = 47, tank B = 49, tank C = 50, tank D = 50. N = total number of shrimp counted in a series of observations.

FIGURE 25.—Distribution of postlarval white and brown shrimp (*P. setiferus* and *P. aztecus*) under continuous low level red illumination in experiment 17, tanks A & C. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 25


GRADIENT TANK 17-A
P. setiferus
SALINITY (PARTS PER THOUSAND)
70
60
50
40
30
20
10
0
DAY
NIGHT
DAY
NIGHT
DAY
NIGHT
DAY
ELAPSED TIME (hrs) 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
DATE (1972) 7/4 7/4 7/4 7/4 7/5 7/5 7/5 7/5 7/6 7/6 7/6 7/7
OBSERVED N 254 263 266 254 264 270 254 265 260 262 255 246
MORTALITY (0) (0) (0) (0) (0) (0) (1) (1) (1) (1) (1) (1)
TEMPERATURE (C) 22.9 22.9 23.0 23.1 23.1 25.5 29.3 30.3 30.4 30.5 30.5 23.2

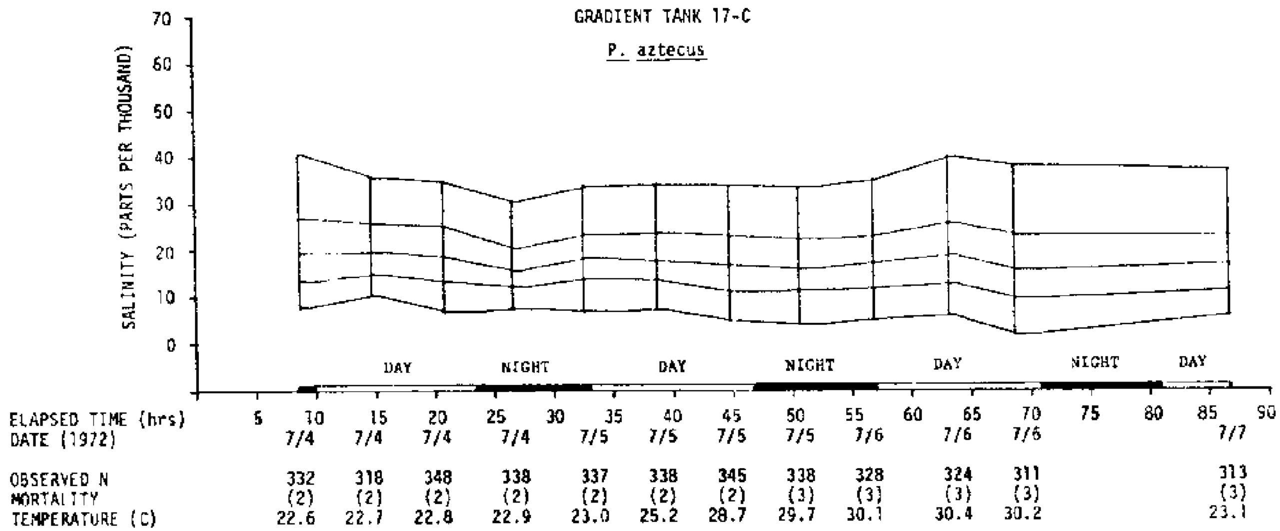
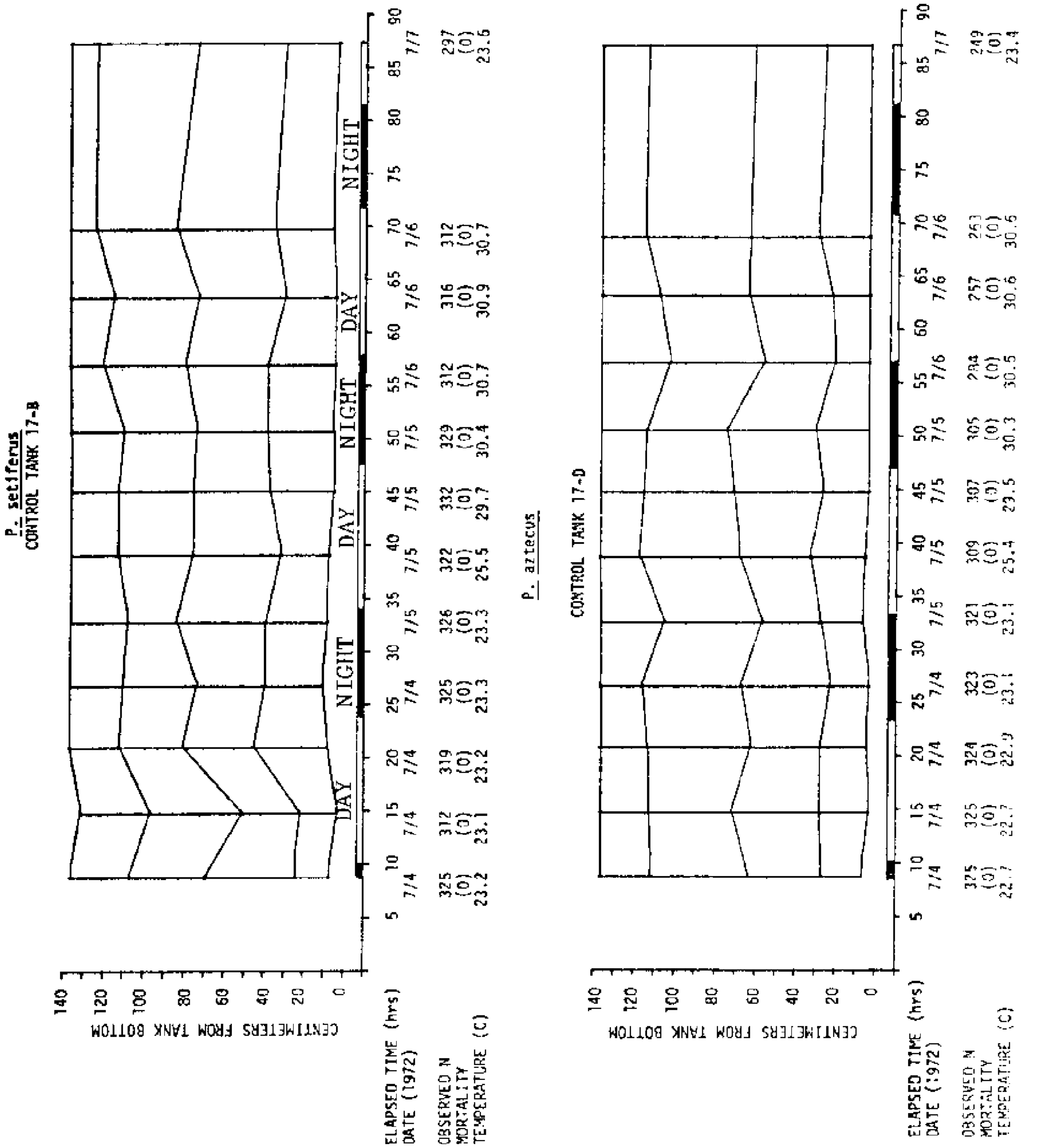

GRADIENT TANK 17-C
P. aztecus
SALINITY (PARTS PER THOUSAND)
70
60
50
40
30
20
10
0
DAY
NIGHT
DAY
NIGHT
DAY
NIGHT
DAY
ELAPSED TIME (hrs) 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
DATE (1972) 7/4 7/4 7/4 7/4 7/5 7/5 7/5 7/5 7/6 7/6 7/6 7/7
OBSERVED N 332 318 348 338 337 338 345 338 328 324 311 313
MORTALITY (2) (2) (2) (2) (2) (2) (2) (3) (3) (3) (3) (3)
TEMPERATURE (C) 22.6 22.7 22.8 22.9 23.0 25.2 28.7 29.7 30.1 30.4 30.2 23.1

FIGURE 26.—Distribution of postlarval white and brown shrimp (*P. setiferus* and *P. aztecus*) under continuous low level red illumination in experiment 17, tanks B & D. Vertical lines indicate distributions. Midline represents medians and other four lines, from top to bottom, show the 95th, 75th, 25th and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = total number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 26


P. setiferus
CONTROL TANK 17-B
P. aztecus
CONTROL TANK 17-D
CENTIMETERS FROM TANK BOTTOM
DAY
NIGHT
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)

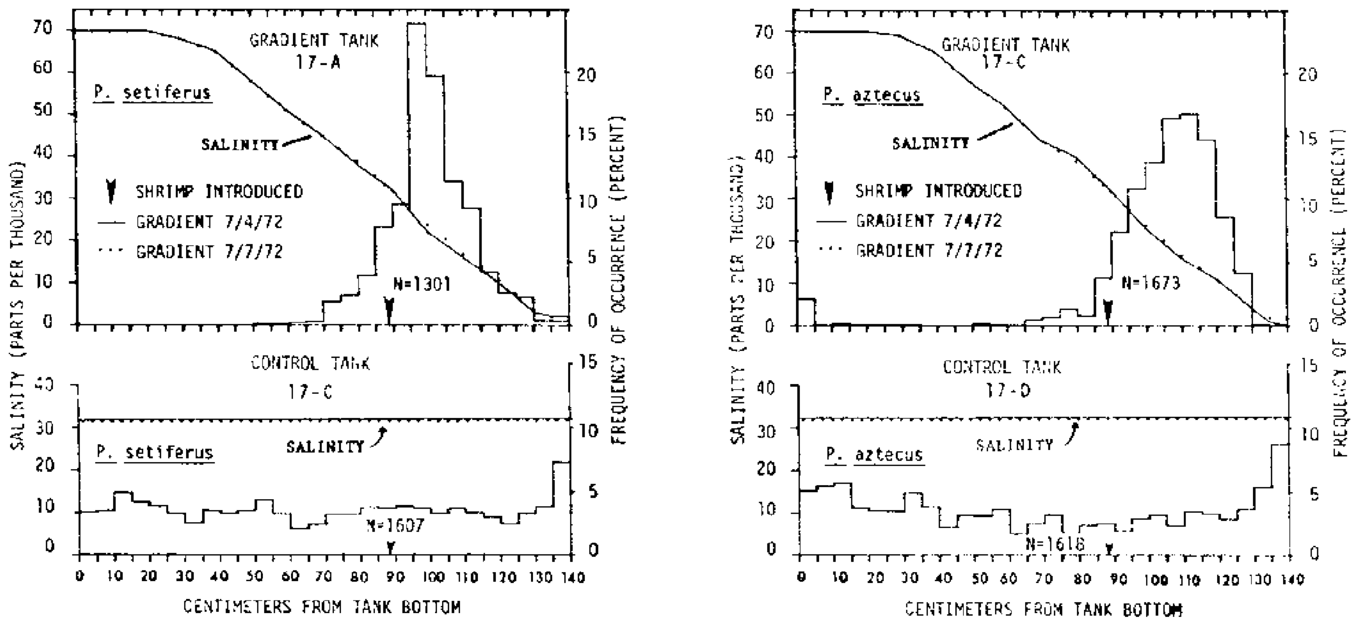


FIGURE 27.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) and salinity in experiment 17 during observations made from 8.7 to 32.8 hours after shrimp were introduced. Temperature approximated 23 C during this time interval. Number of shrimp introduced into tank A = 39, tank B = 40, tank C = 50, tank D = 50. N = total number of shrimp counted in a series of observations.

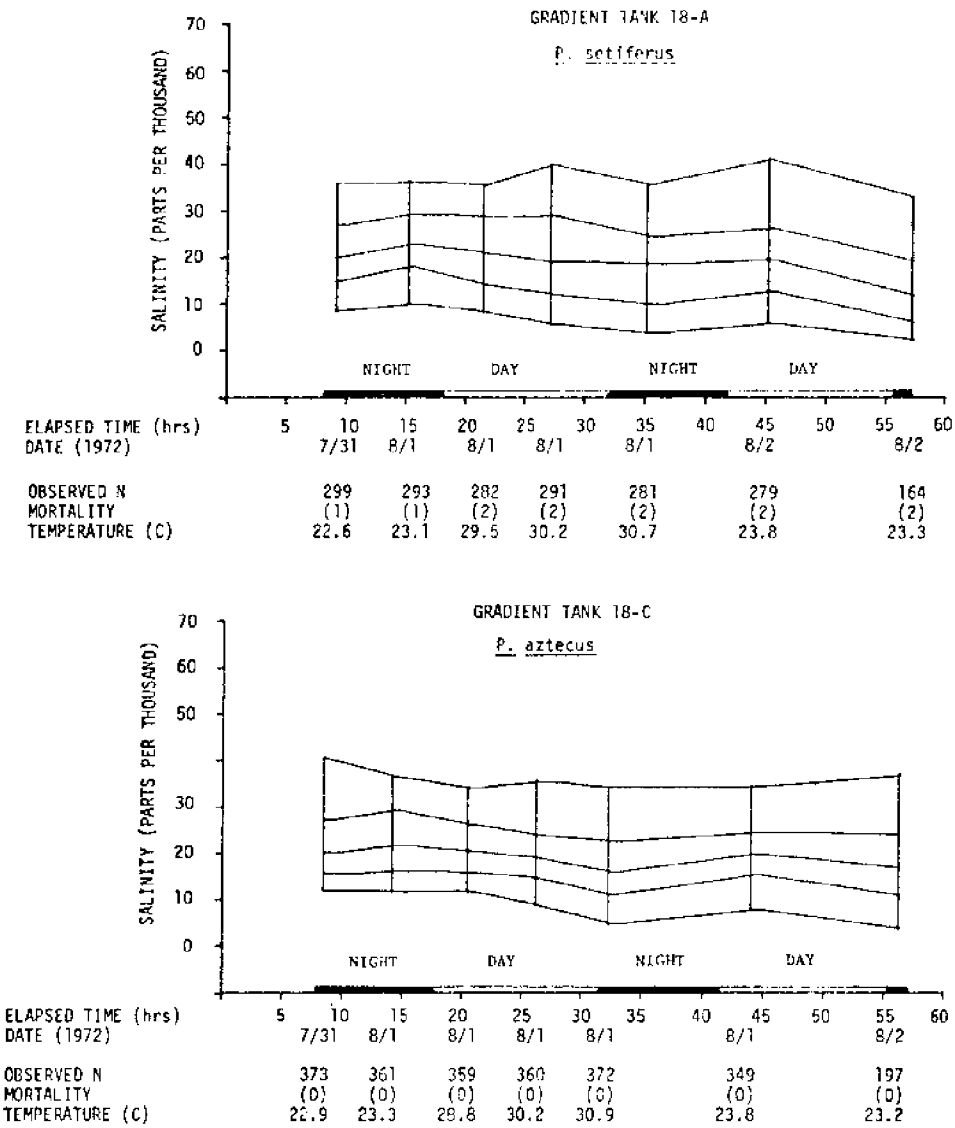


FIGURE 28.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under continuous low level red illumination in experiment 18, tanks A & C. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

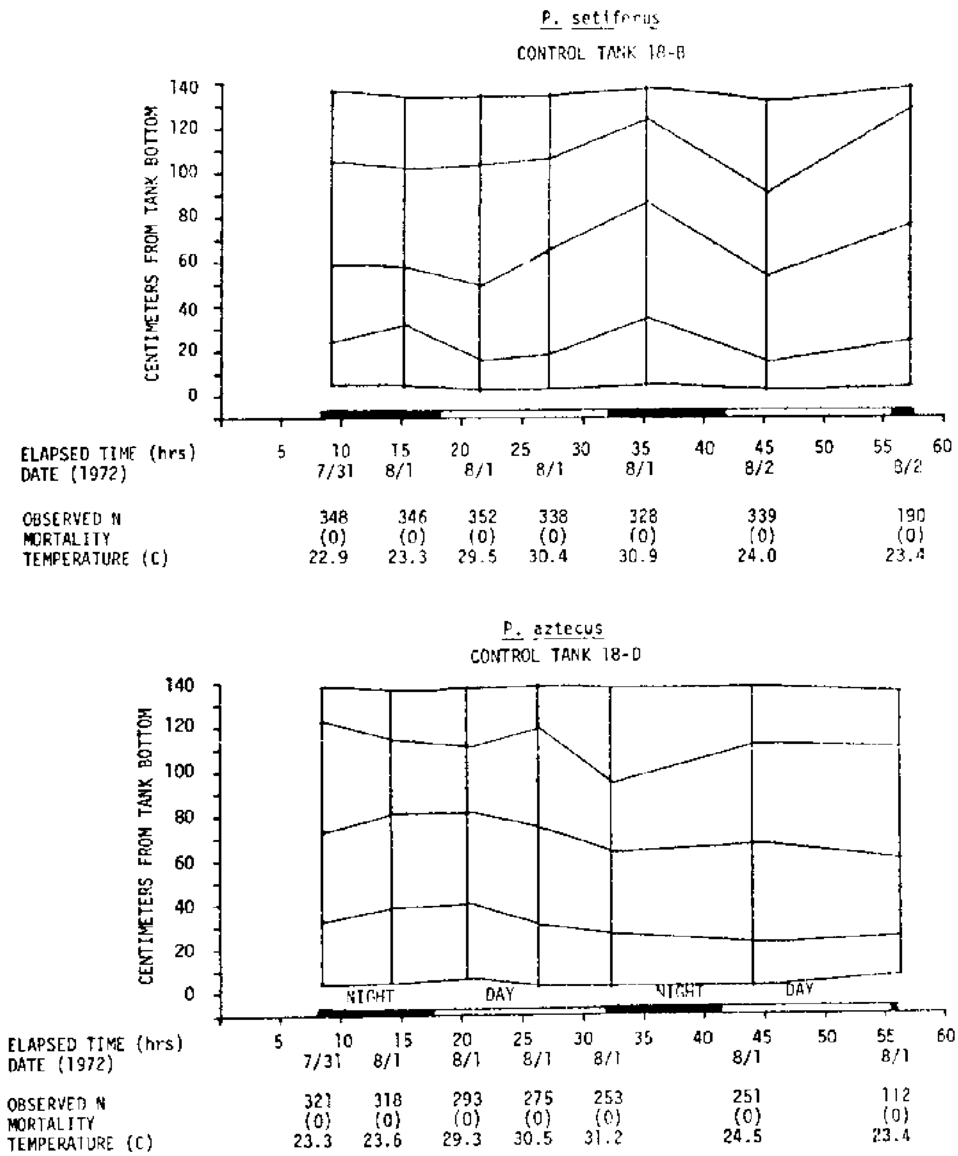


FIGURE 29.—Distribution of postlarval white and brown shrimp (*P. setiferus* and *P. aztecus*) under continuous low level red illumination in experiment 18, tanks B & D. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, indicate the 95th, 75th, 25th and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

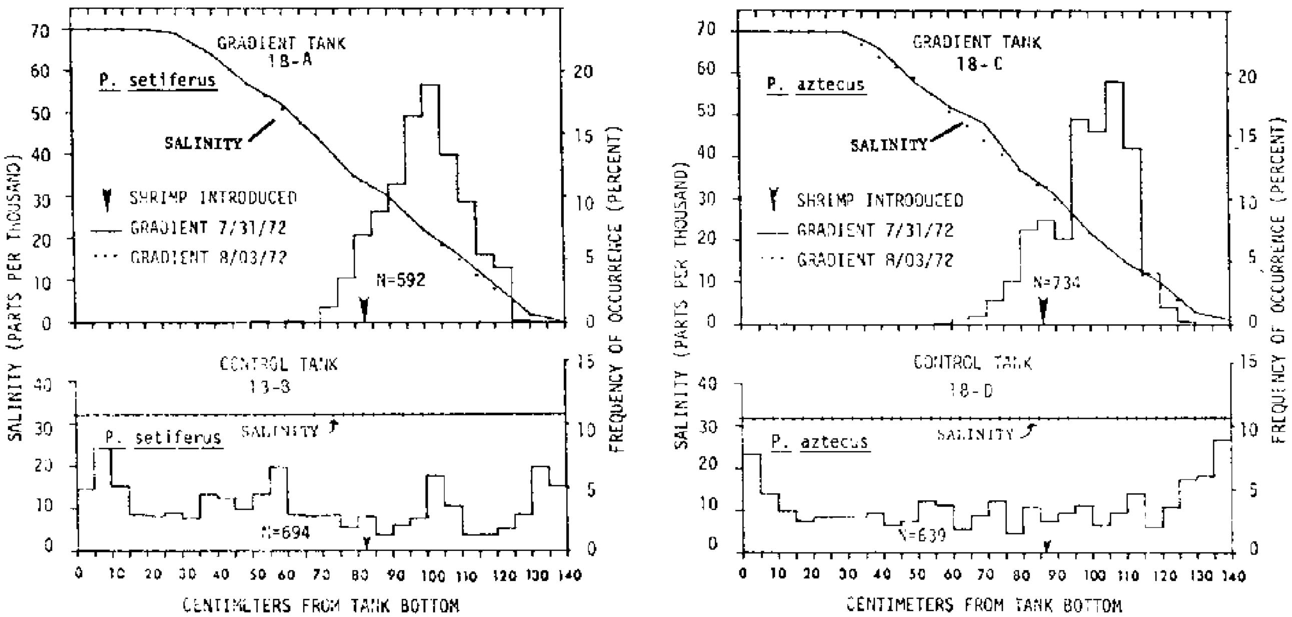


FIGURE 30.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) and salinity in experiment 18 during observations made from 8.5 to 15.2 hours after shrimp were introduced. Temperature approximated 23 C. Number of shrimp introduced into tank A = 52, tank B =52, tank C =50, tank D =47. N = total number of shrimp counted in a series of observations.

FIGURE 31.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 19, tanks A & C (replicates). Postlarvae were collected between 8/24 and 8/25/72 and acclimated for 6 days to 22 C and 33 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted during a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 31

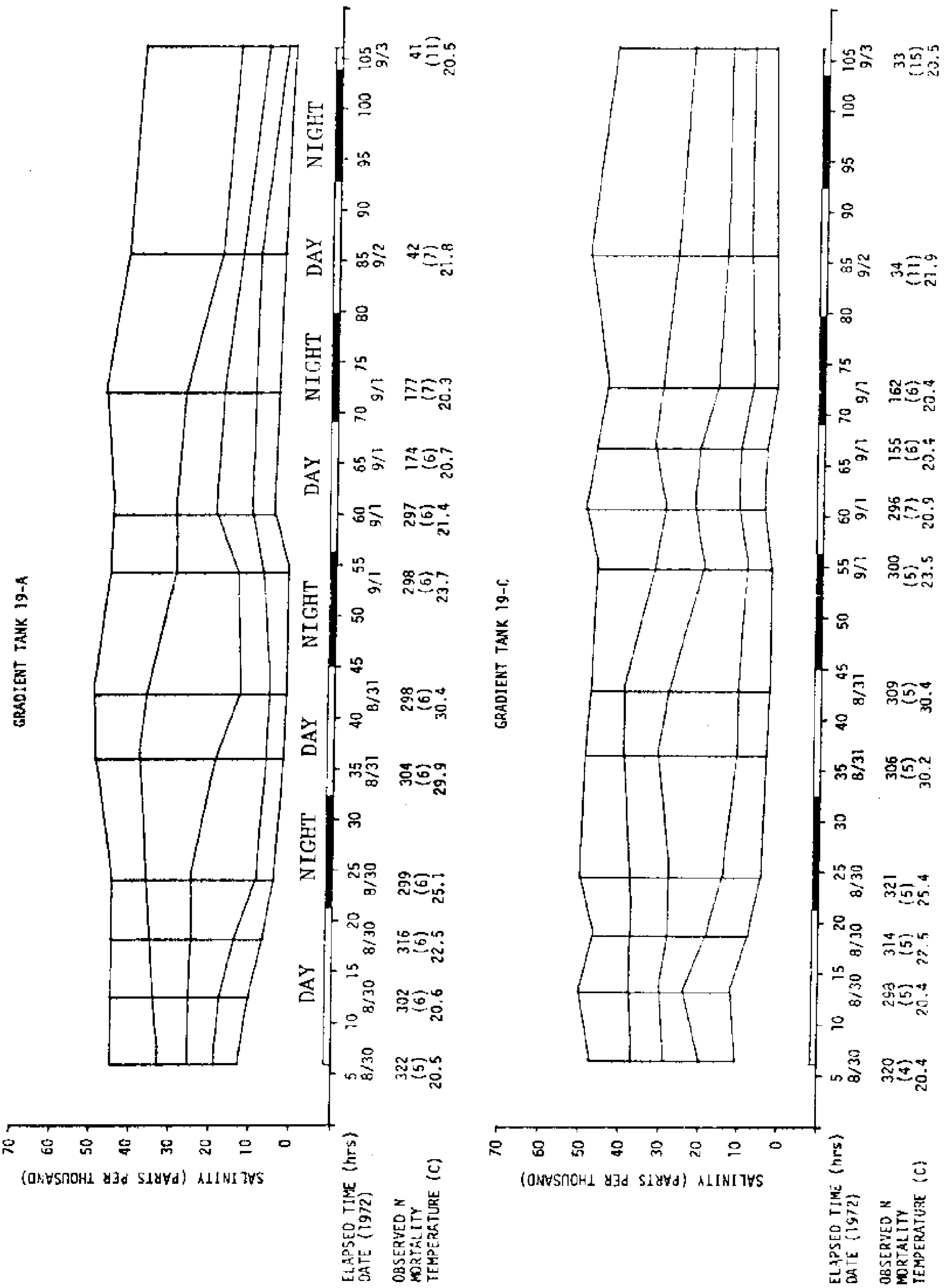
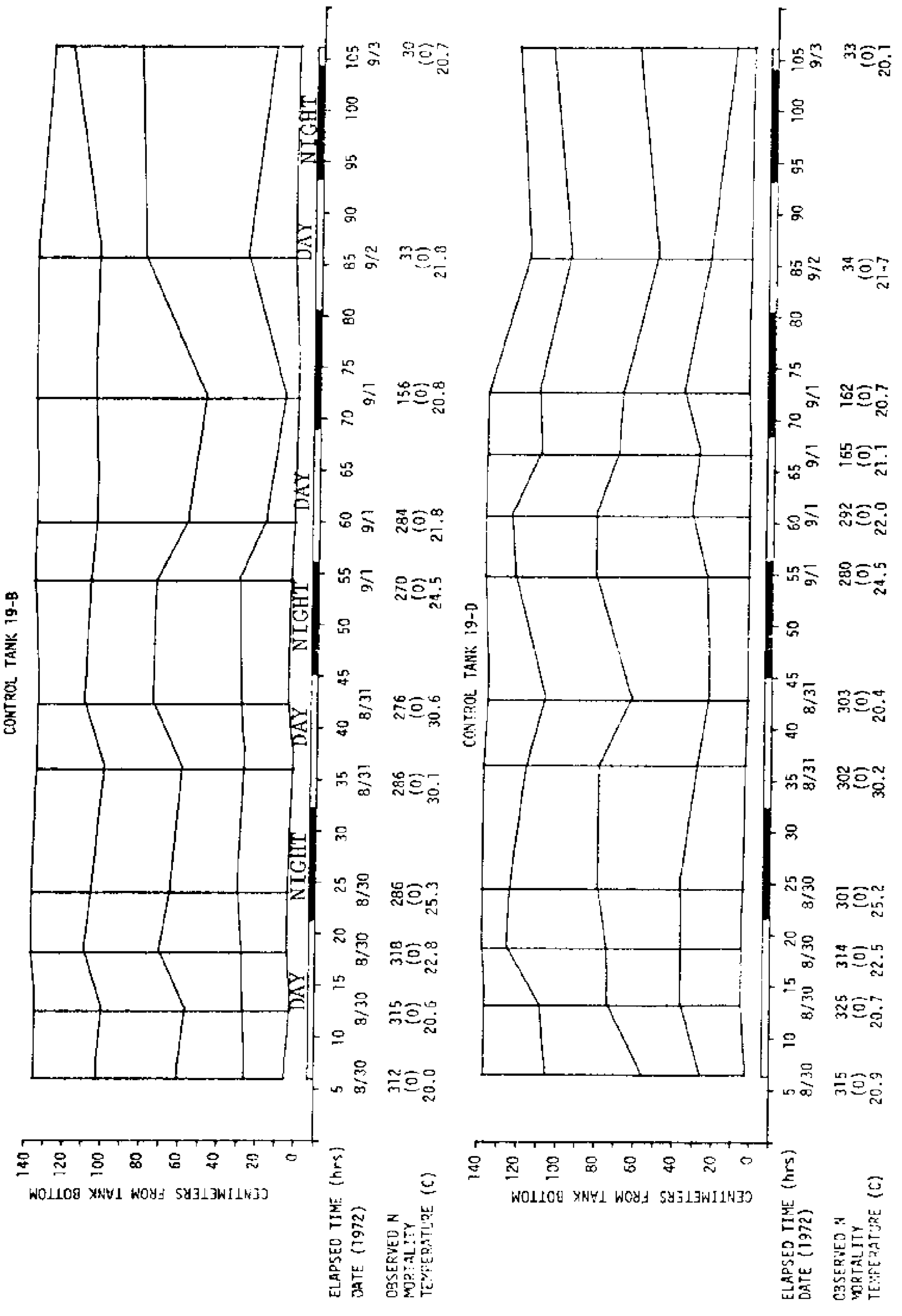

GRADIENT TANK 19-A
GRADIENT TANK 19-C
SALINITY (PARTS PER THOUSAND)
0 10 20 30 40 50 60 70
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)
DAY NIGHT DAY NIGHT DAY NIGHT DAY NIGHT
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105
8/30 8/30 8/30 8/30 8/31 8/31 9/1 9/1 9/1 9/1 9/2 9/3
322 (5) 20.5
302 (6) 20.6
316 (6) 22.5
299 (6) 25.1
304 (6) 29.9
298 (6) 30.4
298 (6) 23.7
297 (6) 21.4
174 (6) 20.7
177 (7) 20.3
42 (7) 21.8
41 (11) 20.5
320 (4) 20.4
293 (5) 20.4
314 (5) 22.5
321 (5) 25.4
306 (5) 30.2
309 (5) 30.4
300 (5) 23.5
296 (7) 20.9
155 (6) 20.4
162 (6) 20.4
34 (11) 21.9
33 (15) 20.5

FIGURE 32.—Distribution of postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiment 19, tanks B & D (replicates). Postlarvae were collected between 8/24 and 8/25/72 and acclimated for 6 days at 22 C and 33 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 32


CONTROL TANK 19-B
CONTROL TANK 19-D
CENTIMETERS FROM TANK BOTTOM
DAY
NIGHT
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)

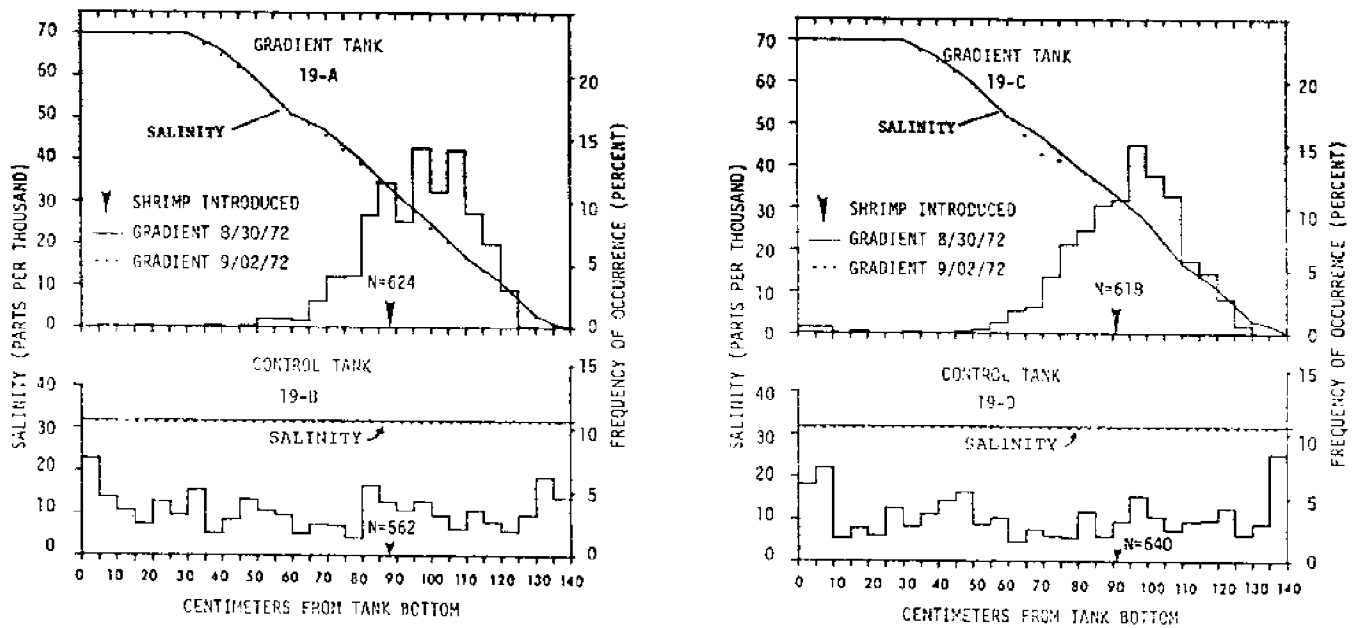


FIGURE 33.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 19 during observations made 6.0 to 13.2 hours after shrimp were introduced. Temperature approximated 20.5 C during this time interval. Tanks A & C and tanks B & D are replicates. Postlarvae were collected between 8/24/72 and 8/25/72 and acclimated for 6 days to 22 C and 33 o/oo. Temperatures approximated 20.5 C during this time interval. Number of shrimp introduced into tank A = 50, tank B = 49, tank C = 50, tank D = 50. N = total number of shrimp counted in a series of observations.

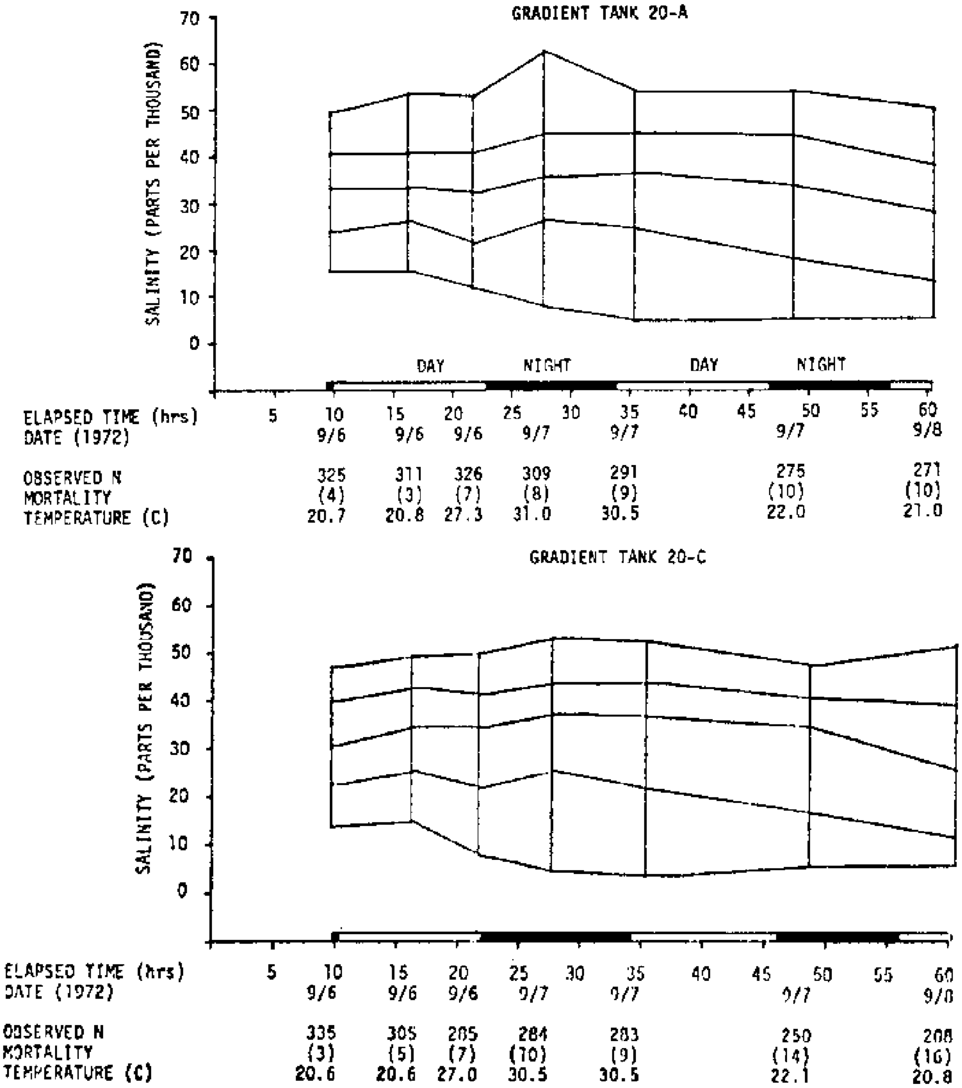


FIGURE 34.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 20, tanks A & C (replicates). Postlarvae were collected between 8/24 and 8/25/72 and acclimated for 11 days to 22 C and 33 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

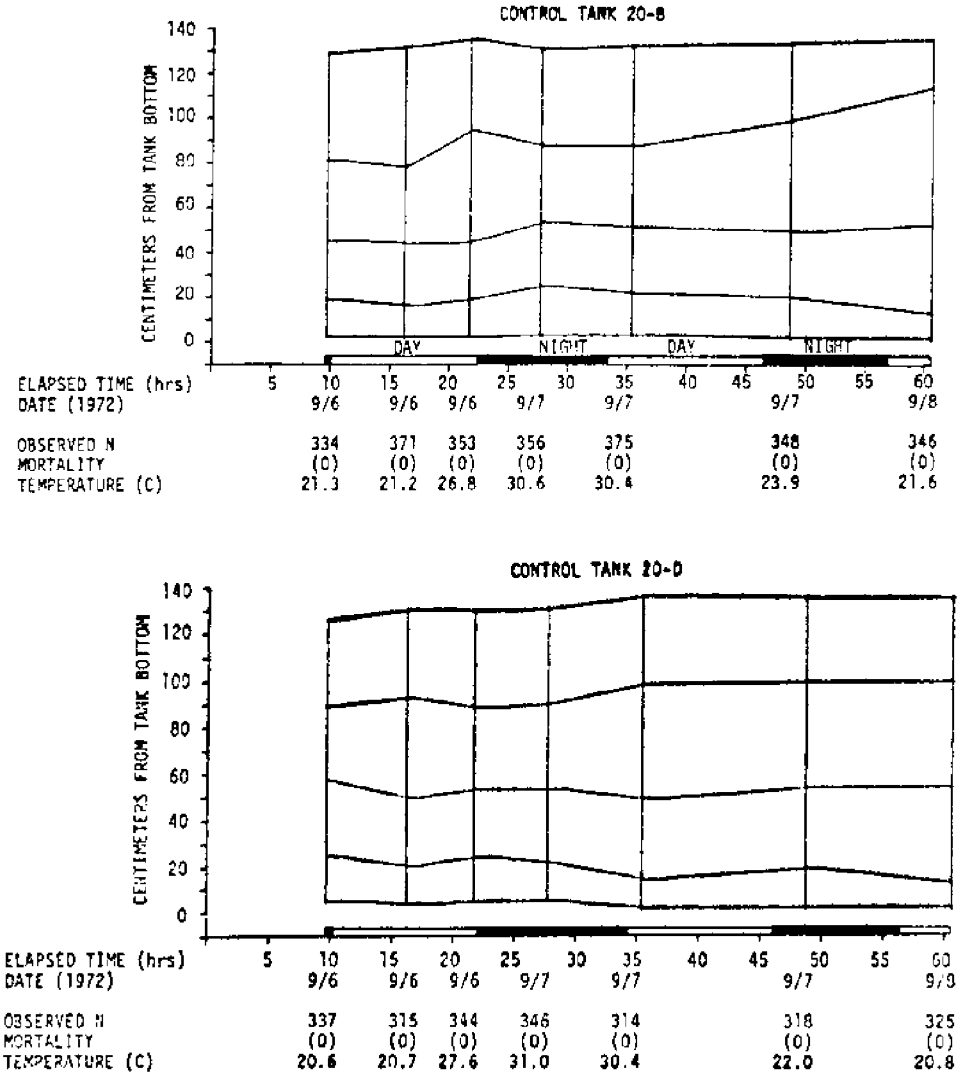


FIGURE 35.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 20, tanks B & D (replicates). Postlarvae were collected between 8/24 and 8/25/72 and acclimated for 11 days to 22 C and 33 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

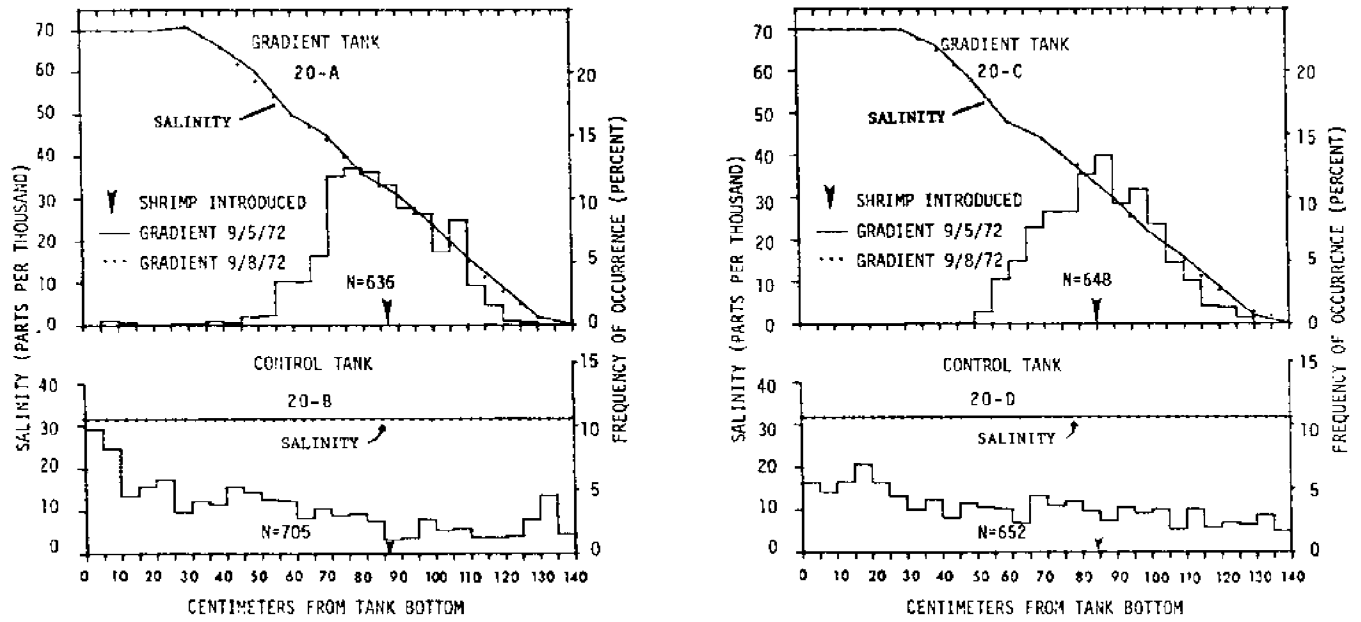
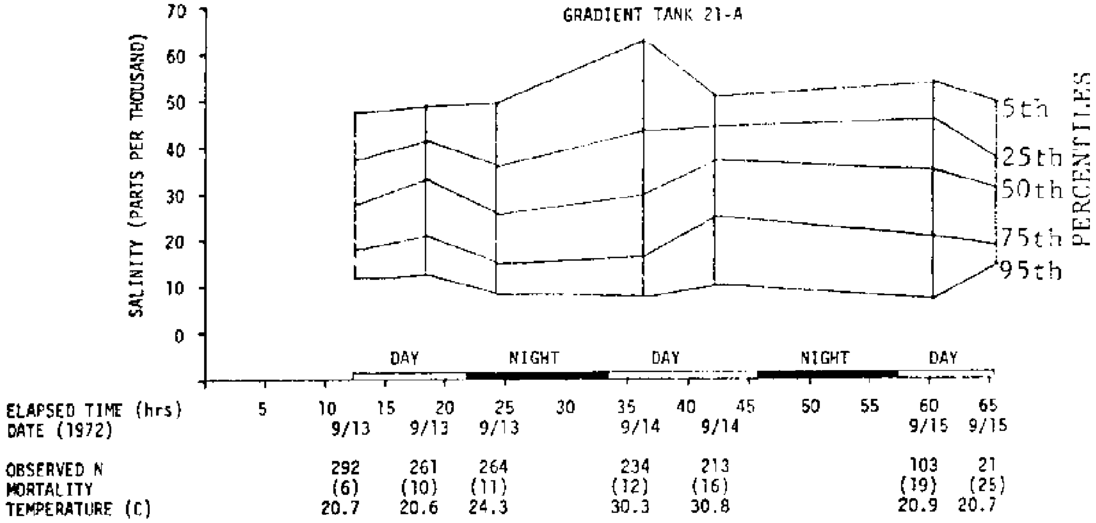


FIGURE 36.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 20 during observations made from 9.5 to 16.2 hours after shrimp were introduced. Temperature approximated 22 C during this time interval. Tanks A & C and B & D are replicates. Postlarvae were collected between 8/24 and 8/25/72 and acclimated for 11 days to 22 C and 33 o/oo. Number of shrimp introduced into tank A = 50, tank B =50, tank C = 50, tank D = 50. N = total number of shrimp counted in a series of observations.



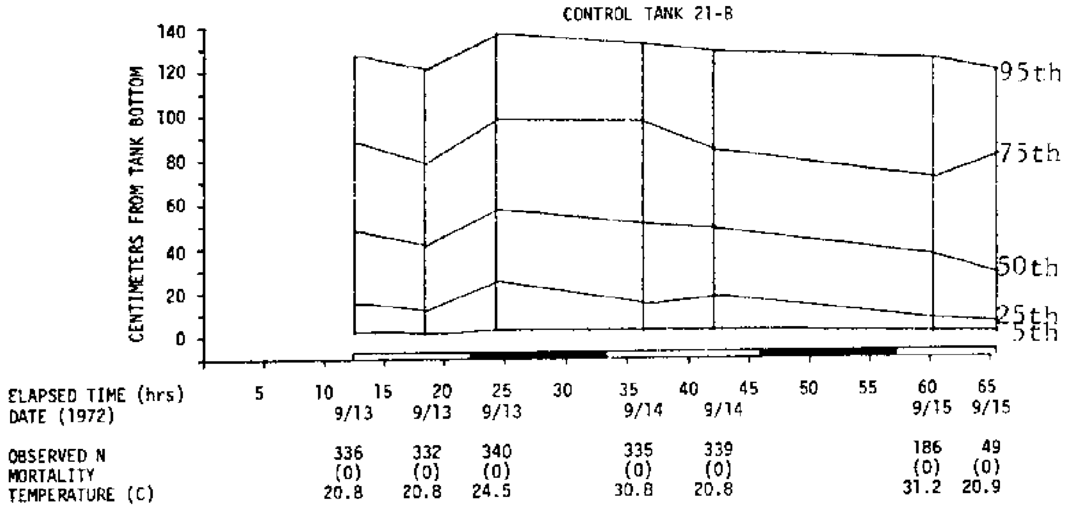


FIGURE 37.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 21, tanks A & B. Postlarval shrimp were collected between 8/24 and 8/25/72 and acclimated for 19 days to 22 C and 33 o/oo. Vertical lines indicate distributions. Midline represent medians and the other four lines indicate percentiles; percentiles are oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

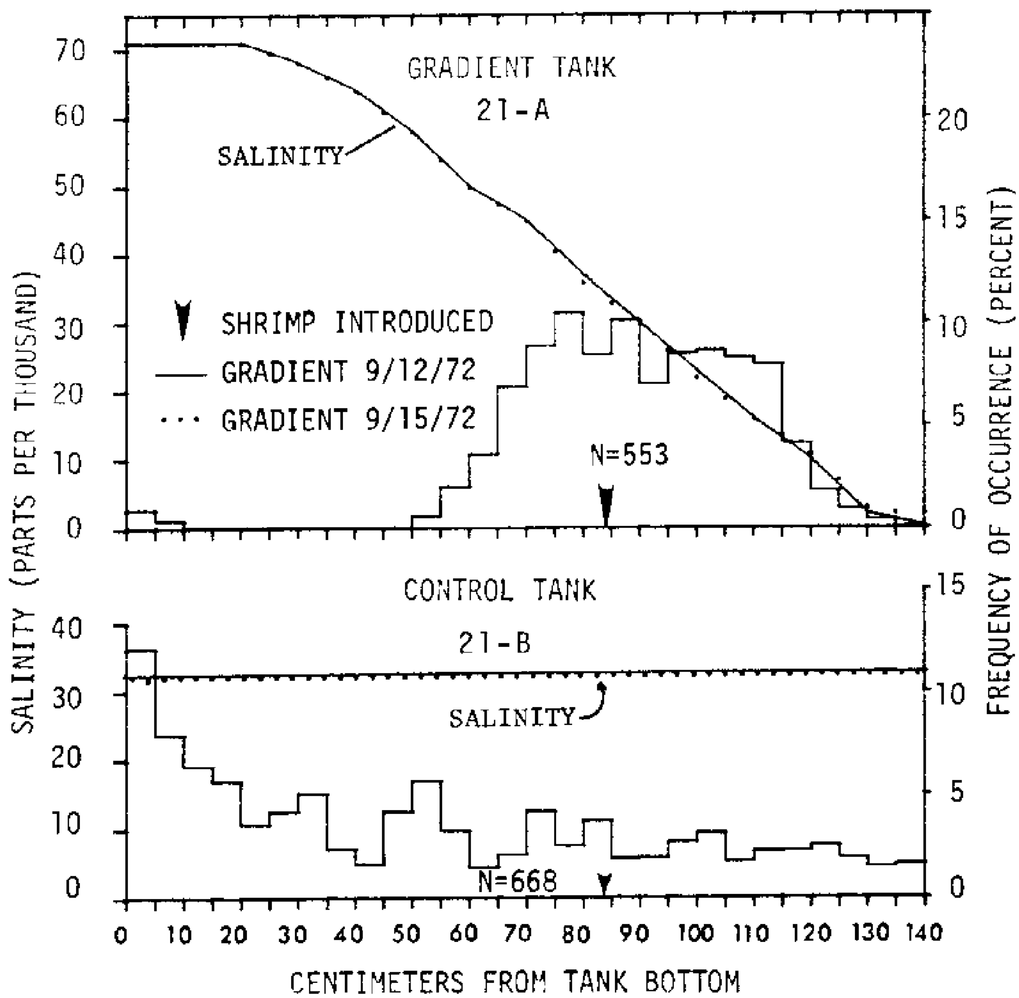


FIGURE 38.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 21, tanks A & B, during observations made from 12.5 to 18.4 hours after shrimp were introduced. Temperature approximated 20.5 C during this time interval. Postlarvae were collected between 8/24 and 8/25/72 and acclimated for 19 days to 22 C and 33 o/oo. Number of shrimp introduced into tank A = 50, tank B = 49. N = total number of shrimp counted in a series of observations.

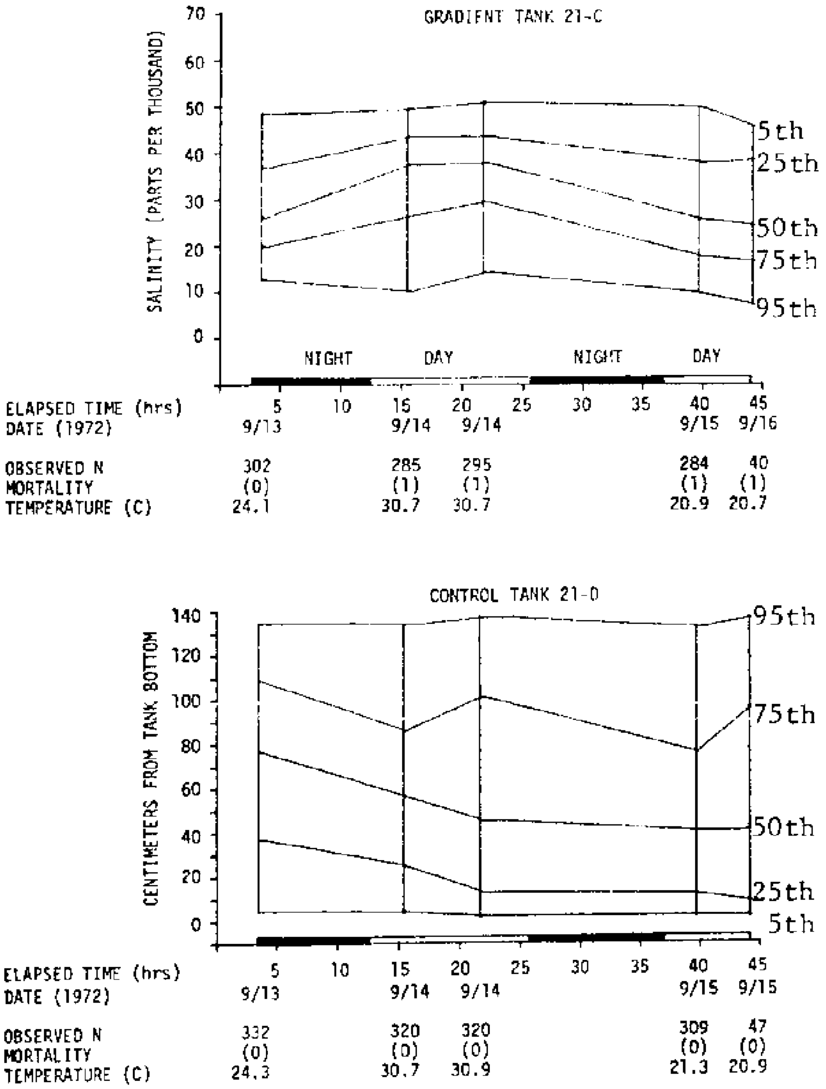


FIGURE 39.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 21, tanks C & D. Postlarvae were collected 9/08/72 and acclimated for 5 days to 24 C and 33 o/oo. Vertical lines indicate distributions. Mid-line represents medians and the four other lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

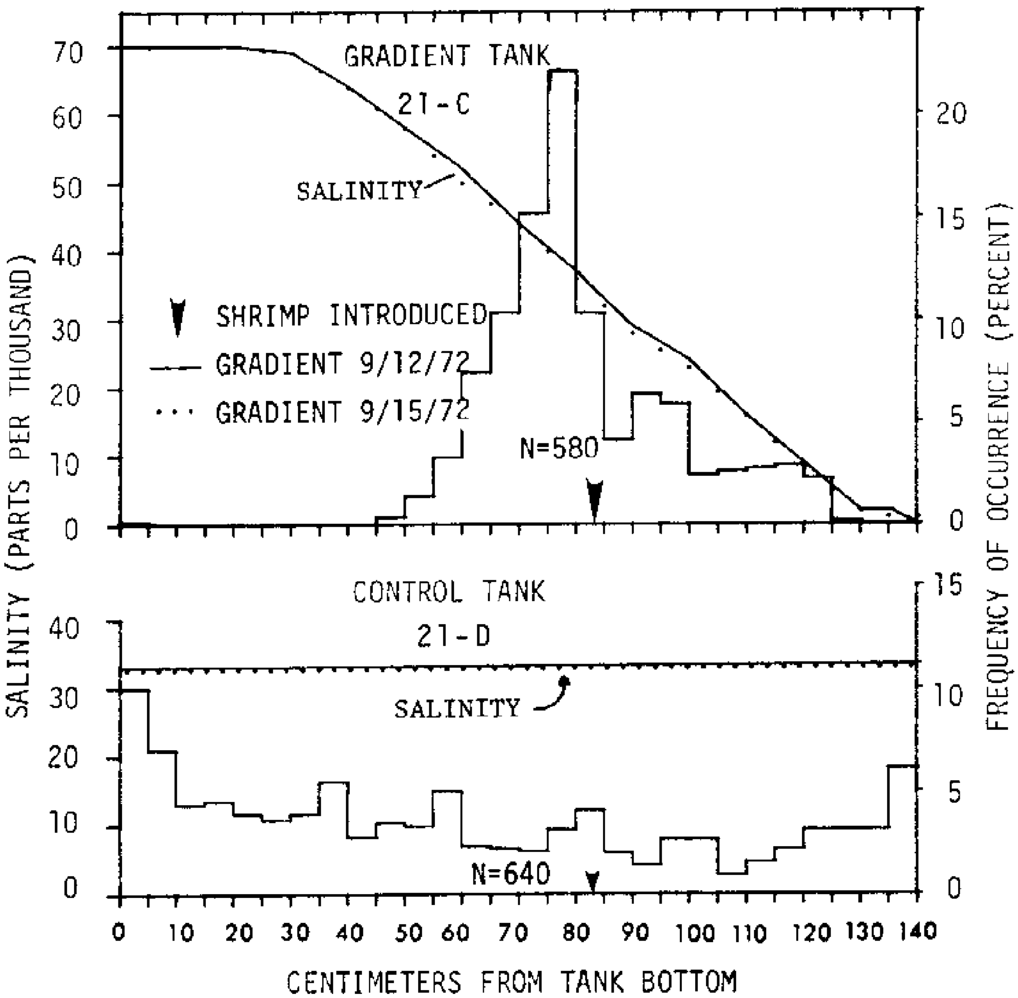


FIGURE 40.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 21, tanks C & D, during observations made from 15.5 to 21.7 hours after shrimp were introduced. Temperature approximated 30.7 C for this time interval. Number of shrimp introduced into tank C = 50, tank D = 50. N = total number of shrimp counted in a series of observations.

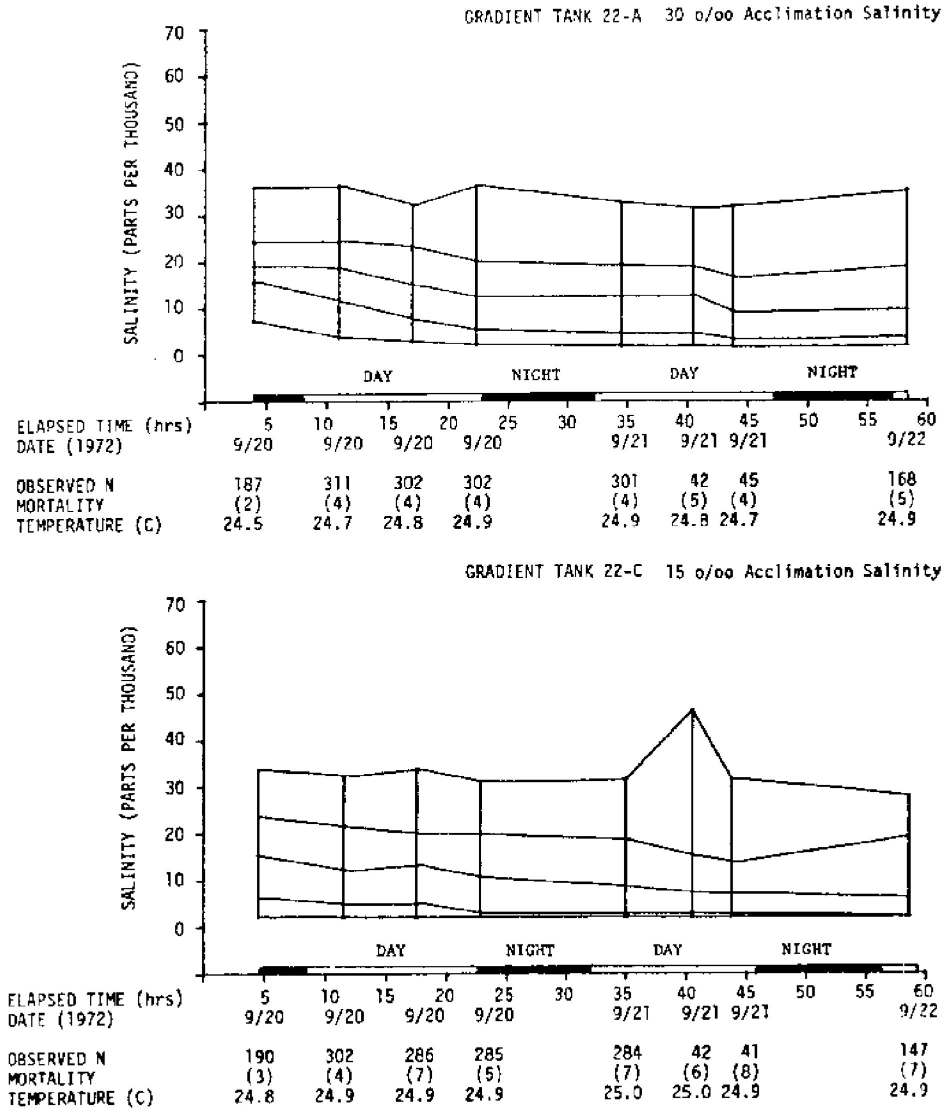


FIGURE 41.—Distribution of postlarval white shrimp (P. setiferus) acclimated to different salinities and tested under continuous low level red illumination in experiment 22, tanks A & C. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

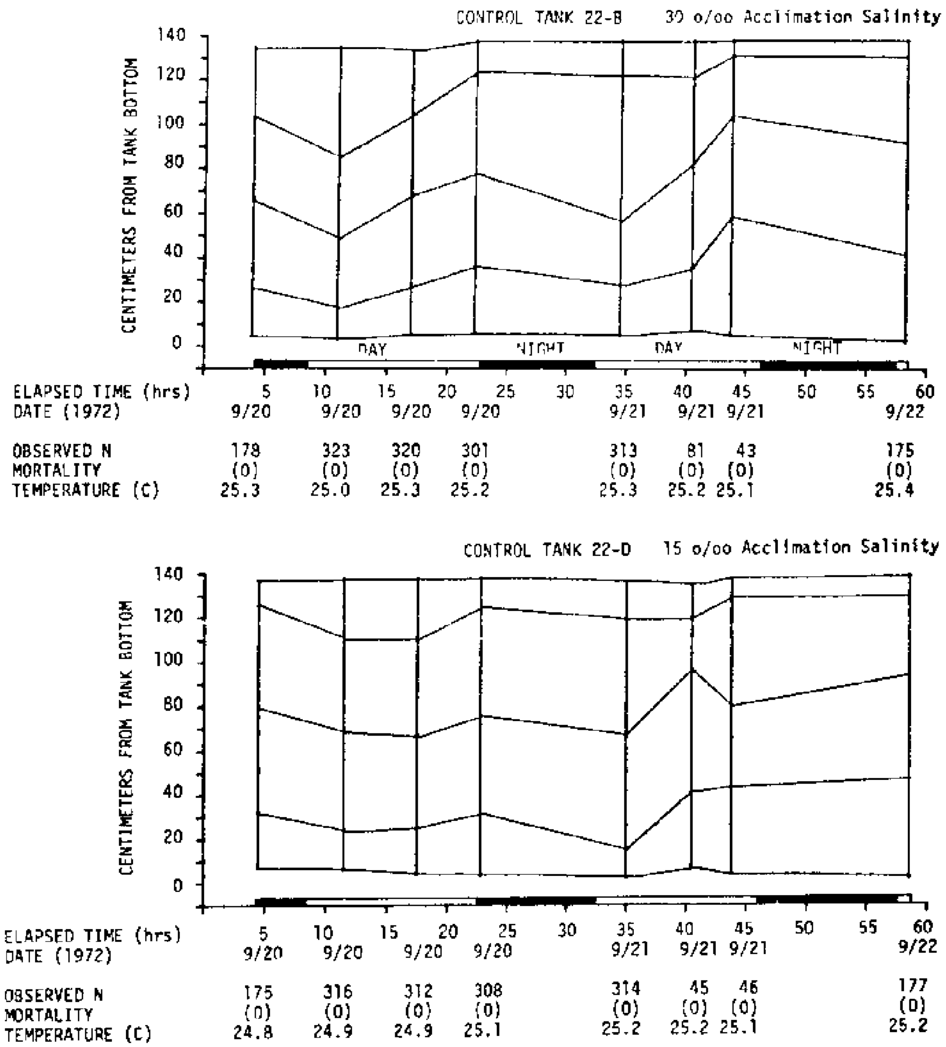


FIGURE 42.—Distribution of postlarval white shirmp (P. setiferus) acclimated to different salinities and tested under continuous low level red illumination in experiment 22, tanks B & D. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th, and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

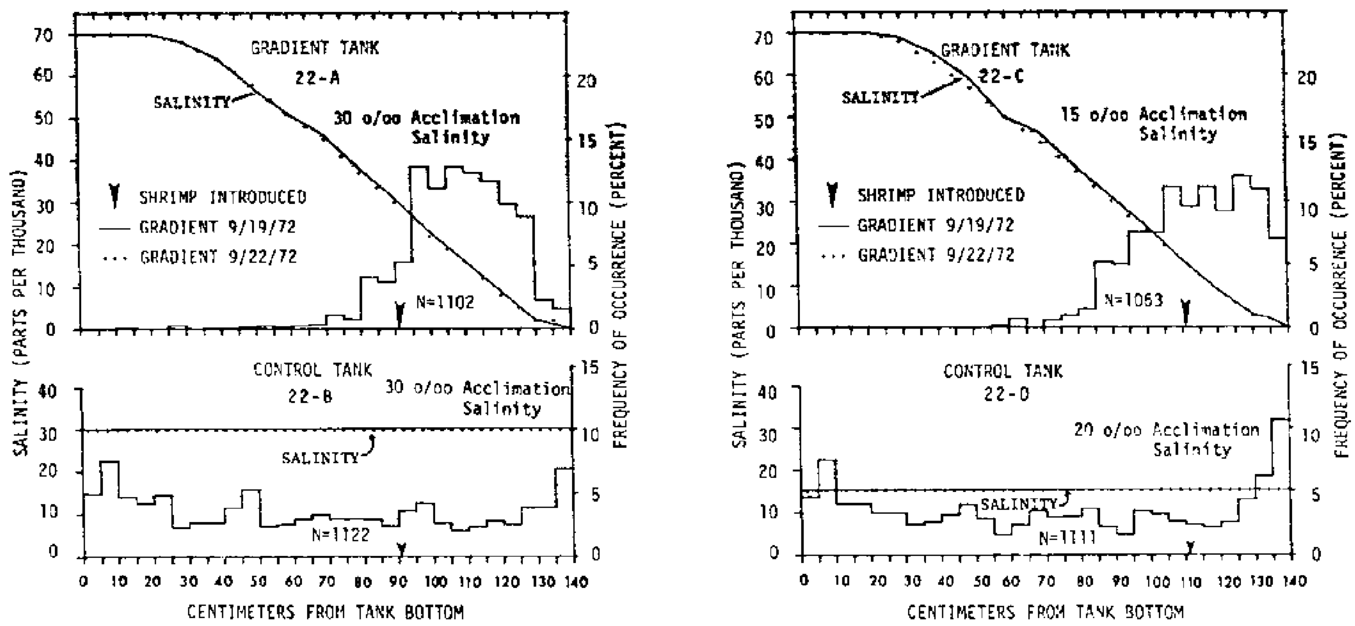


FIGURE 43.—Distribution of postlarval white shrimp (P. setiferus) acclimated to different salinities and salinity in experiment 22 during observations made from 4.0 to 22.8 hours after shrimp were introduced. Temperature approximated 25.0 C during this time interval. Number of shrimp introduced into tank A = 49, tank B = 46, tank C = 47, tank D = 45. N = total number of shrimp counted in a series of observations.

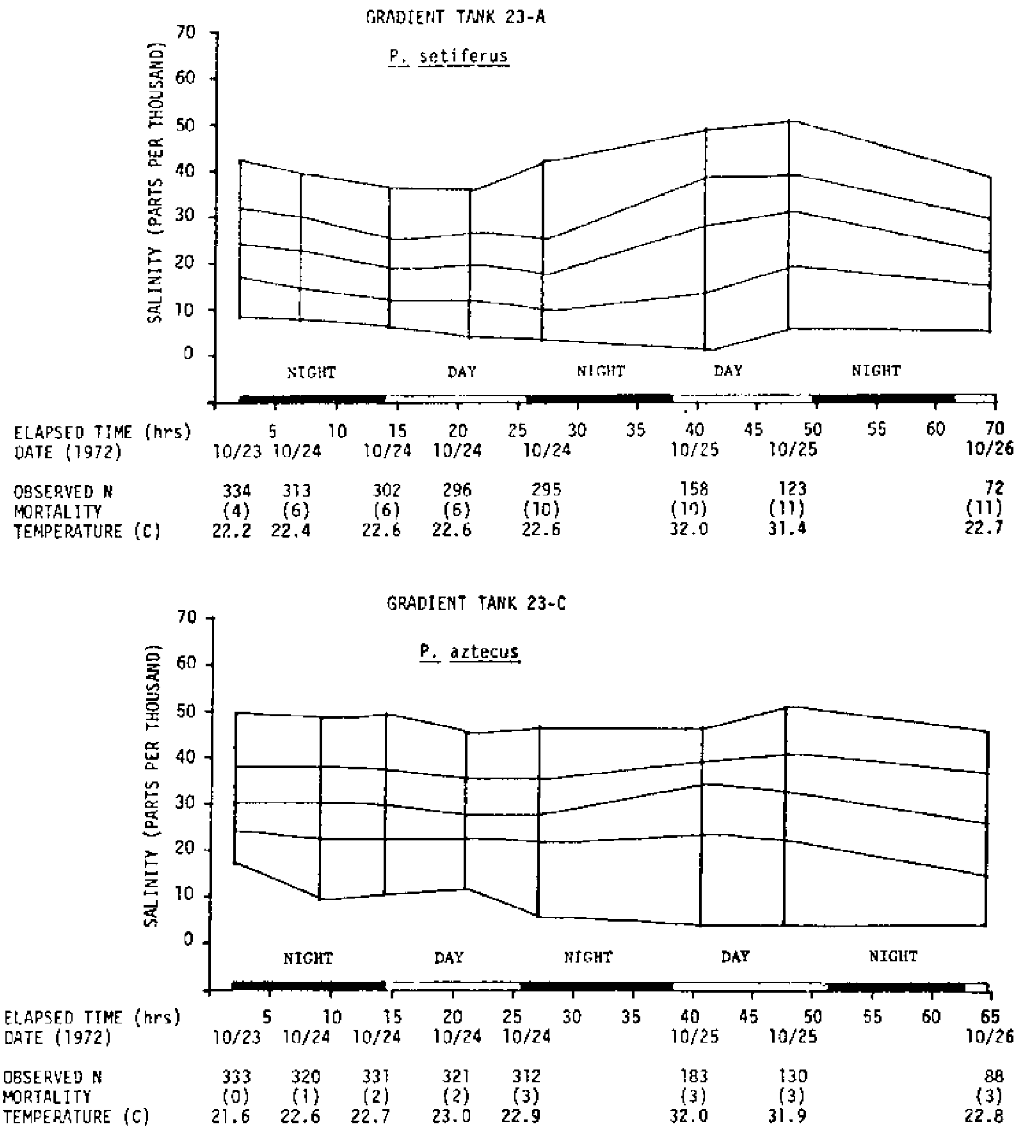


FIGURE 44.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under continuous low-level red illumination in experiment 23, tanks A & C. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th, and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

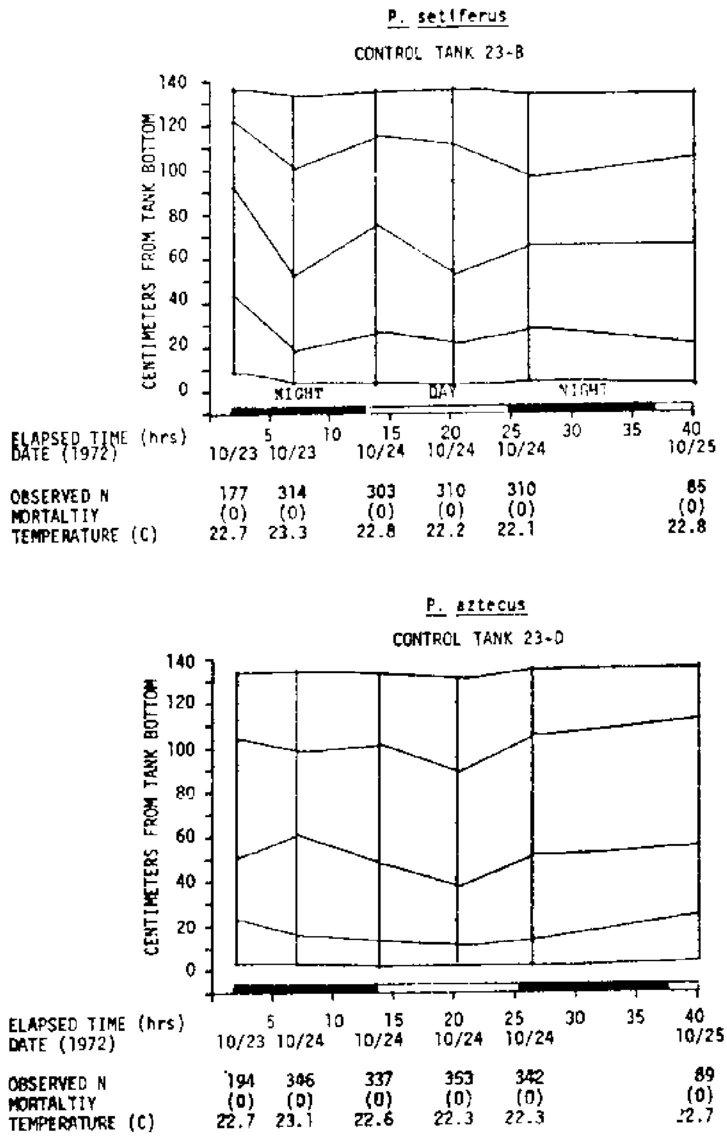


FIGURE 45.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under continuous low level red illumination in experiment 23, tanks B & D. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th, and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

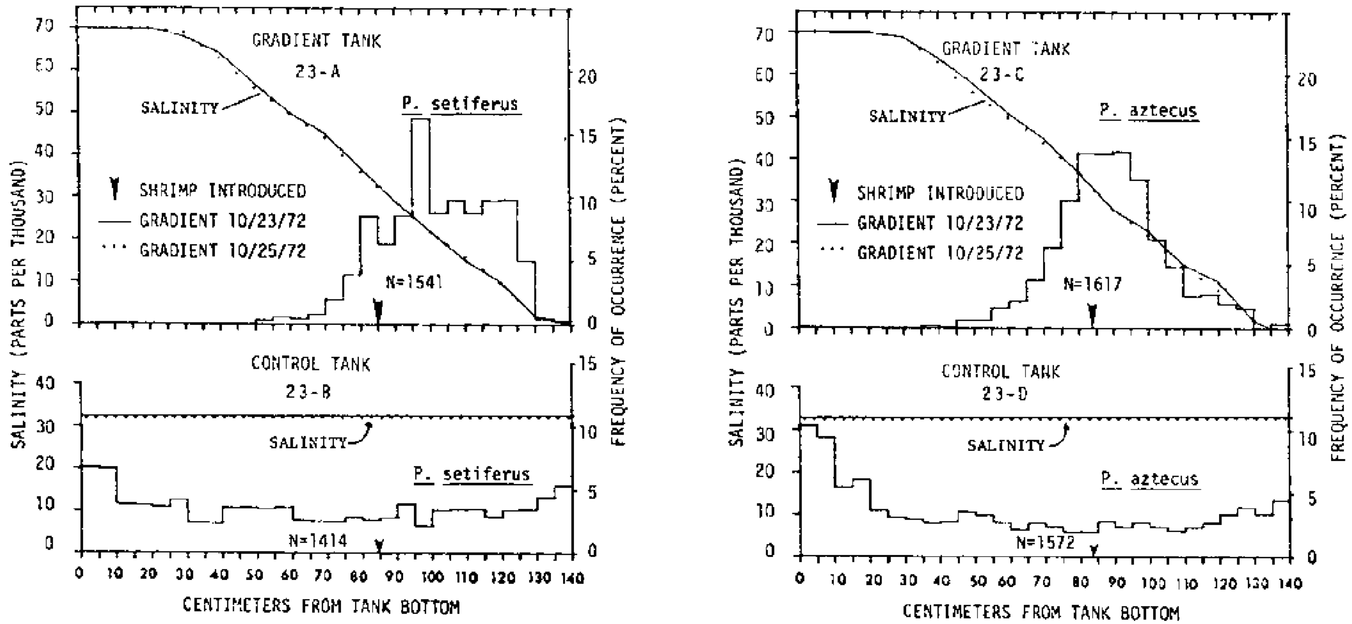
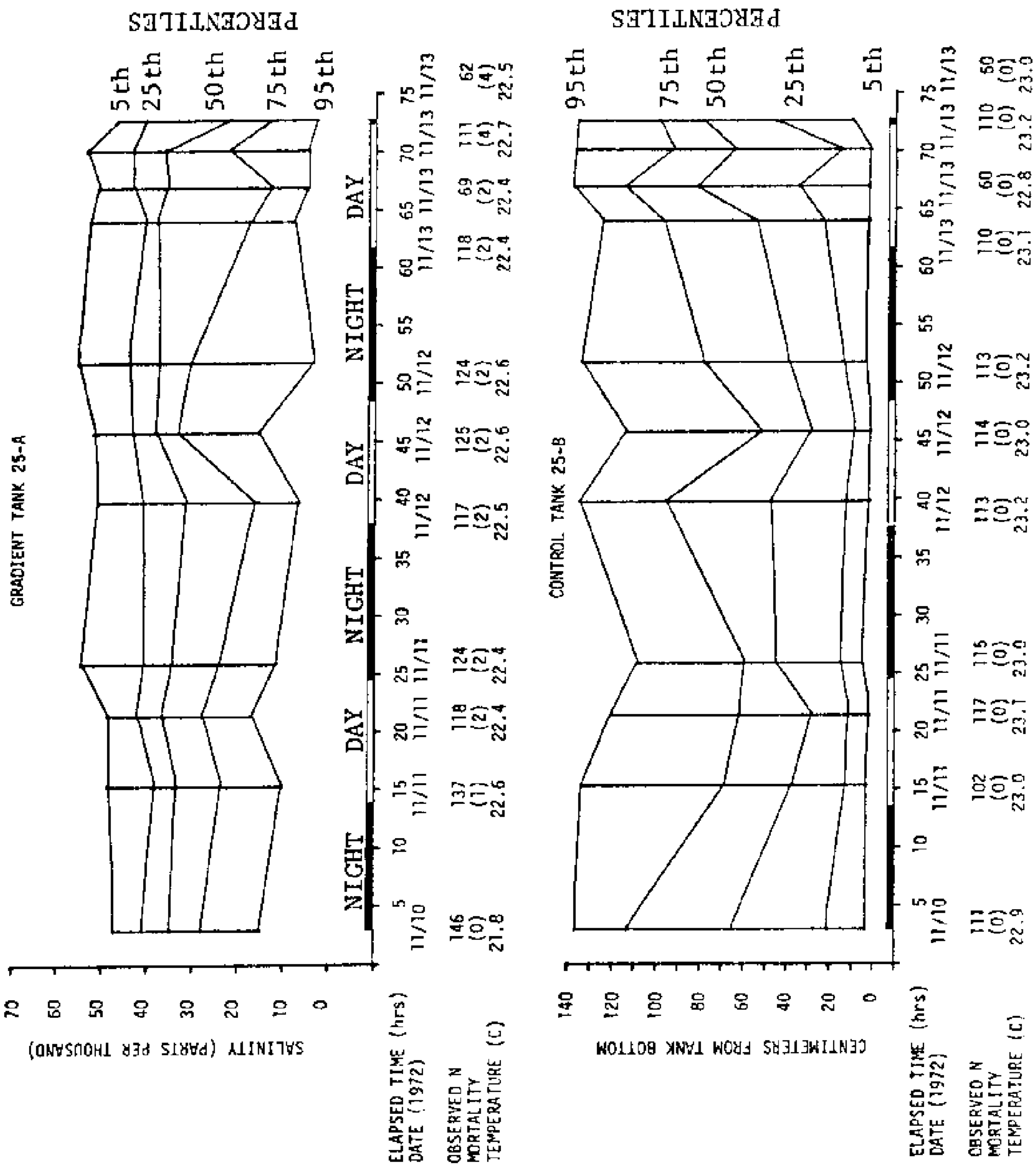


FIGURE 46.--Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) and salinity in experiment 23 during observations made from 2.0 to 27.0 hours after shrimp were introduced. Temperature approximated 22.5 C during this time interval. Number of shrimp introduced into tank A = 50, tank B = 50, tank C =45, tank D = 50. N = total number of shrimp counted in a series of observations.

FIGURE 47.—Distribution of postlarval white shrimp (*P. setiferus*) under continuous low level red illumination in experiment 25, tanks A & B. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th, and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 47


GRADIENT TANK 25-A
CONTROL TANK 25-B
PERCENTILES
5th
25th
50th
75th
95th
NIGHT
DAY
SALINITY (PARTS PER THOUSAND)
CENTIMETERS FROM TANK BOTTOM
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)

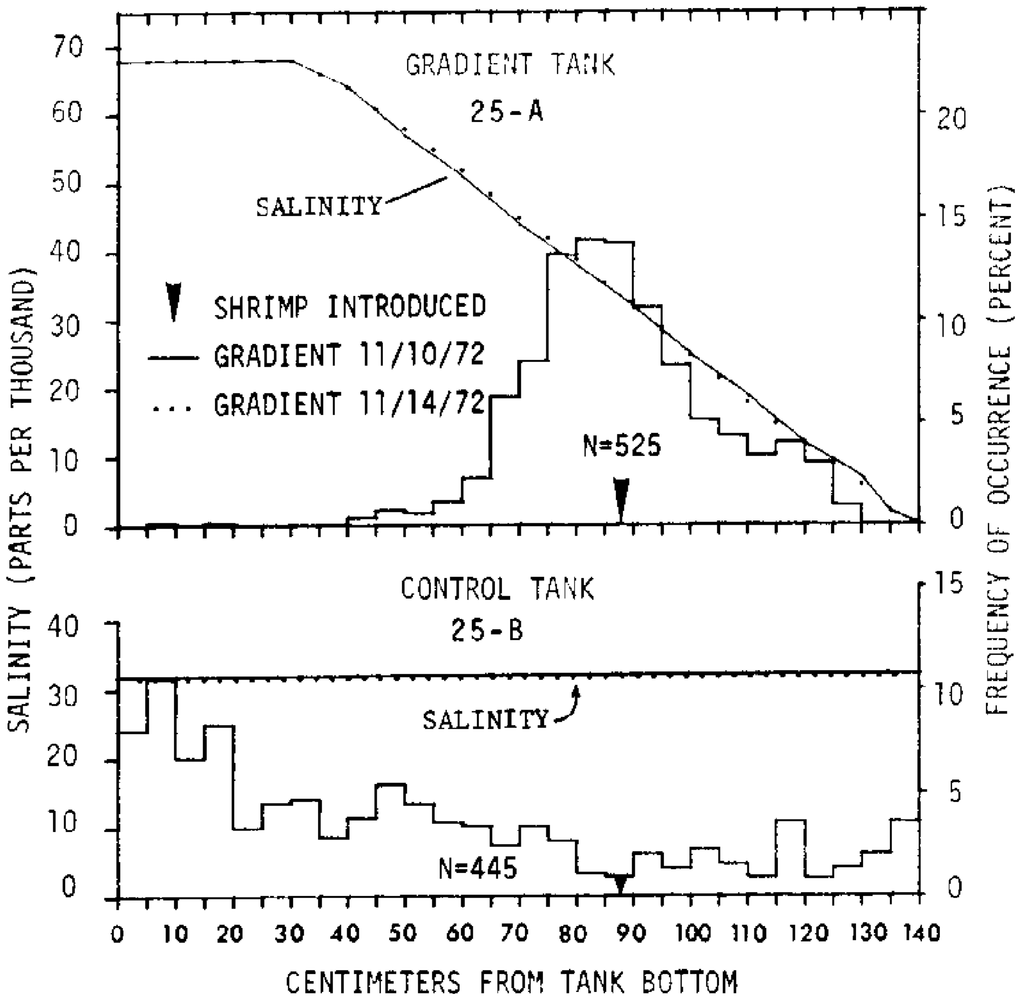
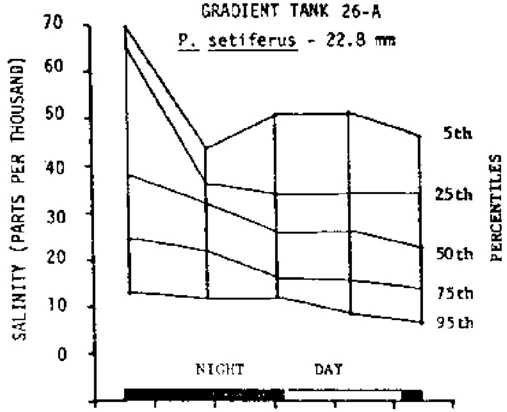


FIGURE 48.—Distribution of postlarval white shrimp (P. setiferus) and salinity during observations made from 3.0 to 25.9 hours after shrimp were introduced. Temperature approximated 23 C during this time interval. Number of shrimp introduced into tank A = 22, tank B = 18. N = total number of shrimp counted in a series of observations.

FIGURE 49.—Distribution of postlarval white shrimp (*P. setiferus*) of different lengths under continuous low level red illumination in experiment 26. Postlarvae were collected on 10/14/72 and acclimated for 61 days to 22 C and 33 o/oo. Vertical lines indicate distribution. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

GRADIENT TANK 26-A

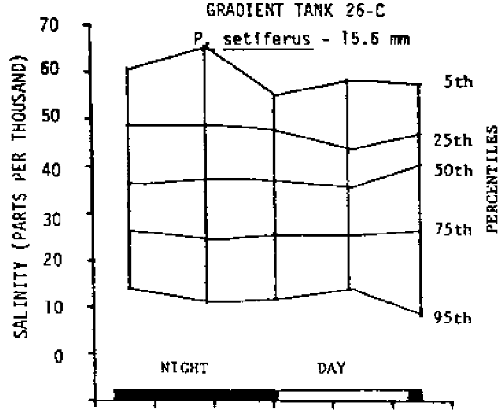
P. setiferus - 22.8 mm



ELAPSED TIME (hrs)	5	10	15	20	25 30
DATE (1972)	12/14	12/14	12/15	12/15	12/15
OBSERVED N	105	96	96	84	84
MORTALITY	(0)	(1)	(1)	(1)	(2)
TEMPERATURE (C)	21.4	20.7	20.1	19.4	18.8

GRADIENT TANK 26-C

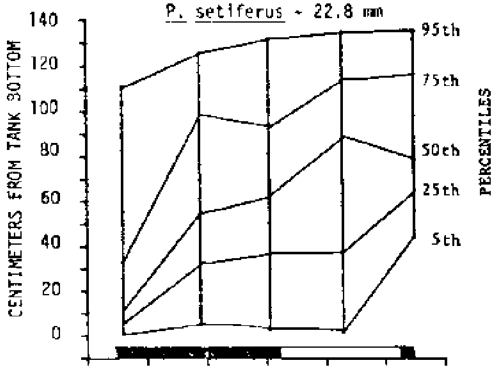
P. setiferus - 15.6 mm



ELAPSED TIME (hrs)	5	10	15	20	25 30
DATE (1972)	12/14	12/15	12/15	12/15	12/15
OBSERVED N	264	227	176	146	124
MORTALITY	(6)	(10)	(16)	(21)	(25)
TEMPERATURE (C)	21.3	22.7	22.9	22.0	21.8

CONTROL TANK 26-B

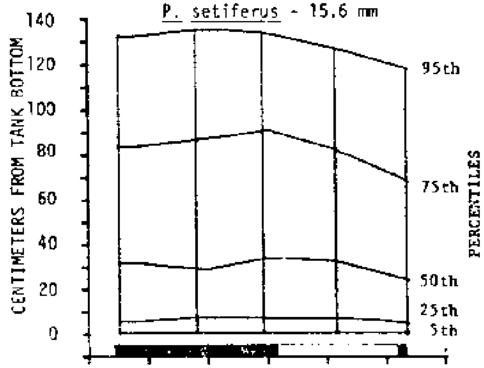
P. setiferus - 22.8 mm



ELAPSED TIME (hrs)	5	10	15	20	25 30
DATE (1972)	12/14	12/15	12/15	12/15	12/15
OBSERVED N	106	106	106	106	99
MORTALITY	(0)	(0)	(0)	(0)	(0)
TEMPERATURE (C)	21.5	20.8	[illegible]	19.6	[illegible]

CONTROL TANK 25-D

P. setiferus - 15.6 mm



ELAPSED TIME (hrs)	5	10	15	20	25 30
DATE (1972)	12/14	12/15	12/15	12/15	12/15
OBSERVED N	295	291	300	293	299
MORTALITY	(0)	(0)	(0)	(0)	(0)
TEMPERATURE (C)	[illegible]	[illegible]	[illegible]	22.0	21.8

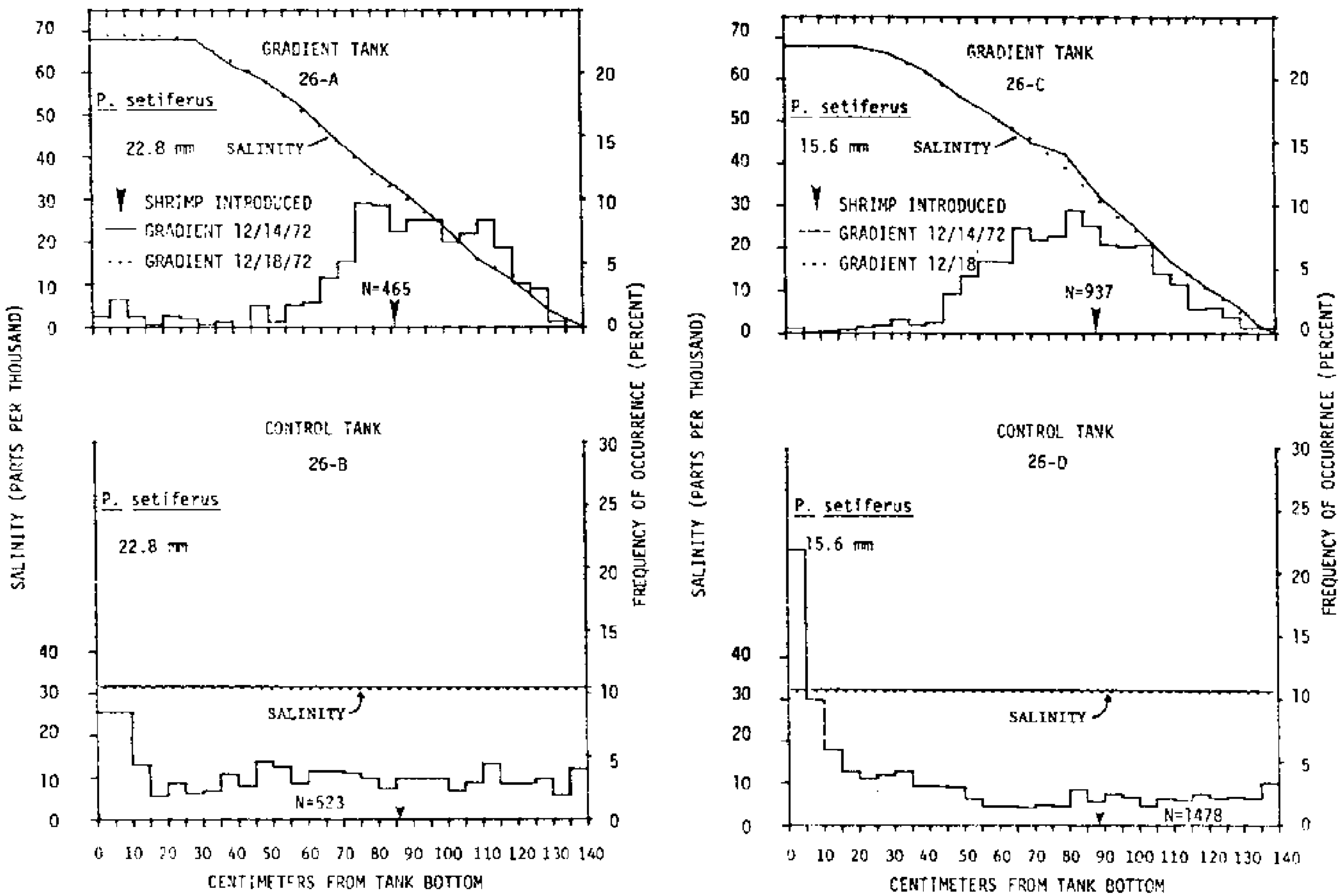
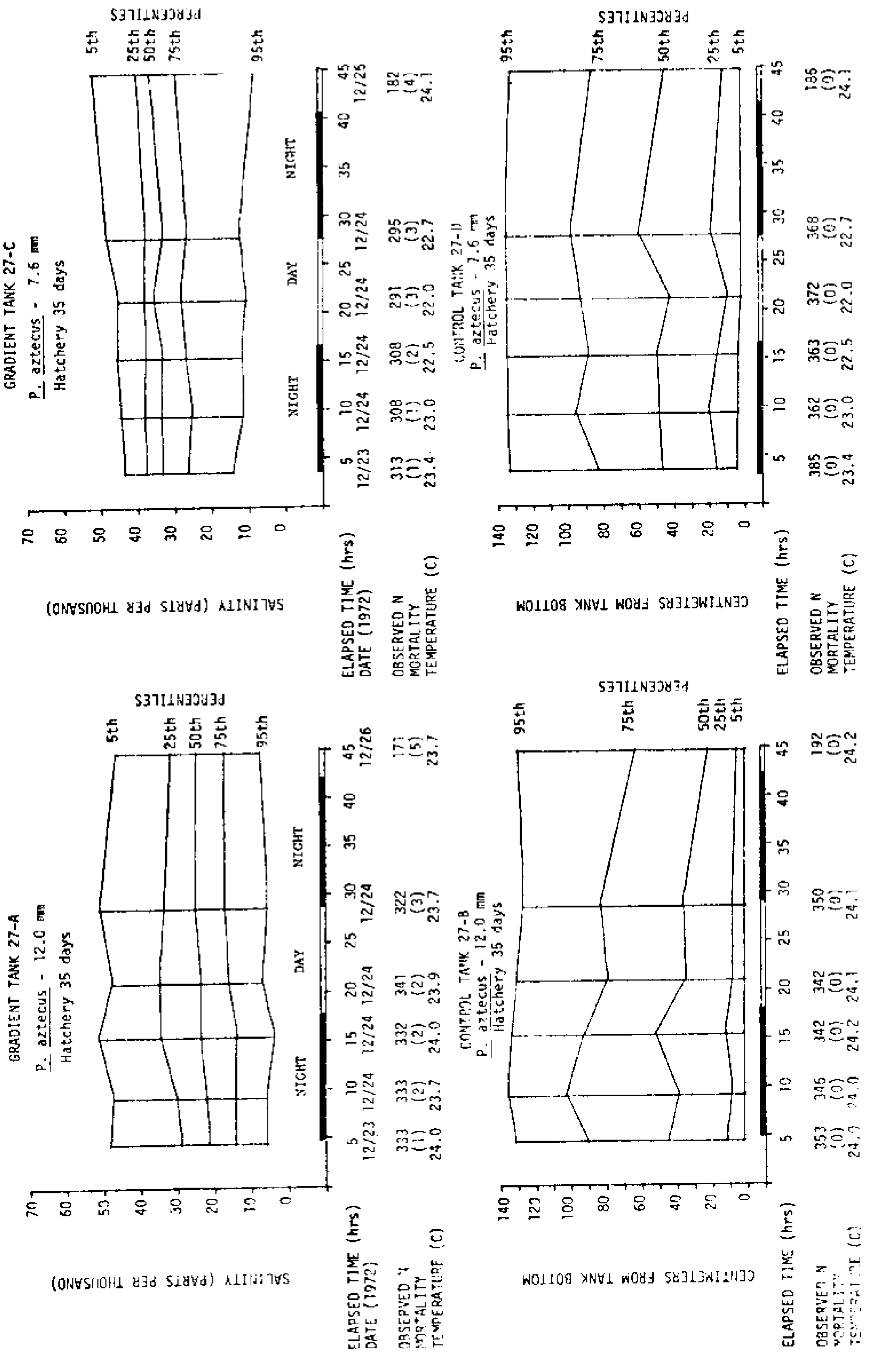


FIGURE 50.—Distribution of postlarval white shrimp (P. setiferus) and salinity in experiment 26 during observations made from 2.6 to 27.5 hours after shrimp were introduced. Temperature approximated 23.0 C during this period. Number of shrimp introduced into tank A = 9, tank B = 9, tank C = 44, tank D = 44.

FIGURE 51.—Distribution of hatchery-raised postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiment 27. Vertical lines indicate distribution. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 51


GRADIENT TANK 27-C
P. aztecus - 7.6 mm
Hatchery 35 days
CONTROL TANK 27-D
P. aztecus - 7.6 mm
Hatchery 35 days
GRADIENT TANK 27-A
P. aztecus - 12.0 mm
Hatchery 35 days
CONTROL TANK 27-B
P. aztecus - 12.0 mm
Hatchery 35 days
SALINITY (PARTS PER THOUSAND)
CENTIMETERS FROM TANK BOTTOM
PERCENTILES
ELAPSED TIME (hrs)
DATE (1972)
OBSERVED N
MORTALITY
TEMPERATURE (C)
NIGHT
DAY

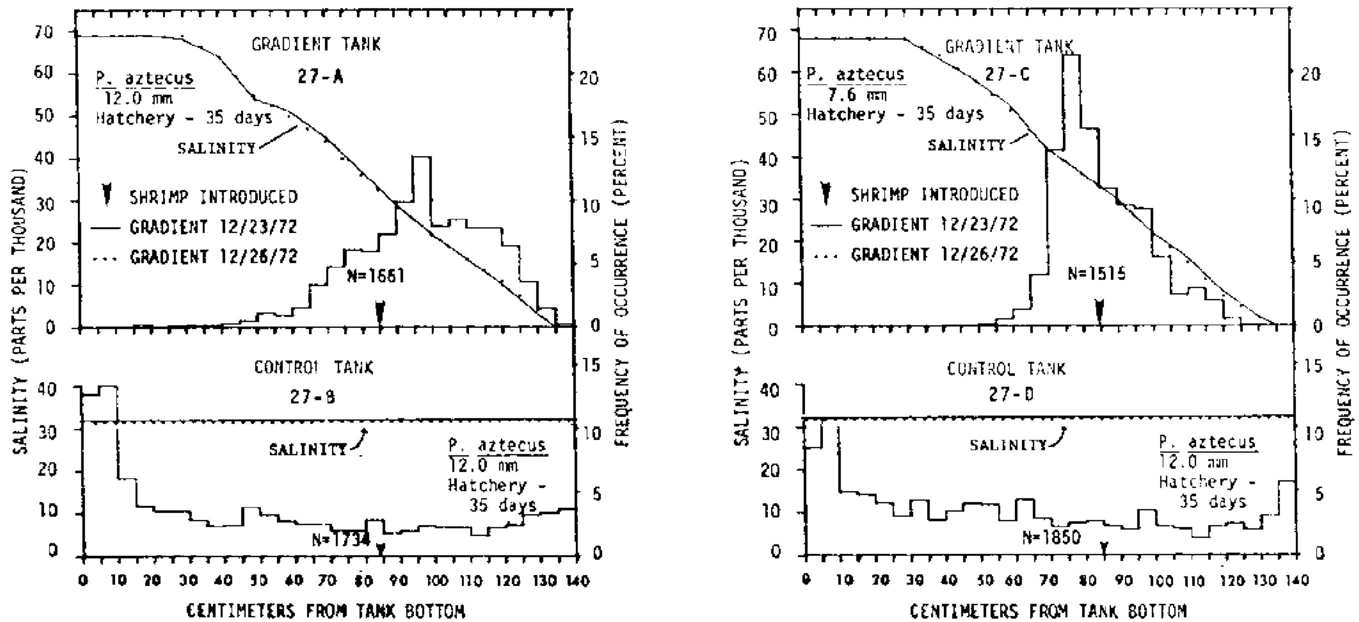
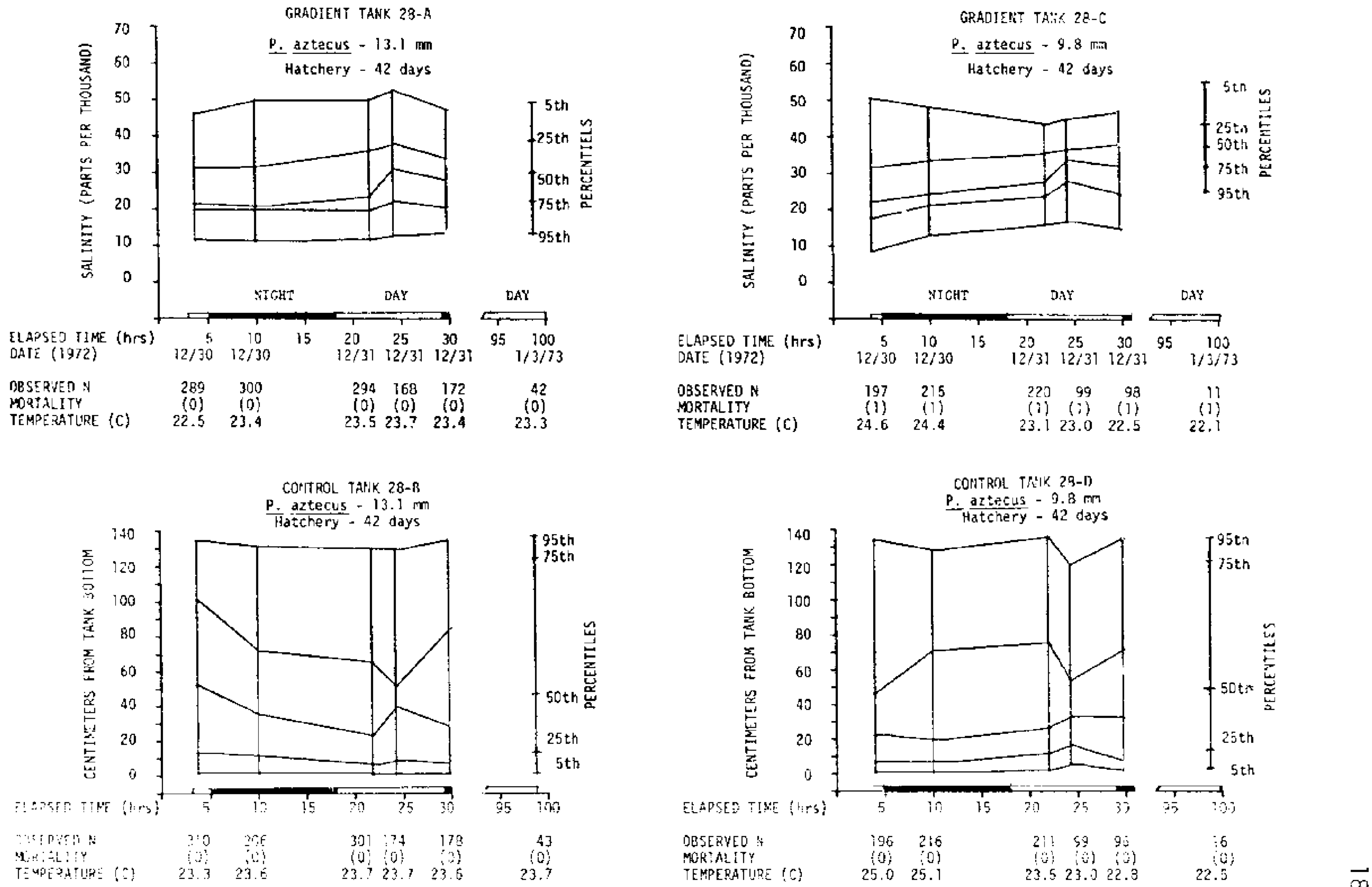


FIGURE 52.—Distribution of hatchery-raised postlarval brown shrimp (P. aztecus) and salinity in experiment 27 during observations made from 3.6 to 28.6 hours after shrimp were introduced. Temperature approximated 23.5 C during this time interval. Number of shrimp introduced into tank A = 50, tank B = 50, tank C = 45, tank D = 49. N = total number of shrimp counted in a series of observations.

FIGURE 53.—Distribution of hatchery-raised postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiment 28. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.


GRADIENT TANK 28-A
P. aztecus - 13.1 mm
Hatchery - 42 days
SALINITY (PARTS PER THOUSAND)
70
60
50
40
30
20
10
0
5th
25th
50th
75th
95th
PERCENTIELS
NIGHT
DAY
DAY
ELAPSED TIME (hrs) 5 10 15 20 25 30 95 100
DATE (1972) 12/30 12/30 12/31 12/31 12/31 1/3/73
OBSERVED N 289 300 294 168 172 42
MORTALITY (0) (0) (0) (0) (0) (0)
TEMPERATURE (C) 22.5 23.4 23.5 23.7 23.4 23.3
GRADIENT TANK 28-C
P. aztecus - 9.8 mm
Hatchery - 42 days
SALINITY (PARTS PER THOUSAND)
70
60
50
40
30
20
10
0
5th
25th
50th
75th
95th
PERCENTILES
NIGHT
DAY
DAY
ELAPSED TIME (hrs) 5 10 15 20 25 30 95 100
DATE (1972) 12/30 12/30 12/31 12/31 12/31 1/3/73
OBSERVED N 197 215 220 99 98 11
MORTALITY (1) (1) (1) (1) (1) (1)
TEMPERATURE (C) 24.6 24.4 23.1 23.0 22.5 22.1
CONTROL TANK 28-B
P. aztecus - 13.1 mm
Hatchery - 42 days
CENTIMETERS FROM TANK BOTTOM
140
120
100
80
60
40
20
0
95th
75th
50th
25th
5th
PERCENTILES
ELAPSED TIME (hrs) 5 10 15 20 25 30 95 100
OBSERVED N 210 206 301 174 178 43
MORTALITY (0) (0) (0) (0) (0) (0)
TEMPERATURE (C) 23.3 23.6 23.7 23.7 23.6 23.7
CONTROL TANK 28-D
P. aztecus - 9.8 mm
Hatchery - 42 days
CENTIMETERS FROM TANK BOTTOM
140
120
100
80
60
40
20
0
95th
75th
50th
25th
5th
PERCENTILES
ELAPSED TIME (hrs) 5 10 15 20 25 30 95 100
OBSERVED N 196 216 211 99 96 16
MORTALITY (0) (0) (0) (0) (0) (0)
TEMPERATURE (C) 25.0 25.1 23.5 23.0 22.8 22.5

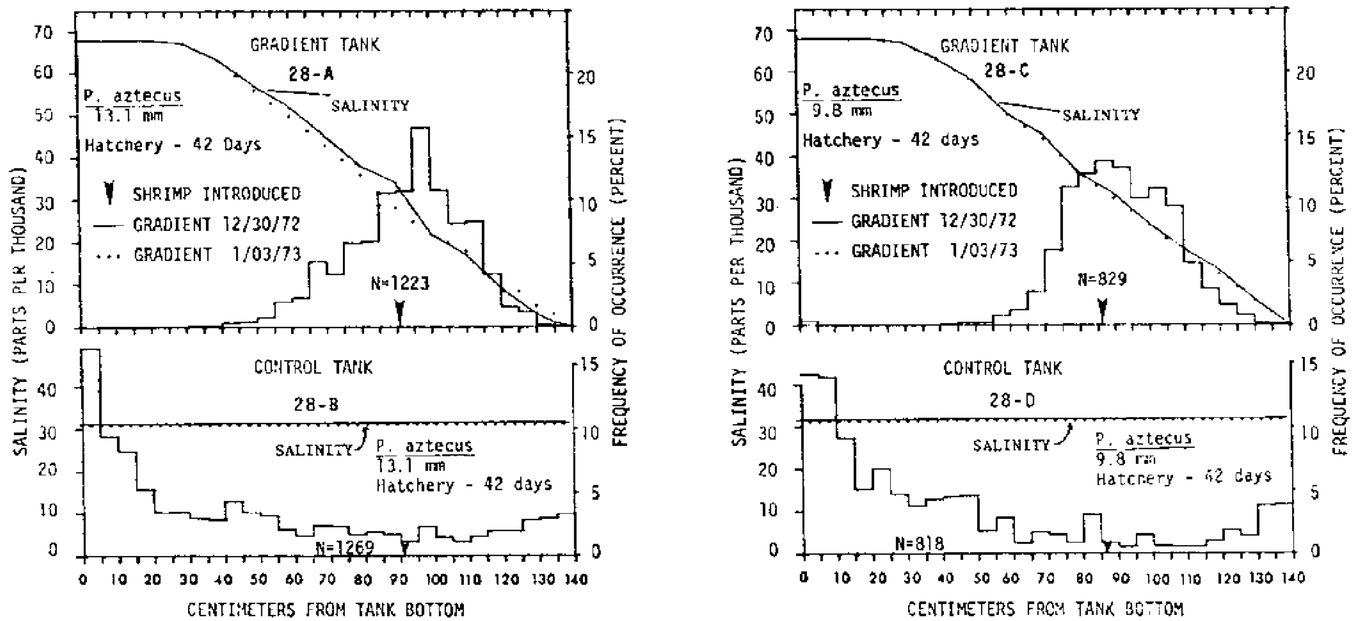


FIGURE 54.—Distribution of hatchery-raised postlarval brown shrimp (P. aztecus) and salinity in experiment 28 during observations made from 3.8 to 29.8 hours after shrimp were introduced. Temperature approximated 23.5 C during this time interval. Number of shrimp introduced into tank A = 44, tank B = 44, tank C = 45, tank D = 49. N = total number of shrimp counted in a series of observations.

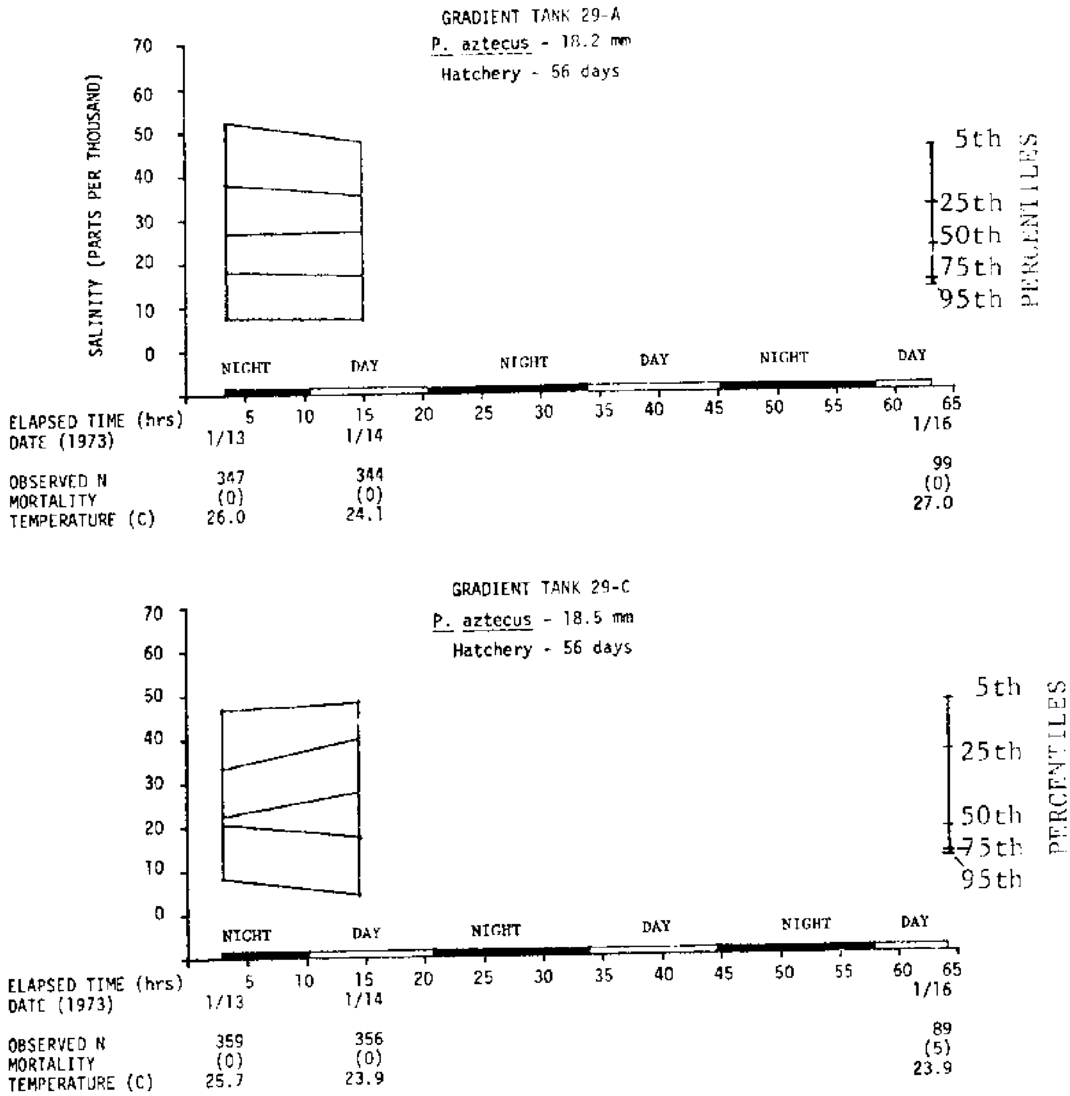


FIGURE 55.—Distribution of hatchery-raised postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 29, tanks A & C. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

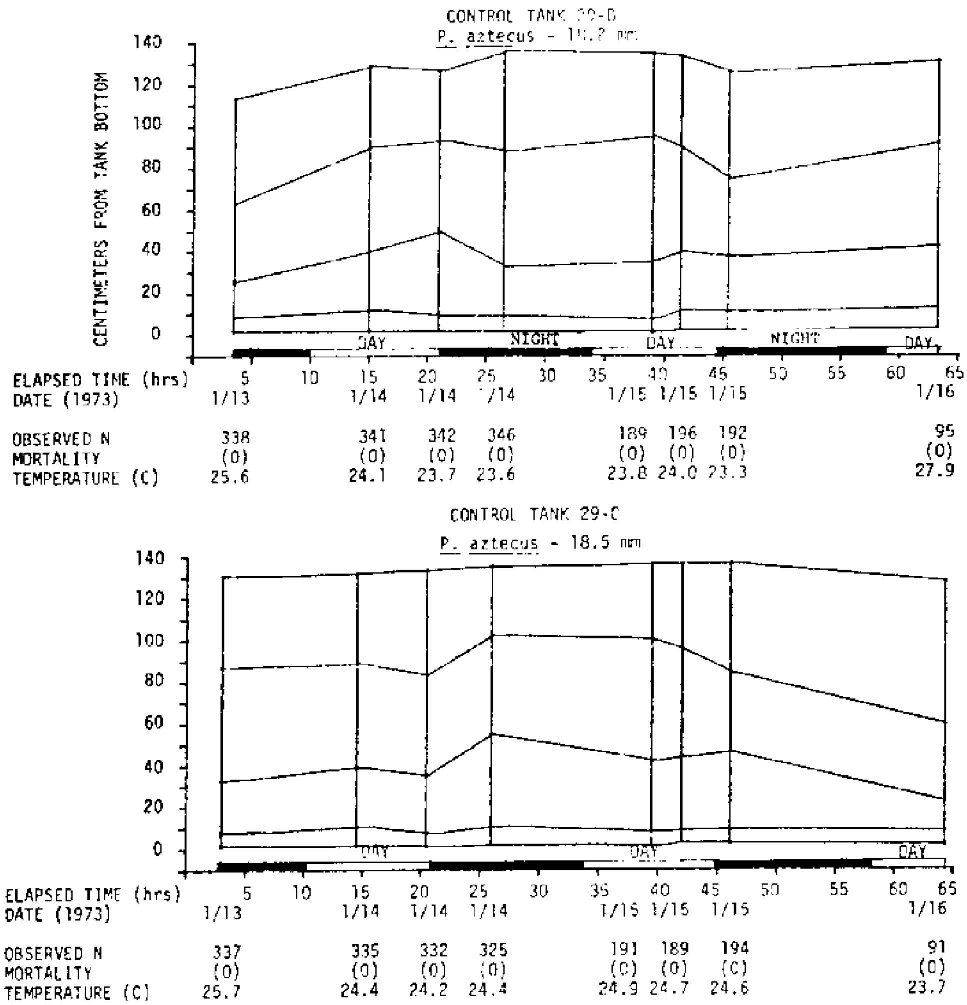


FIGURE 56.—Distribution of hatchery-raised postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 29, tanks B & D. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th and 5th percentiles. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

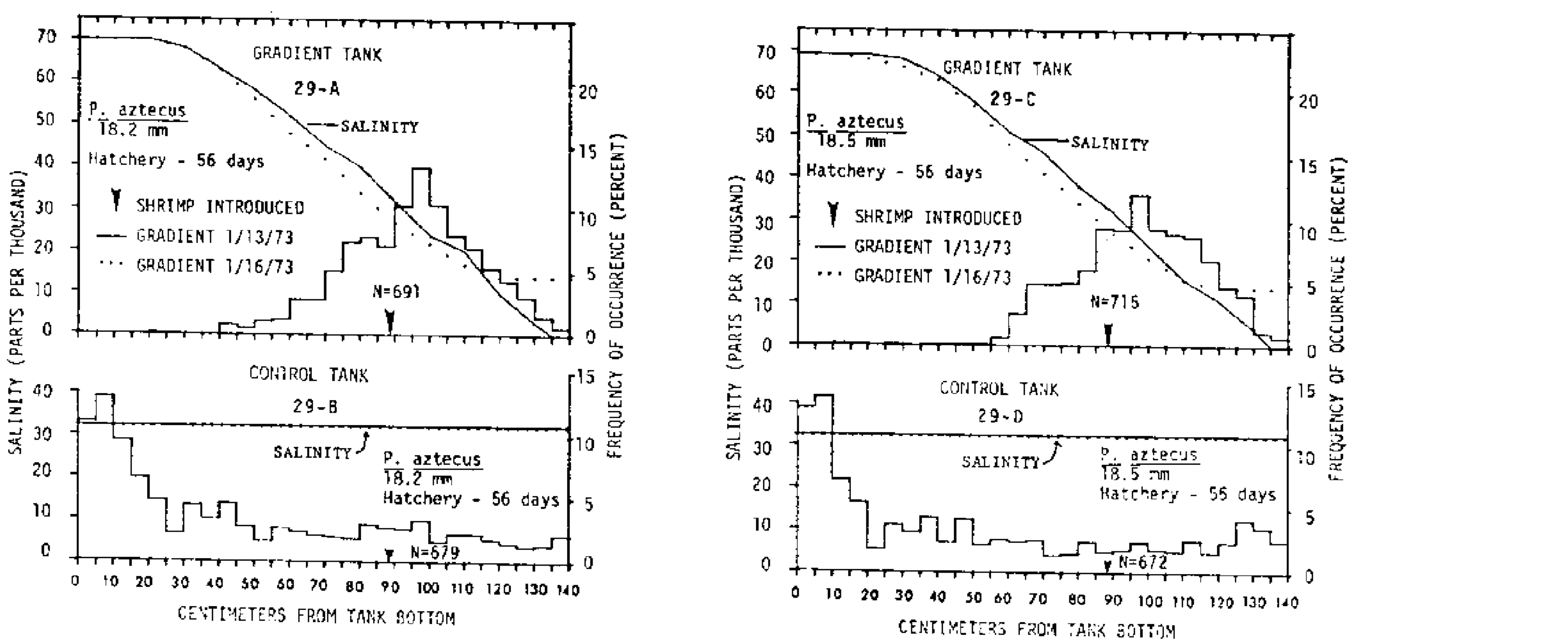
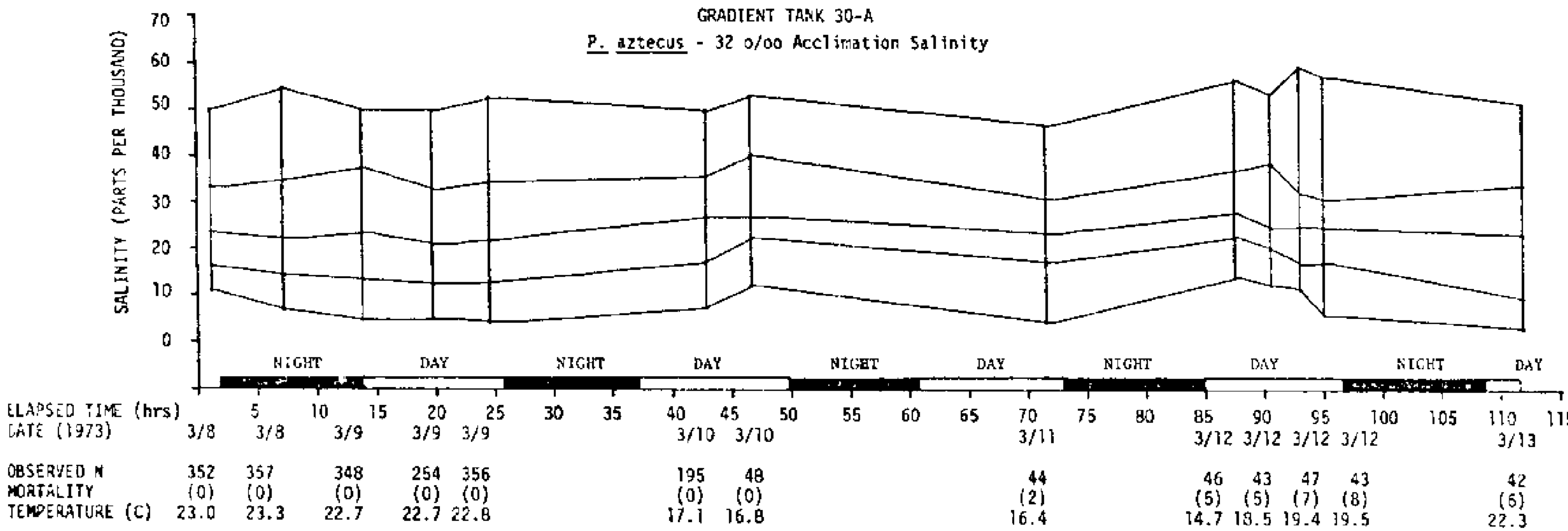


FIGURE 57.—Distribution of hatchery-raised postlarval brown shrimp (P. aztecus) and salinity in experiment 29 during observations made from 3.0 to 15.0 hours after shrimp were introduced. Temperature approximated 25 C during this time interval. Number of shrimp introduced into tank A = 50, tank B = 50, tank C = 50, tank D = 50. N = total number of shrimp counted in a series of observations.

FIGURE 58.—Distribution of postlarval brown shrimp (<u>P. aztecus</u>) acclimated to different salinities and tested under continuous low level red illumination in experiment 30, tanks A & C. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

GRADIENT TANK 30-A

P. aztecus - 32 o/oo Acclimation Salinity



GRADIENT TANK 30-C

P. aztecus - 24 o/oo Acclimation Salinity

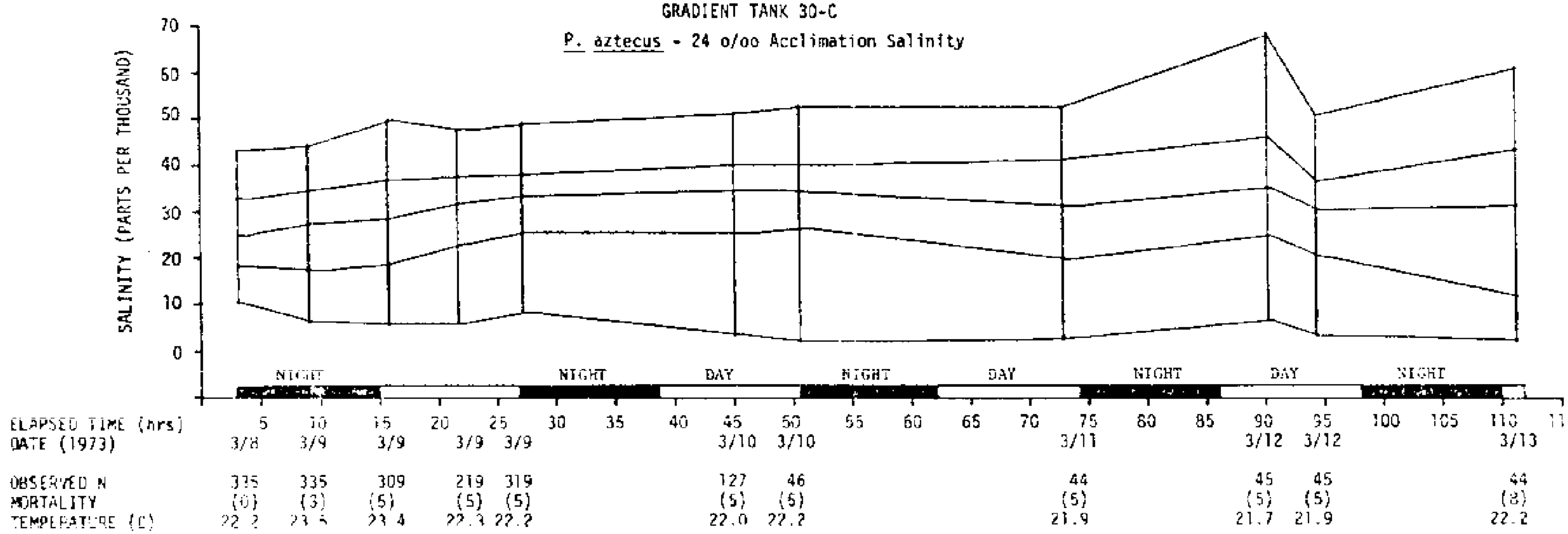
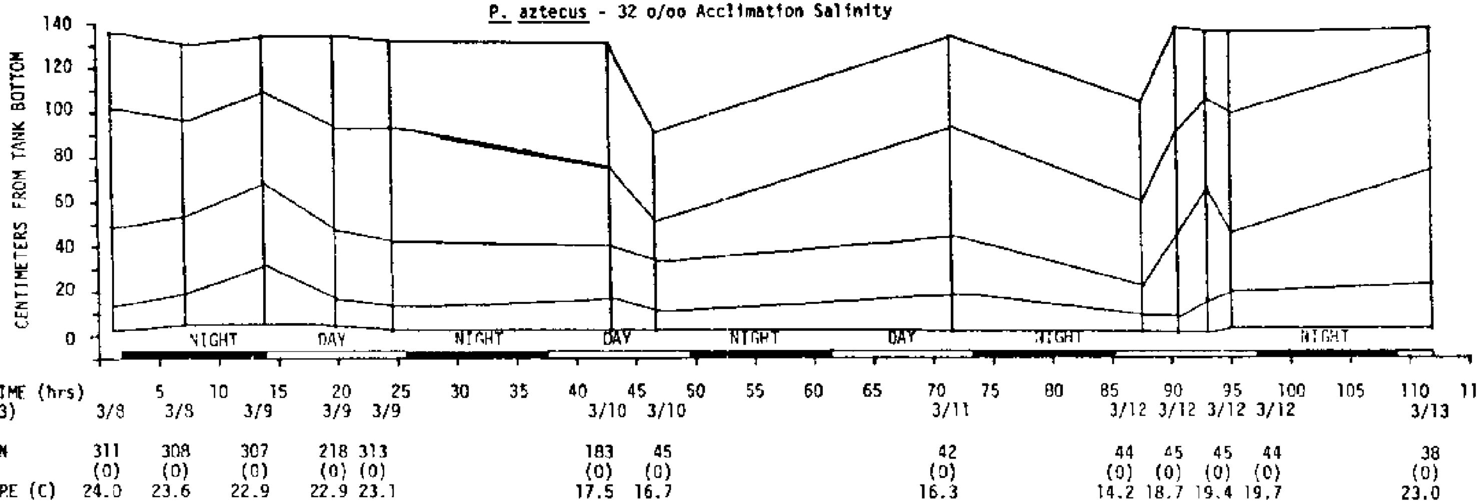


FIGURE 59—Distribution of postlarval brown shrimp (*P. aztecus*) acclimated to different salinities and tested under continuous low level red illumination in experiment 30, tanks B & D. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

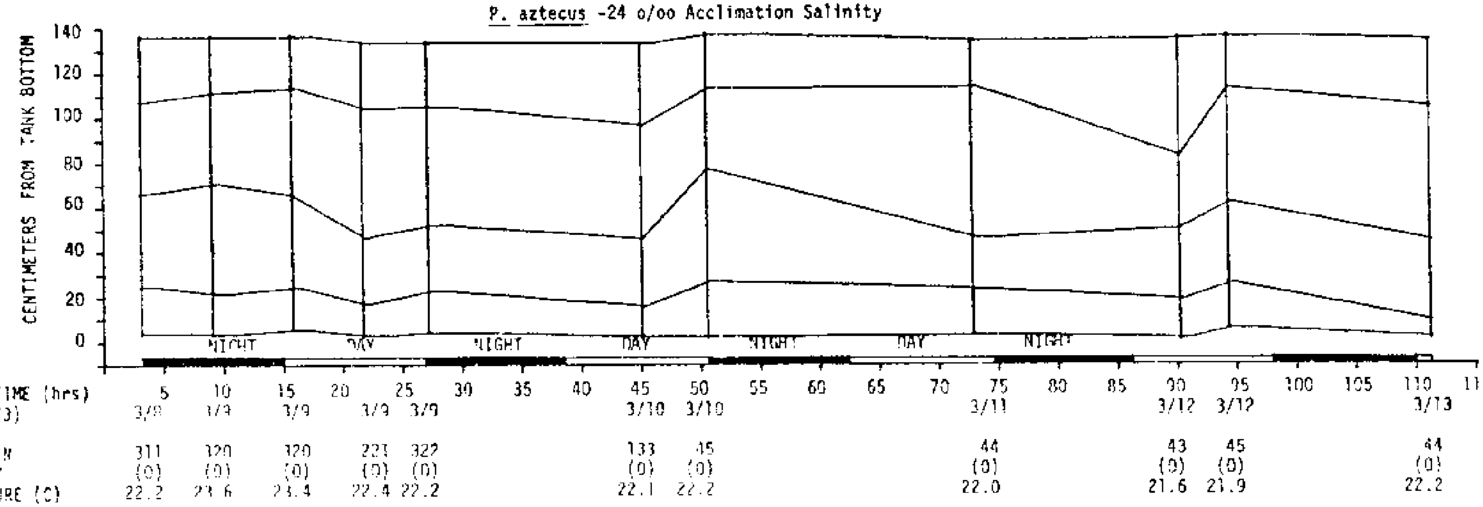
CONTROL TANK 30-B

P. aztecus - 32 o/oo Acclimation Salinity



CONTROL TANK 30-D

P. aztecus -24 o/oo Acclimation Salinity



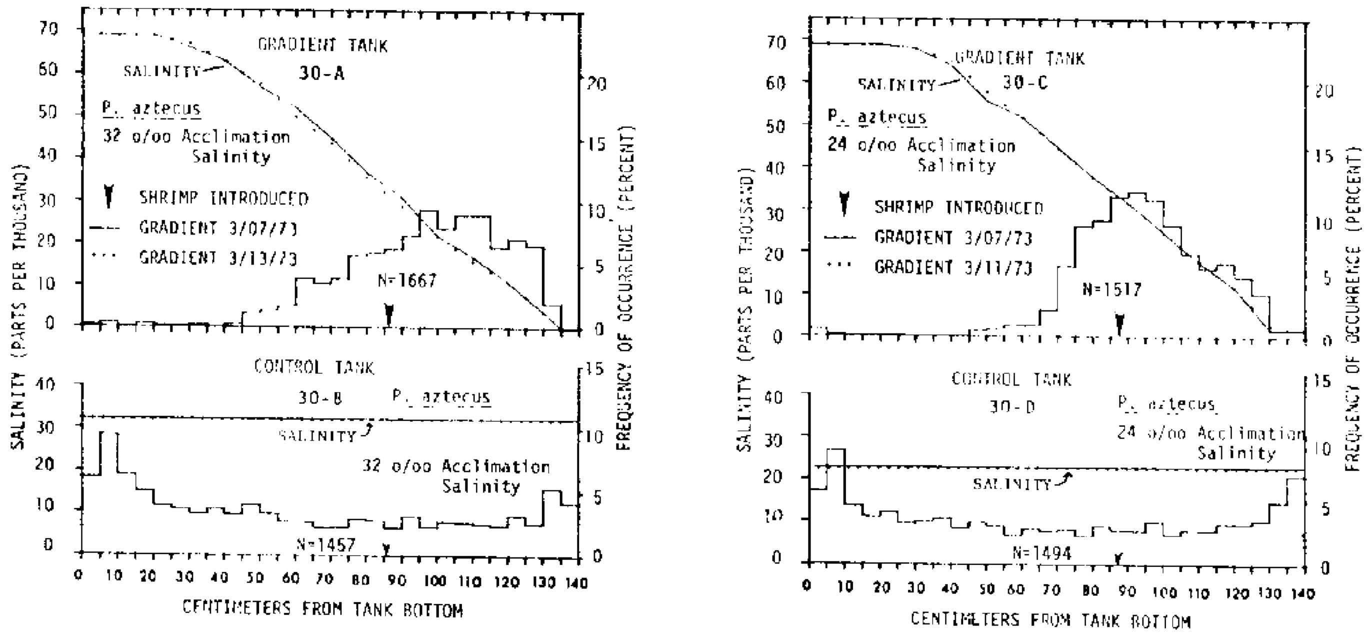


FIGURE 60.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 30 during observations made from 1.2 to 27.2 hours after shrimp were introduced. Postlarvae were acclimated for 5 days to 23 C and to either 24 or 32 o/oo. Number of shrimp introduced into tank A = 50, tank B = 50, tank C = 50, tank D = 50. N = total number of shrimp counted in a series of observations.

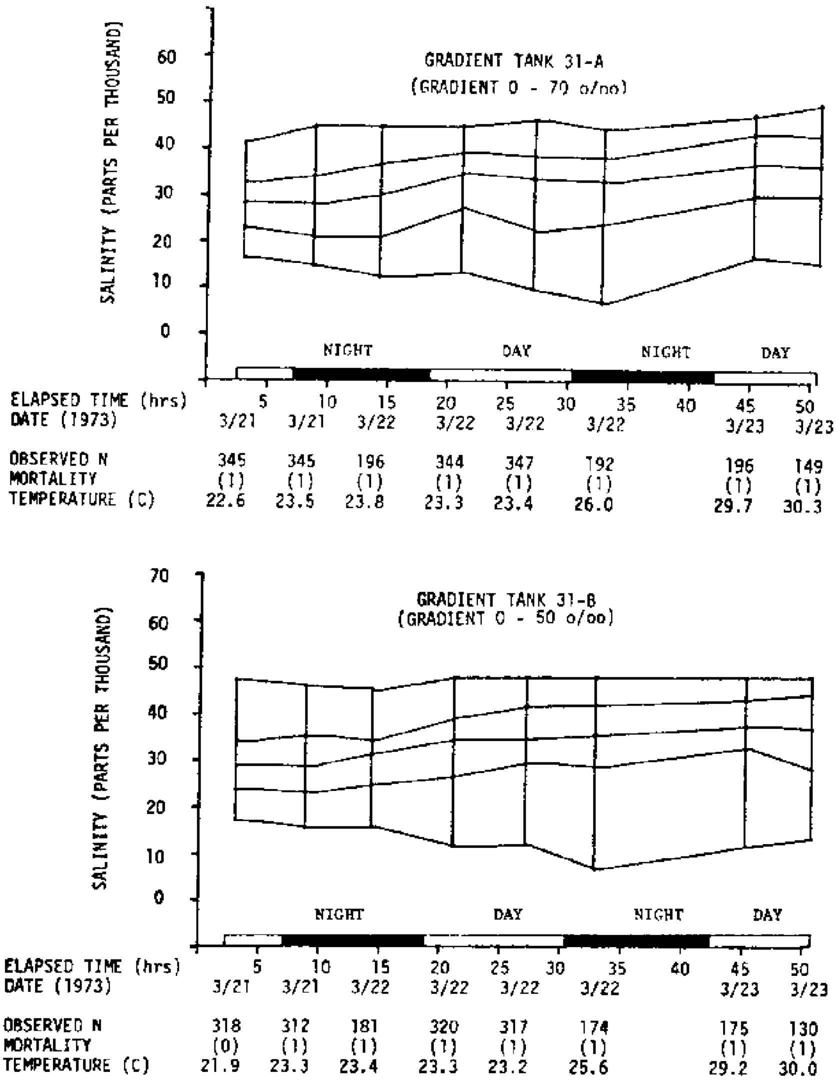


FIGURE 61.—Distribution of postlarval brown shrimp (P. aztecus) in two different salinity gradients and tested under continuous low level red illumination in experiment 31. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; no dead shrimp removed.

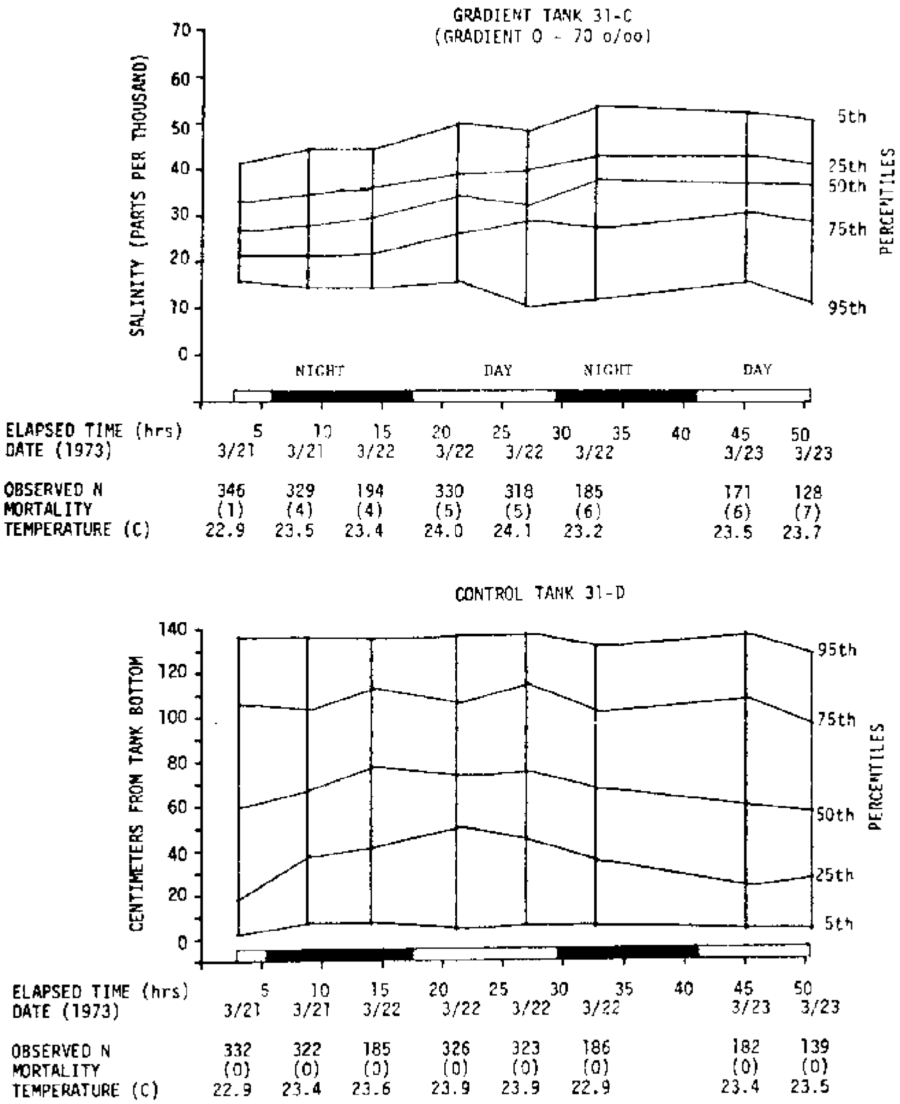


FIGURE 62.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low-level illumination in experiment 31. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

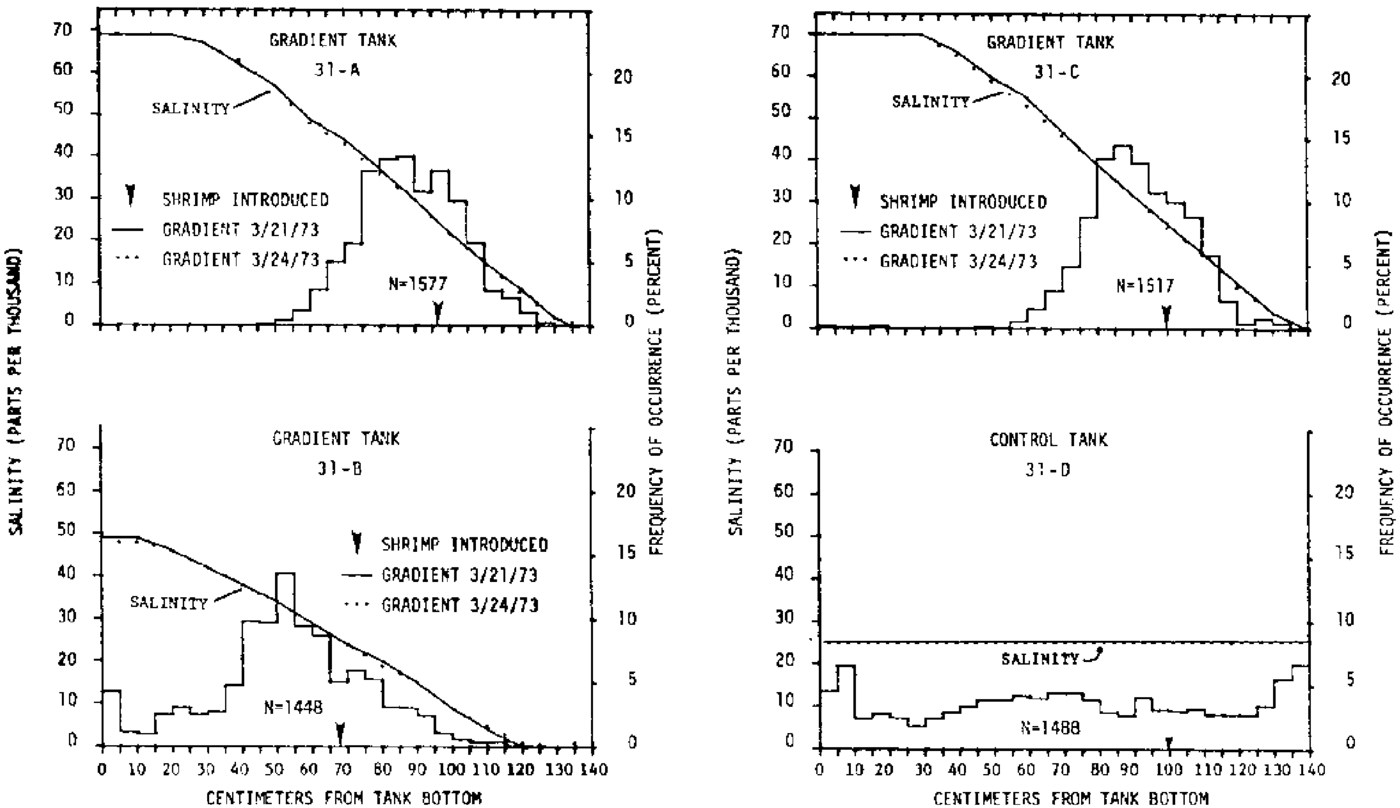


FIGURE 63.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 31 during observations made from 3.1 to 27.1 hours after shrimp were introduced. Temperature approximated 23.5 C during this time interval. Postlarvae were tested in two different salinity gradients; tanks A & C are replicates. Number of shrimp introduced into tank A = 50, tank B = 47, tank C = 50, tank D = 48. N = total number of shrimp counted in a series of observations.

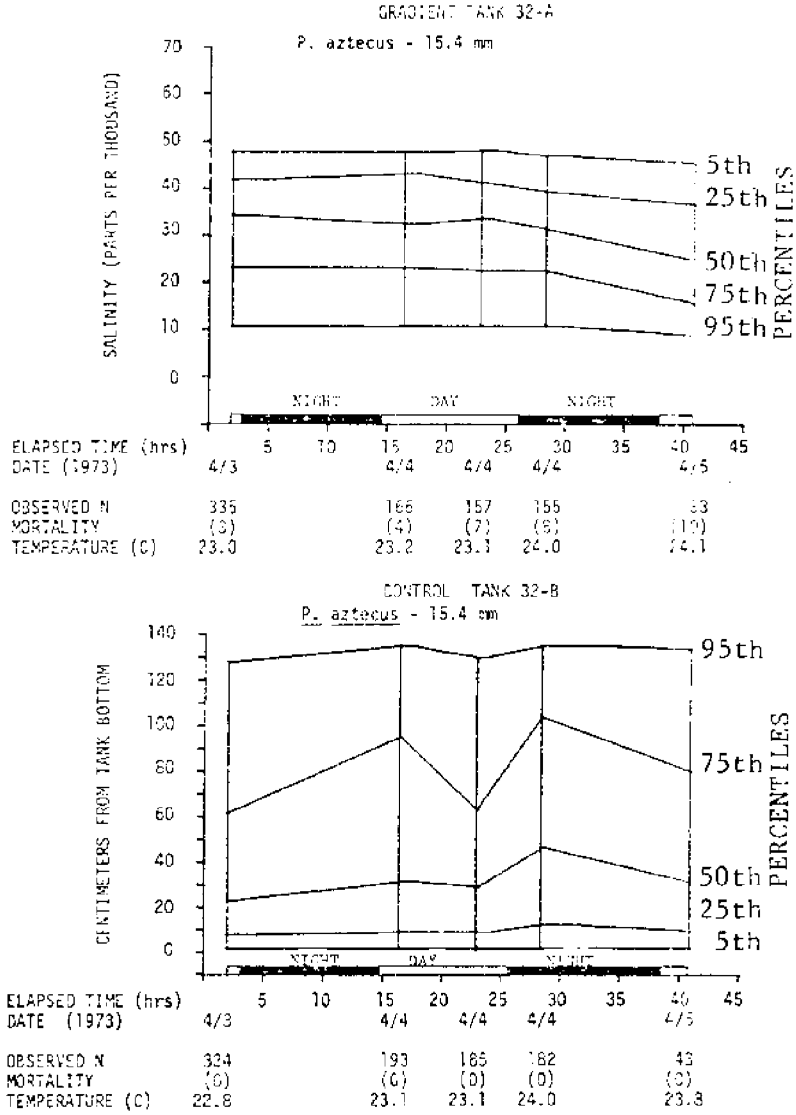


FIGURE 64.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 32. Postlarvae were collected 3/17/73 and acclimated for 19 days to 23 C and 26 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of dead shrimp observed during an observation period; no dead shrimp removed.

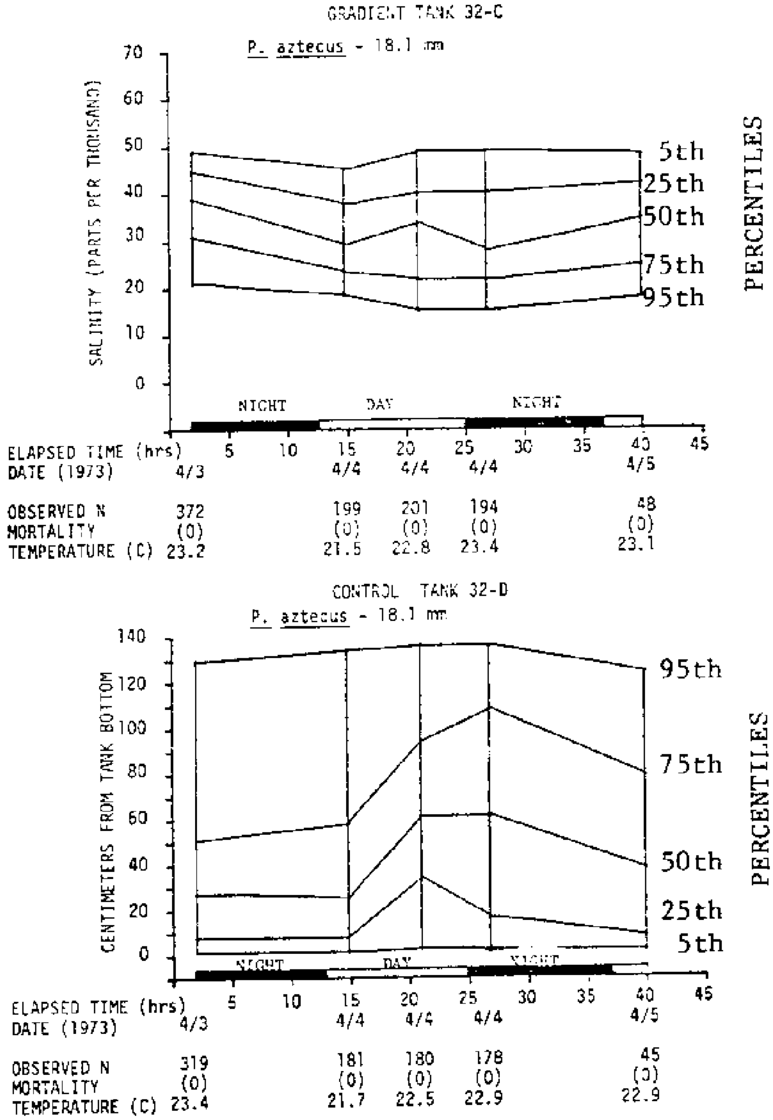


FIGURE 65.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 32. Postlarvae were collected 3/03/73 and acclimated for 31 days to 23 C and 24 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of dead shrimp observed during an observation period; no dead shrimp removed.

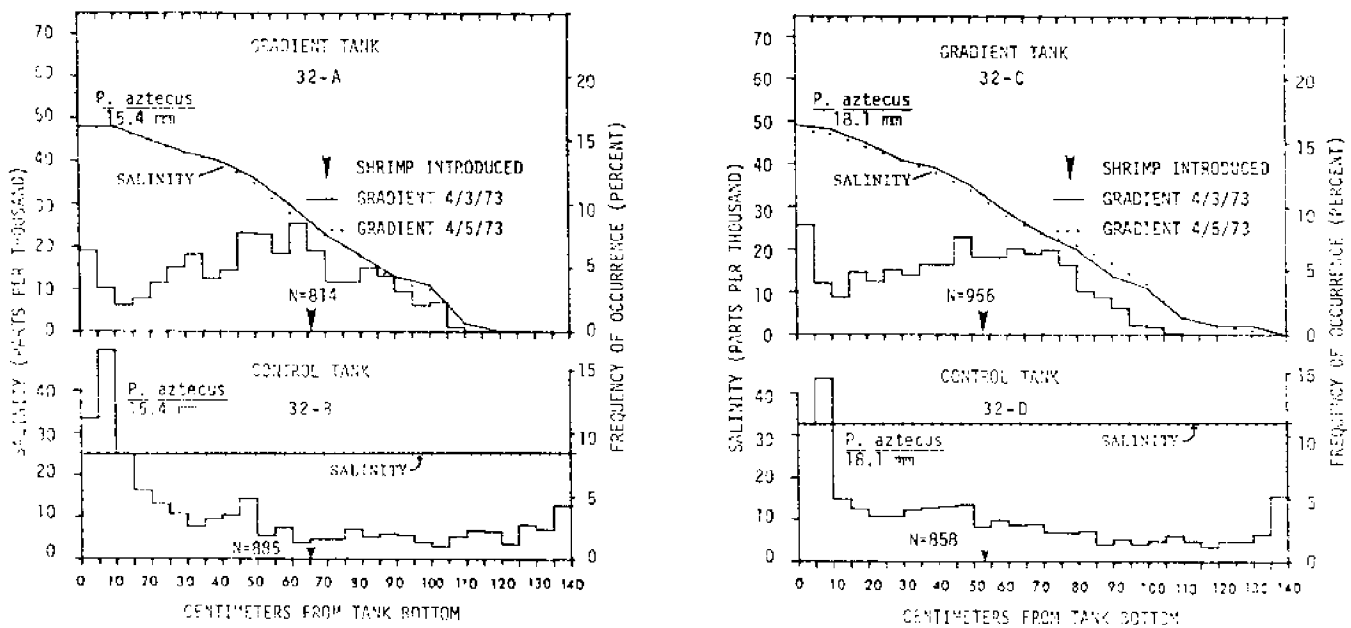
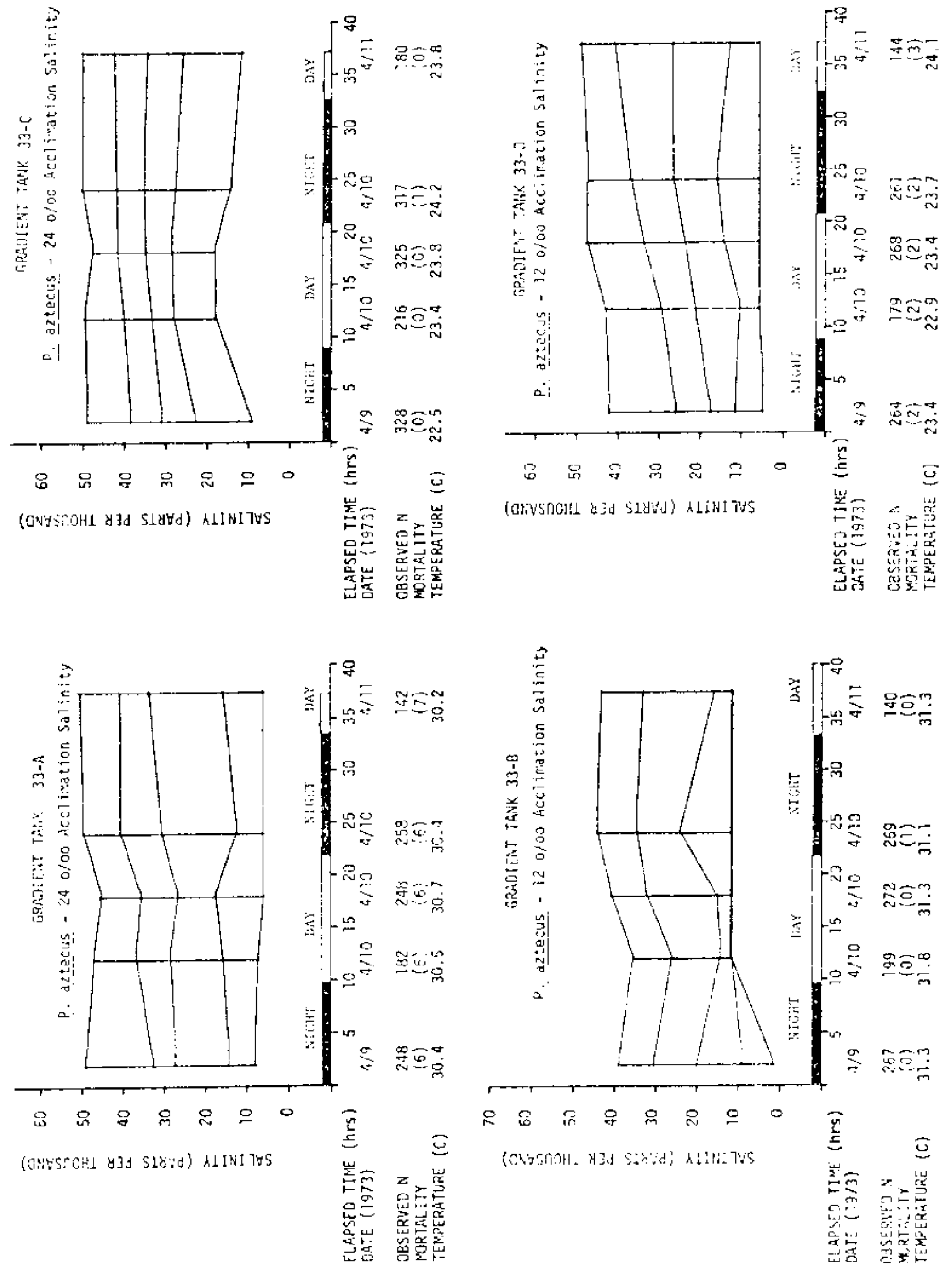


FIGURE 66.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 32 during observations made from 2.0 to 28.4 hours after shrimp were introduced. Temperature approximated 23 C during this time interval. Postlarvae in tanks A & B were collected 3/17/73 and acclimated for 19 days to 23 C and 26 o/oo. Postlarvae in tanks C & D were collected 3/03/73 and acclimated for 31 days to 23 C and 24 o/oo. Number of shrimp introduced into tank A = 50, tank B = 50, tank C = 50, tank D = 48. N = total number of shrimp counted in a series of observations.

FIGURE 67.—Distribution of postlarval brown shrimp (*P. aztecus*) acclimated to different temperatures and salinities and tested under continuous low level red illumination in experiment 33. Vertical lines indicate distributions. Midline represents percentiles and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of dead shrimp observed during an observation period; dead shrimp not removed.

FIGURE 67


GRADIENT TANK 33-C
P. aztecus - 24 o/oo Acclimation Salinity
GRADIENT TANK 33-D
P. aztecus - 12 o/oo Acclimation Salinity
GRADIENT TANK 33-A
P. aztecus - 24 o/oo Acclimation Salinity
GRADIENT TANK 33-B
P. aztecus - 12 o/oo Acclimation Salinity
SALINITY (PARTS PER THOUSAND)
NIGHT
DAY
ELAPSED TIME (hrs)
DATE (1973)
OBSERVED N
MORTALITY
TEMPERATURE (C)

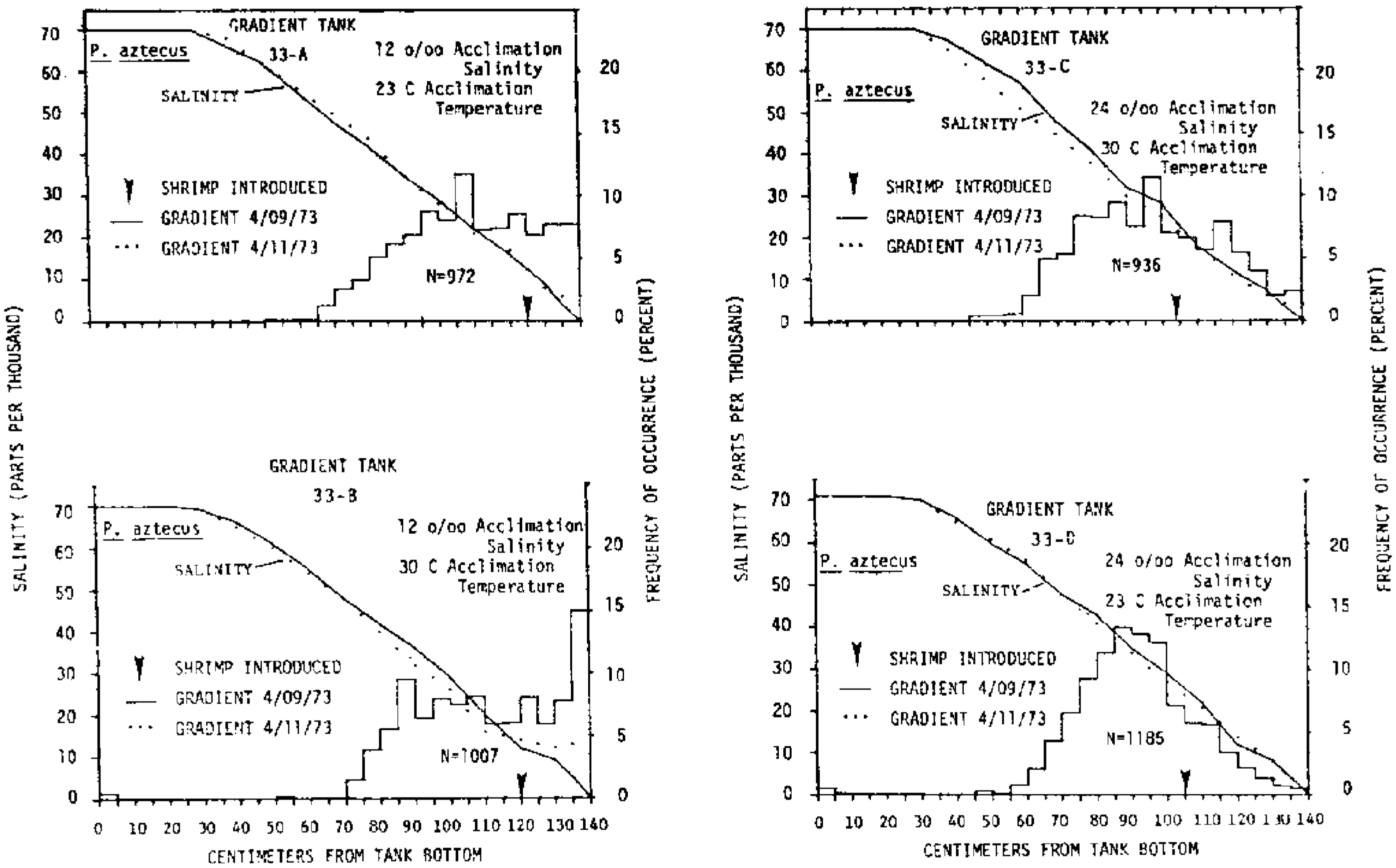
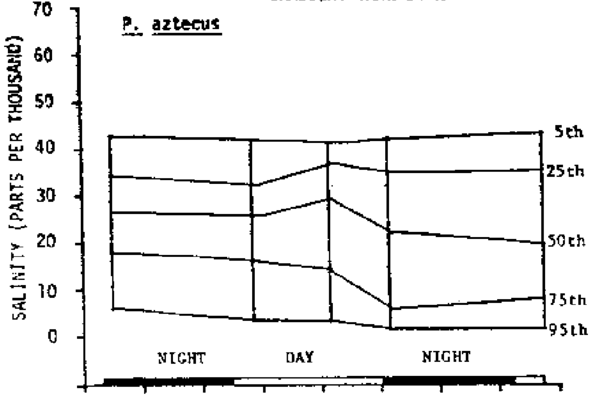


FIGURE 68.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 33 during observations made from 2.0 to 24.1 hours after shrimp were introduced. Postlarvae were acclimated for 8 days to different temperatures and salinities. Number of shrimp introduced into tank A = 40, tank B =40, tank C = 47, tank D = 40. N = total number of shrimp counted in a series of observations.

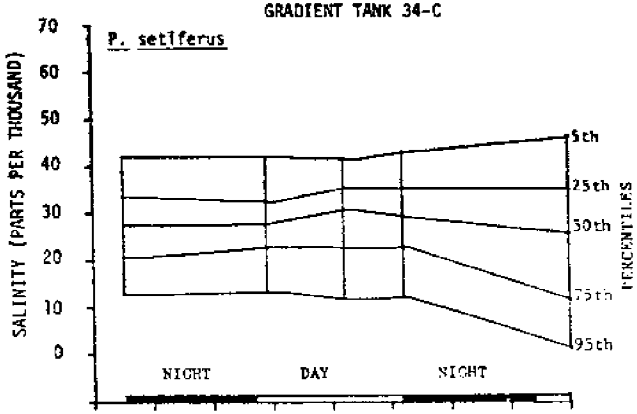
FIGURE 69.—Distribution of postlarval brown and white shrimp (*P. aztecus* and *P. setiferus*) under continuous low level red illumination in experiment 34. Postlarvae were collected in 14 o/oo held in the laboratory at this salinity, and introduced into the gradient tanks at a level corresponding to the holding salinity. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of dead shrimp observed during an observation period; dead shrimp not removed.

GRADIENT TANK 34-A



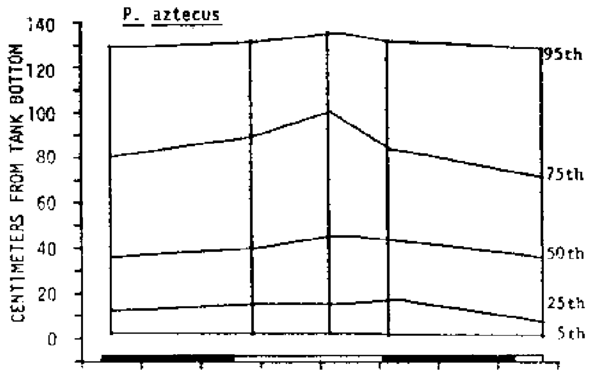
ELAPSED TIME (hrs)	5	10	15	20	25	30	35	40
DATE (1973)	5/11		5/12	5/12	5/12			5/14
OBSERVED N	290		276	272	268			37
MORTALITY	(0)		(0)	(0)	(1)			(2)
TEMPERATURE (C)	23.7		23.2	23.7	24.0			

GRADIENT TANK 34-C



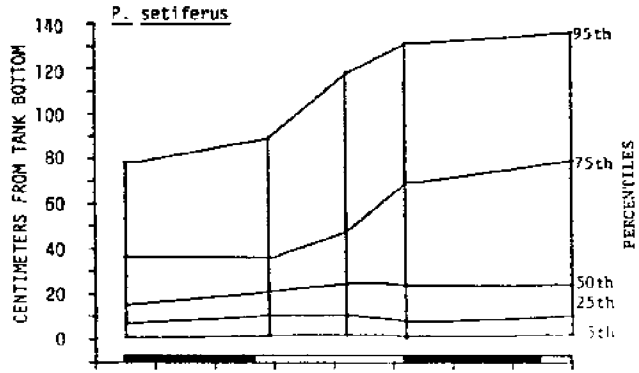
ELAPSED TIME (hrs)	5	10	15	20	25	30	35	40
DATE (1973)	5/11		5/12	5/12	5/12			5/14
OBSERVED N	247		250	235	258			31
MORTALITY	(0)		(4)	(5)	(4)			(4)
TEMPERATURE (C)	24.2		24.5	24.3	24.4			

CONTROL TANK 34-B



ELAPSED TIME	5	10	15	20	25	30	35	40
DATE (1973)	5/11		5/12	5/12	5/12			5/14
OBSERVED N	307		288	281	282			39
MORTALITY	(0)		(0)	(0)	(0)			(0)
TEMPERATURE (C)	23.8		23.7	23.8	24.0			

CONTROL TANK 34-D



ELAPSED TIME (hrs)	5	10	15	20	25	30	35	40
DATE (1973)	5/11		5/12	5/12	5/12			5/14
OBSERVED N	265		267	273	265			36
MORTALITY	(0)		(0)	(0)	(0)			(0)
TEMPERATURE (C)	24.0		24.3	24.3	24.3			

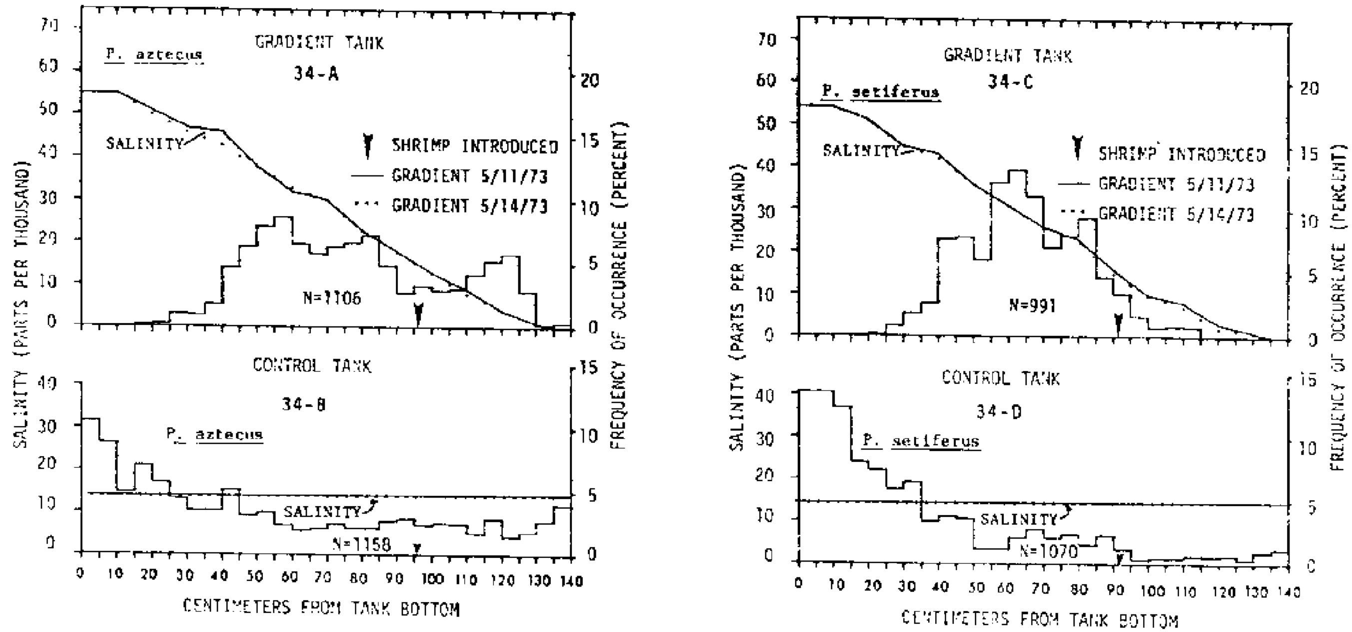


FIGURE 70.—Distribution of postlarval brown and white shrimp (P. aztecus and P. setiferus) and salinity in experiment 34 during observations made from 2.5 to 26.1 hours after shrimp were introduced. Temperature approximated 24 C during this time interval. Postlarvae were collected in 14 o/oo and introduced into gradient tanks at this salinity. Number of shrimp introduced into tank A = 42, tank B = 43, tank C =39, tank D = 39. N = total number of shrimp counted in a series of observations.

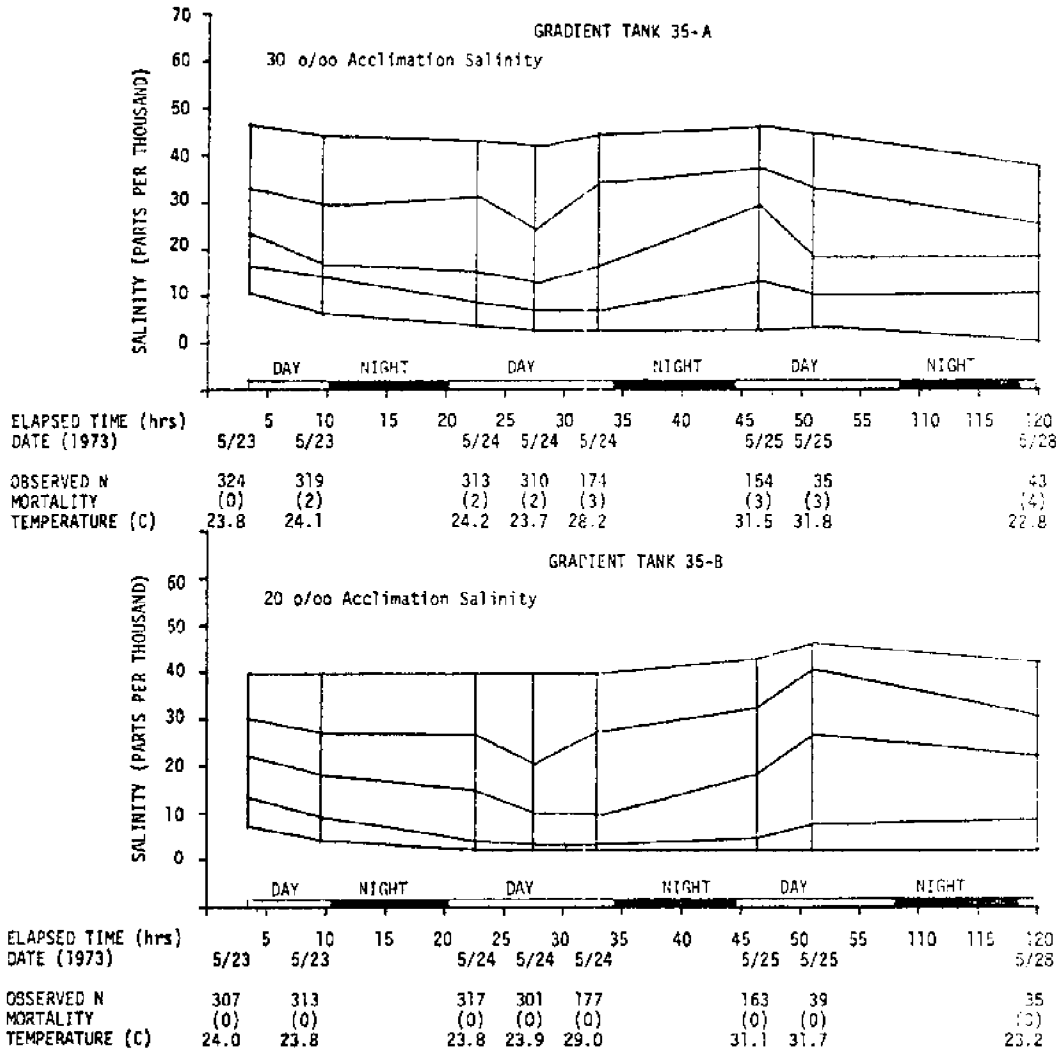


FIGURE 71.—Distribution of postlarval brown shrimp (P. aztecus) acclimated to different salinities and tested under continuous low level red illumination in experiment 35, tanks A & B. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

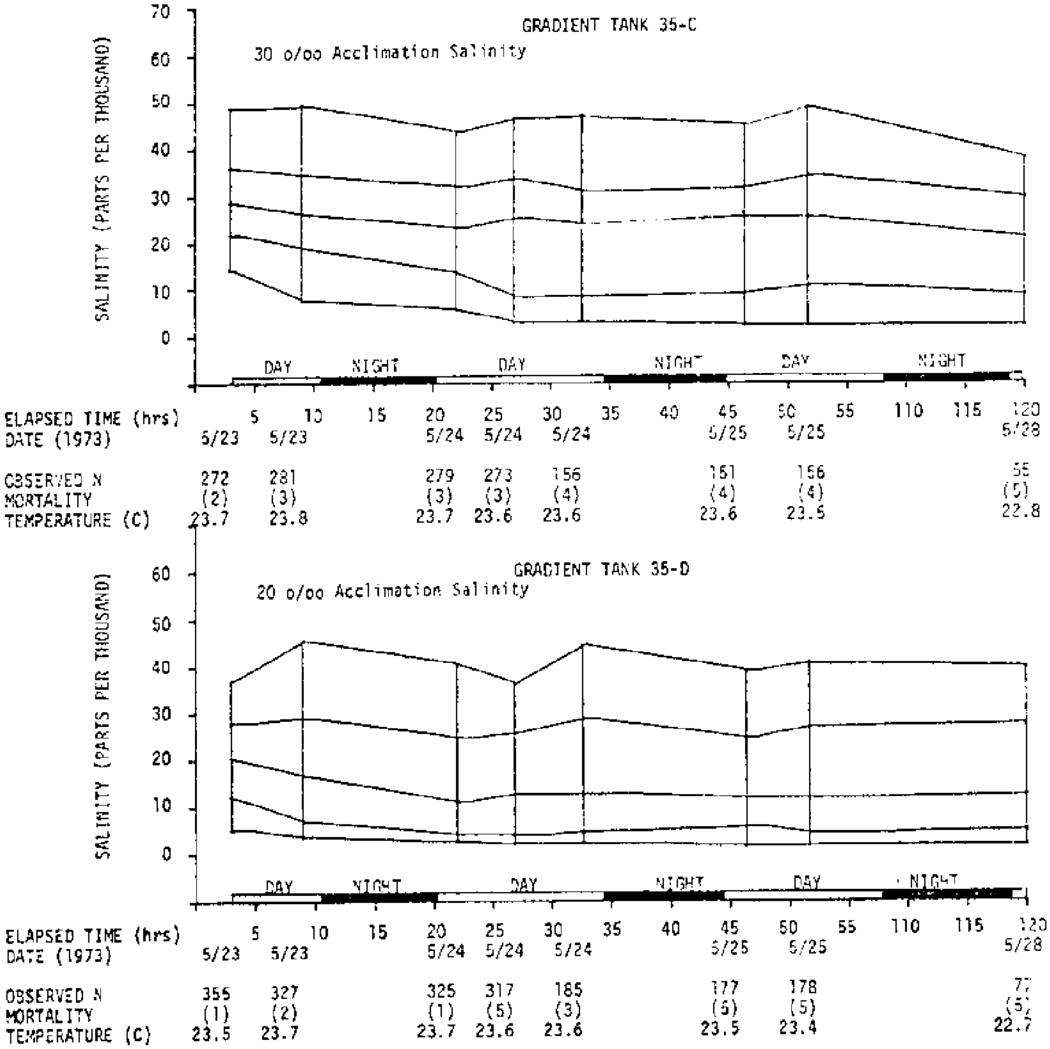


FIGURE 72.—Distribution of postlarval brown shrimp (P. aztecus) acclimated to different salinities and tested under continuous low level red illumination in experiment 35, tanks C & D. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

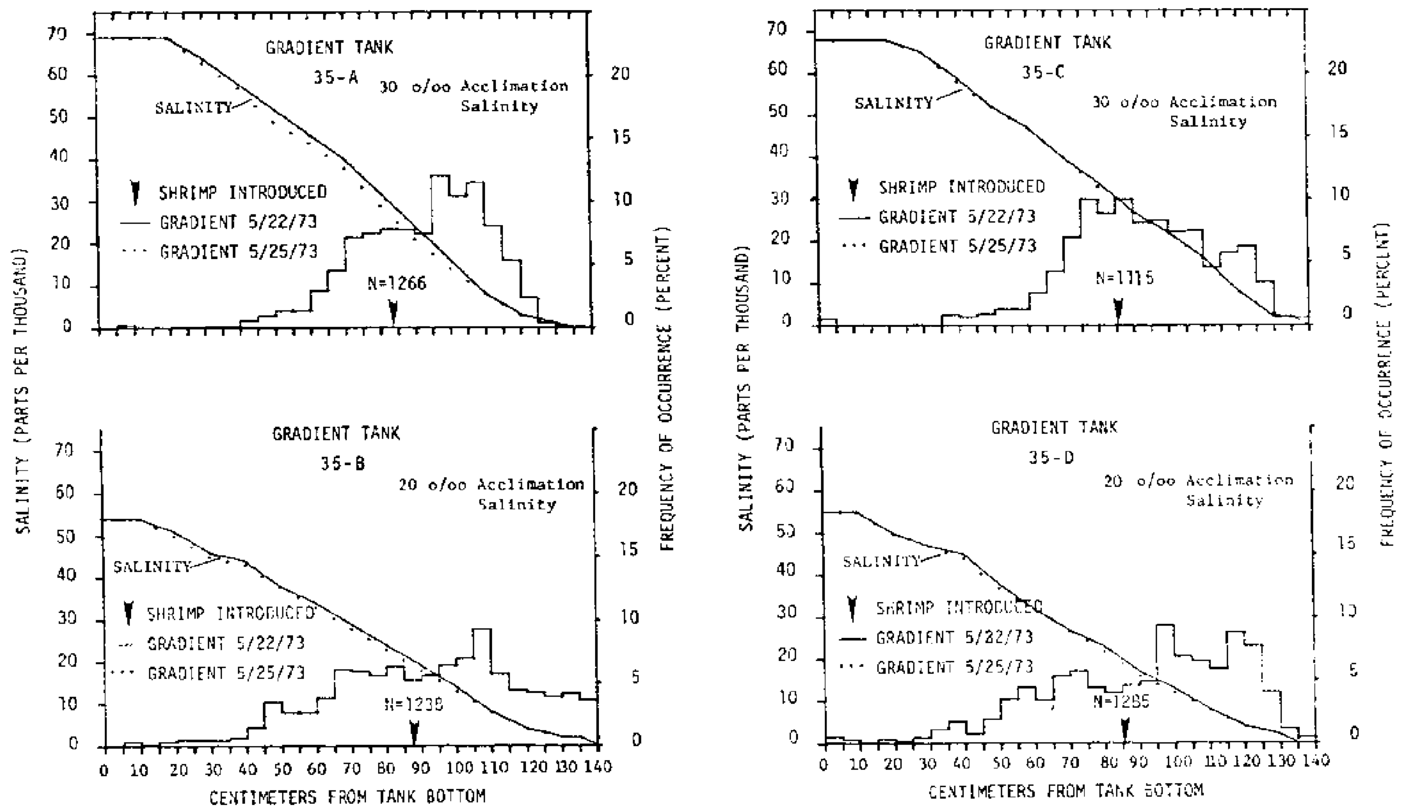
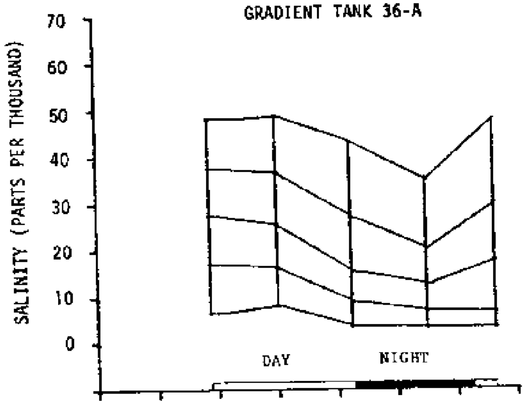


FIGURE 73.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 35 during observations made from 3.0 to 27.5 hours after shrimp were introduced. Temperature approximated 23 C during this time interval. Postlarvae were collected 5/18/73 and acclimated for 5 days to either 20 o/oo or 30 o/oo. Number of shrimp introduced into tank A = 46, tank B = 45, tank C = 45, tank D = 46. N = total number of shrimp counted in a series of observations.

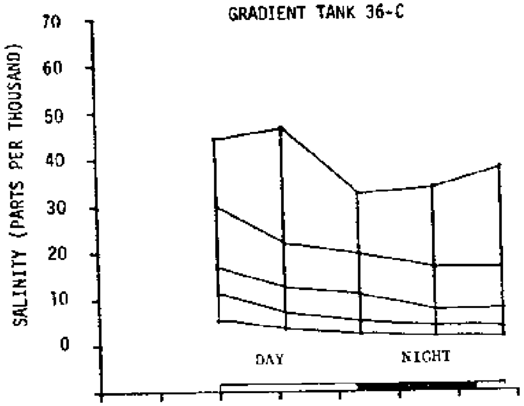
FIGURE 74.—Distribution of postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiment 36. All four tanks are replicates. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

GRADIENT TANK 36-A



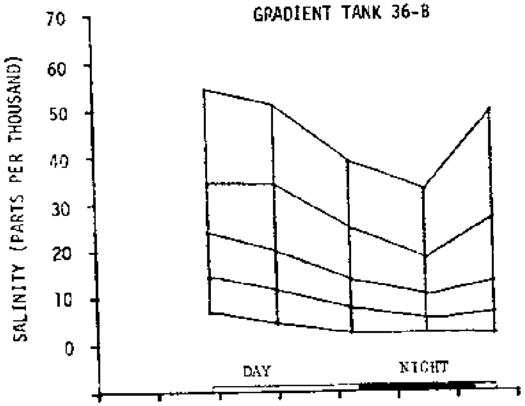
ELAPSED TIME (hrs)	5	10	15	20	25	30	35
DATE (1973)		5/29	5/29	5/29	5/30		5/30
OBSERVED N		299	307	297	299		297
MORTALITY		(3)	(4)	(4)	(4)		(4)
TEMPERATURE (C)		23.7	24.1	24.1	23.3		24.0

GRADIENT TANK 36-C



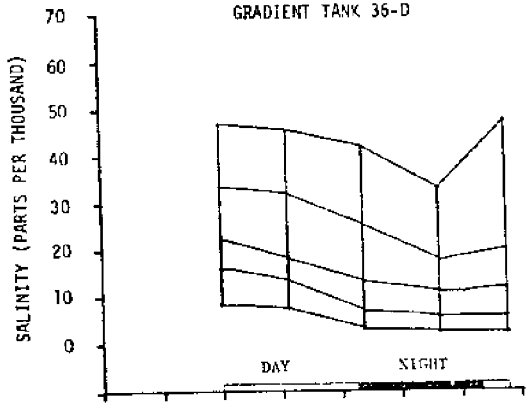
ELAPSED TIME (hrs)	5	10	15	20	25	30	35
DATE (1973)		5/29	5/29	5/29	5/30		5/30
OBSERVED N		317	329	317	323		320
MORTALITY		(1)	(3)	(2)	(3)		(3)
TEMPERATURE (C)		23.2	23.3	23.5	23.6		23.2

GRADIENT TANK 36-B



ELAPSED TIME (hrs)	5	10	15	20	25	30	35
DATE (1973)		5/29	5/29	5/29	5/30		5/30
OBSERVED N		293	296	294	293		297
MORTALITY		(3)	(4)	(4)	(4)		(4)
TEMPERATURE (C)		23.8	24.2	23.6	23.3		23.7

GRADIENT TANK 36-D



ELAPSED TIME (hrs)	5	10	15	20	25	30	35
DATE (1973)		5/29	5/29	5/29	5/30		5/30
OBSERVED N		352	335	342	348		341
MORTALITY		(1)	(1)	(1)	(1)		(1)
TEMPERATURE (C)		22.8	23.0	23.3	23.4		23.2

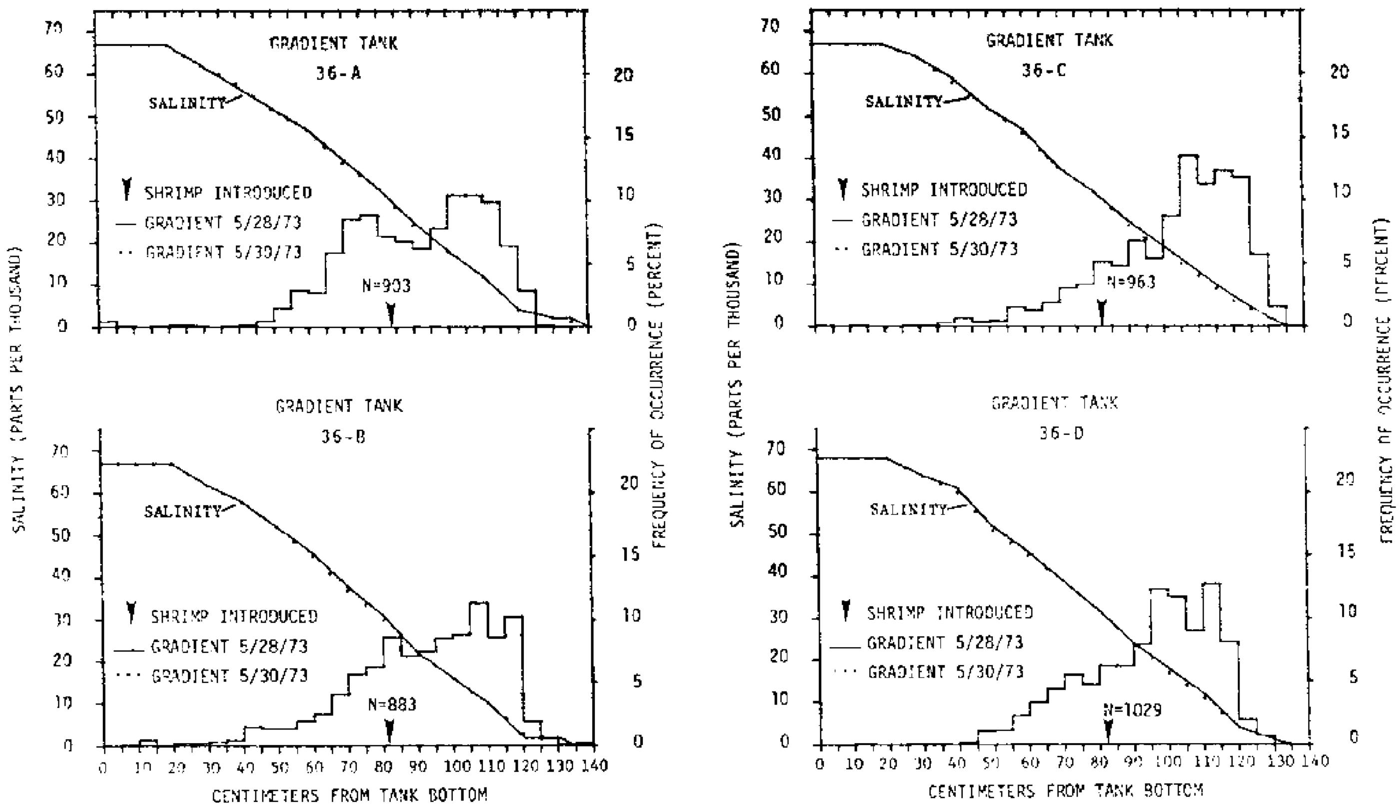


FIGURE 75.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 36, tanks A - D (replicates), during observations made from 9.4 to 21.9 hours after shrimp were introduced. Temperature approximated 23.5 C during this time interval. Number of shrimp introduced into tank A = 45, tank B = 47, tank C = 48, tank D = 50.

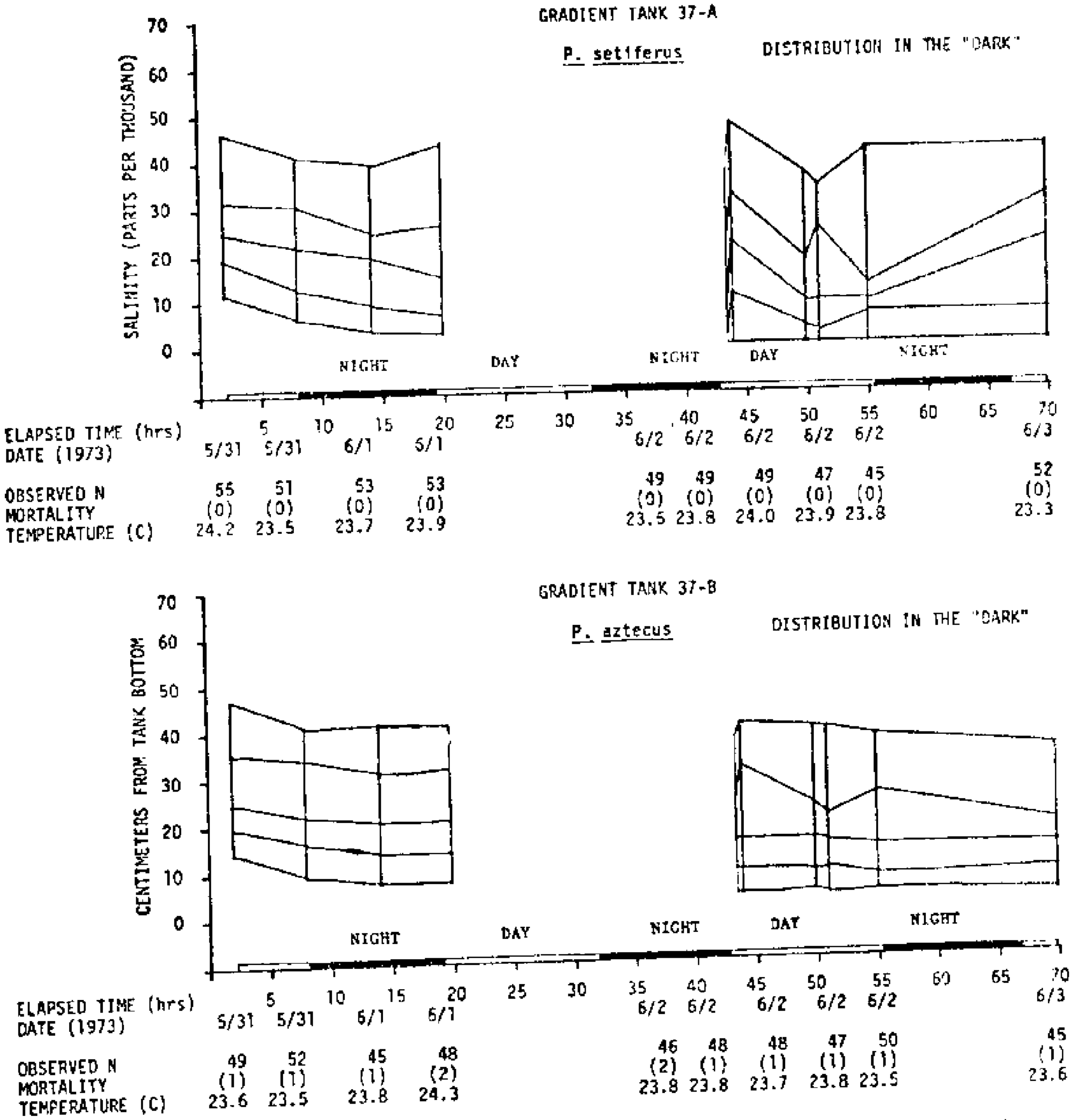


FIGURE 76.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under periodic low level red illumination in experiment 37, tanks A & B. "Dark" defined on page 73. Vertical lines indicate distributions. Midline represent medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

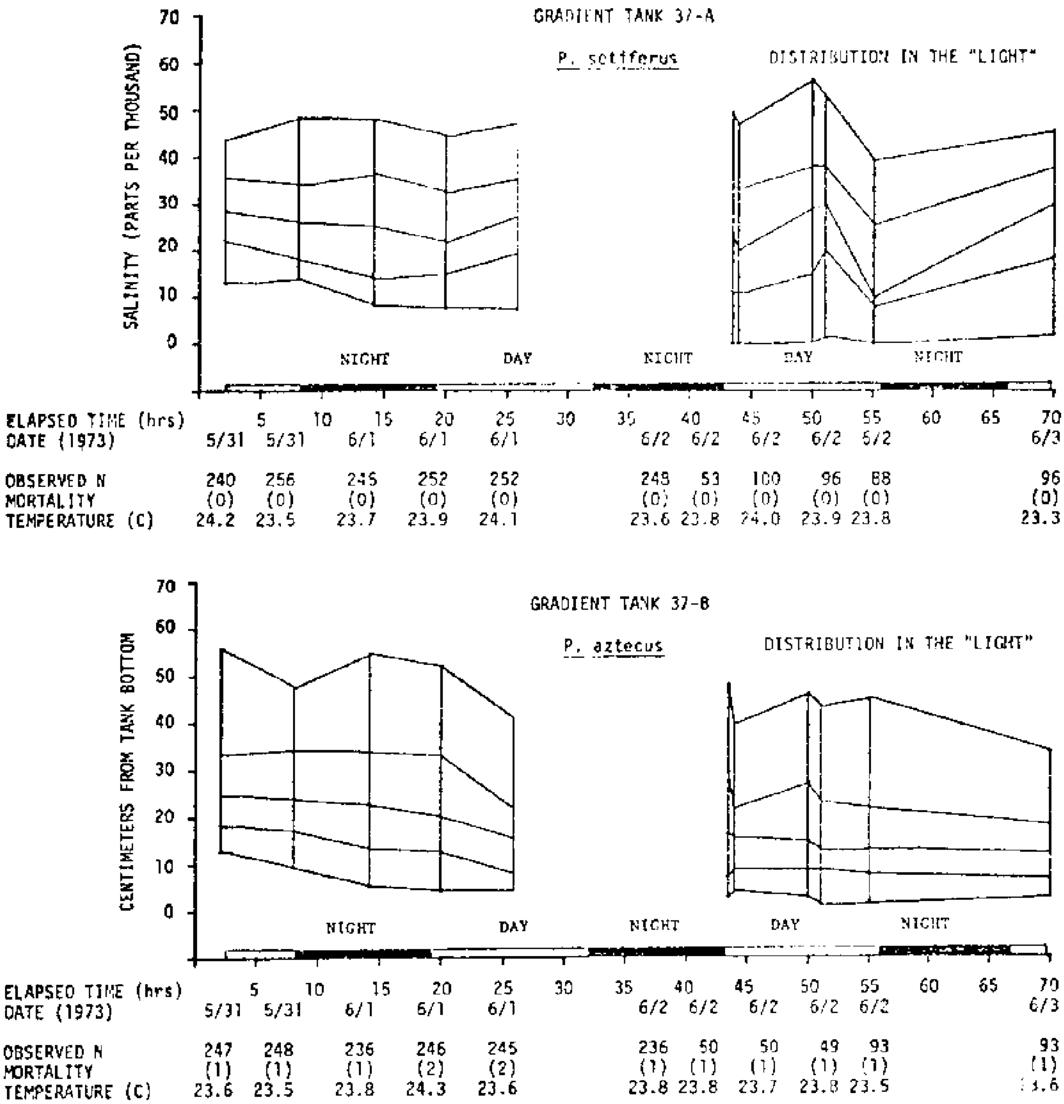
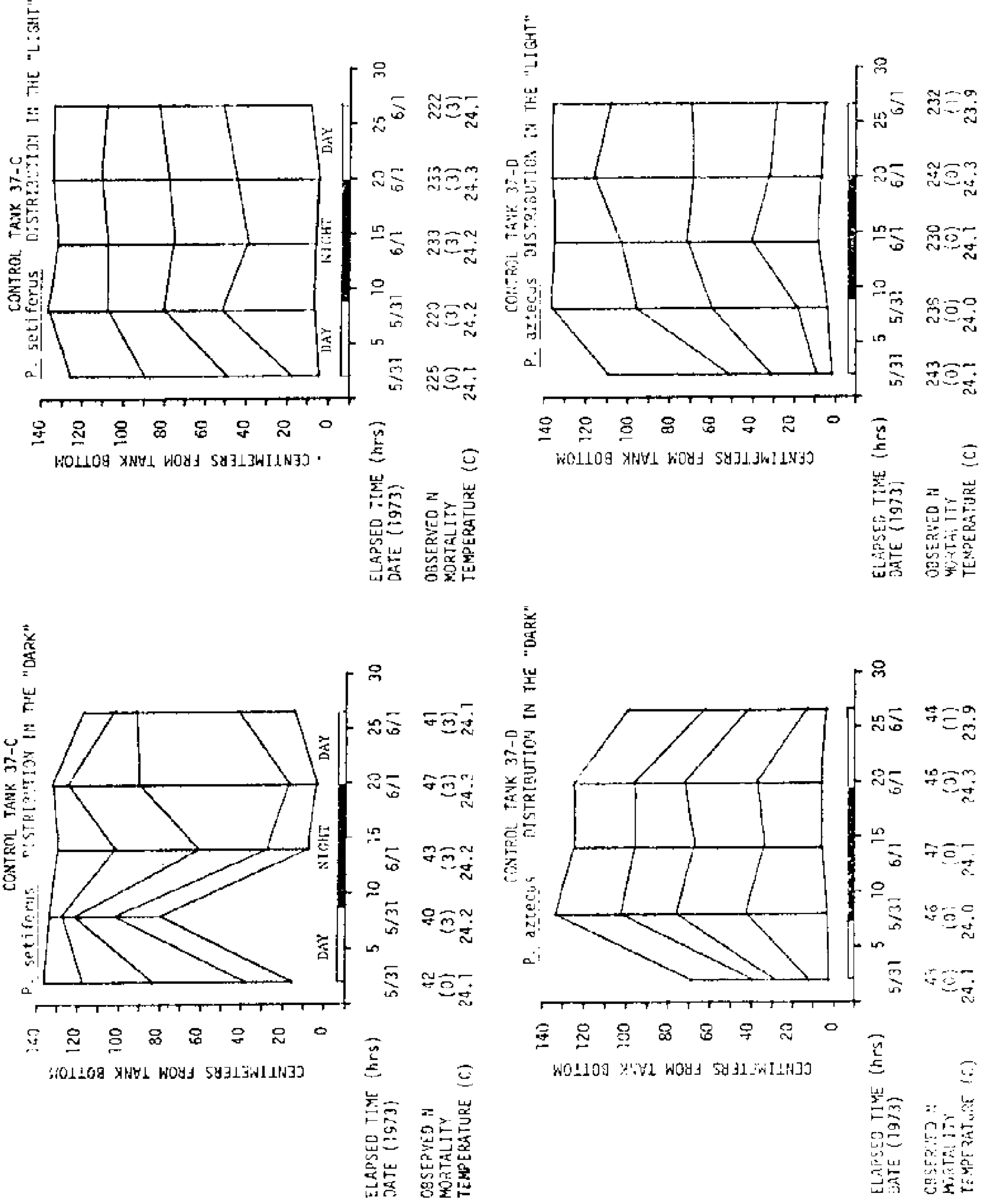


FIGURE 77.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under periodic low level red illumination in experiment 37, tanks A & B. "Light" defined on page 73. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 78.—Distribution of postlarval white and brown shrimp (*P. setiferus* and *P. aztecus*) under periodic low level red illumination in experiment 37. "Dark" and "Light" are defined on page 73. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th and 5th percentiles. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 78


CONTROL TANK 37-C
P. setiferus DISTRIBUTION IN THE "DARK"
P. setiferus DISTRIBUTION IN THE "LIGHT"
CONTROL TANK 37-D
P. aztecus DISTRIBUTION IN THE "DARK"
P. aztecus DISTRIBUTION IN THE "LIGHT"
CENTIMETERS FROM TANK BOTTOM
DAY
NIGHT
ELAPSED TIME (hrs)
DATE (1973)
OBSERVED N
MORTALITY
TEMPERATURE (C)

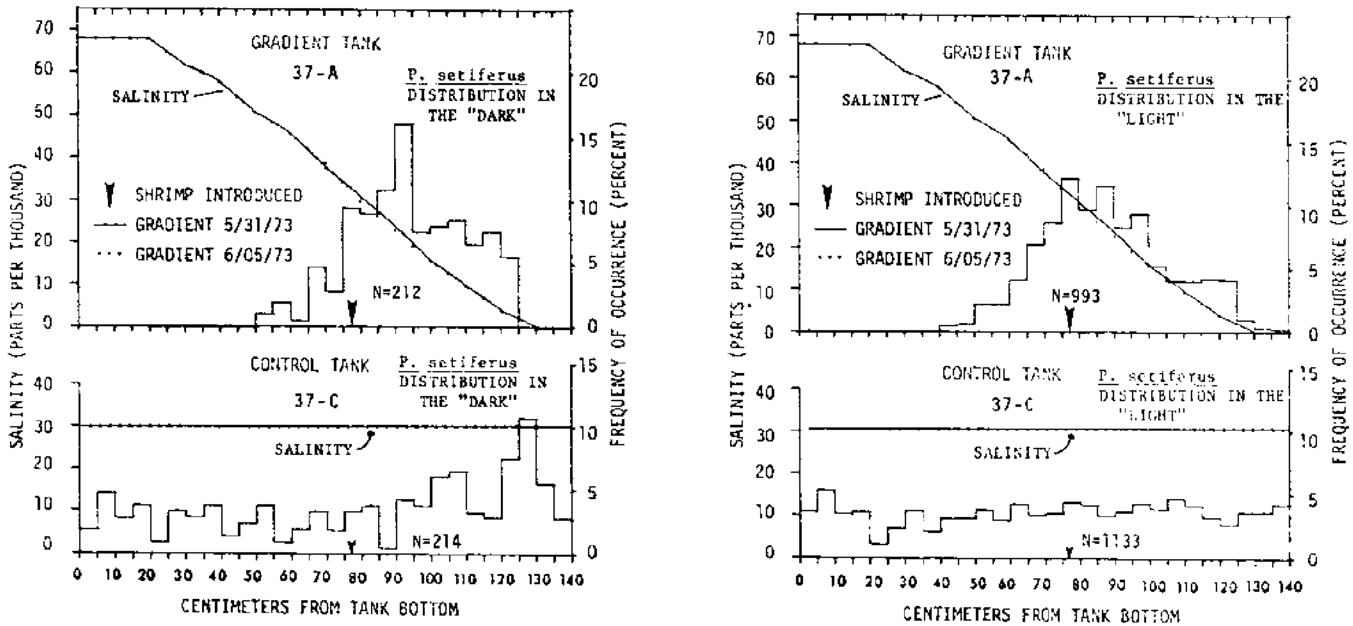


FIGURE 79.—Distribution of postlarval white shrimp (P. setiferus) and salinity in experiment 37 during observations made from 2.0 to 26.6 hours after shrimp were introduced. Temperature approximated 24 C during this time interval. Tanks were periodically illuminated with low level red light. "Dark" and "Light" are defined on page 73. Number of shrimp introduced into tank A = 50, tank C = 47. N = total number of shrimp counted in a series of observations.

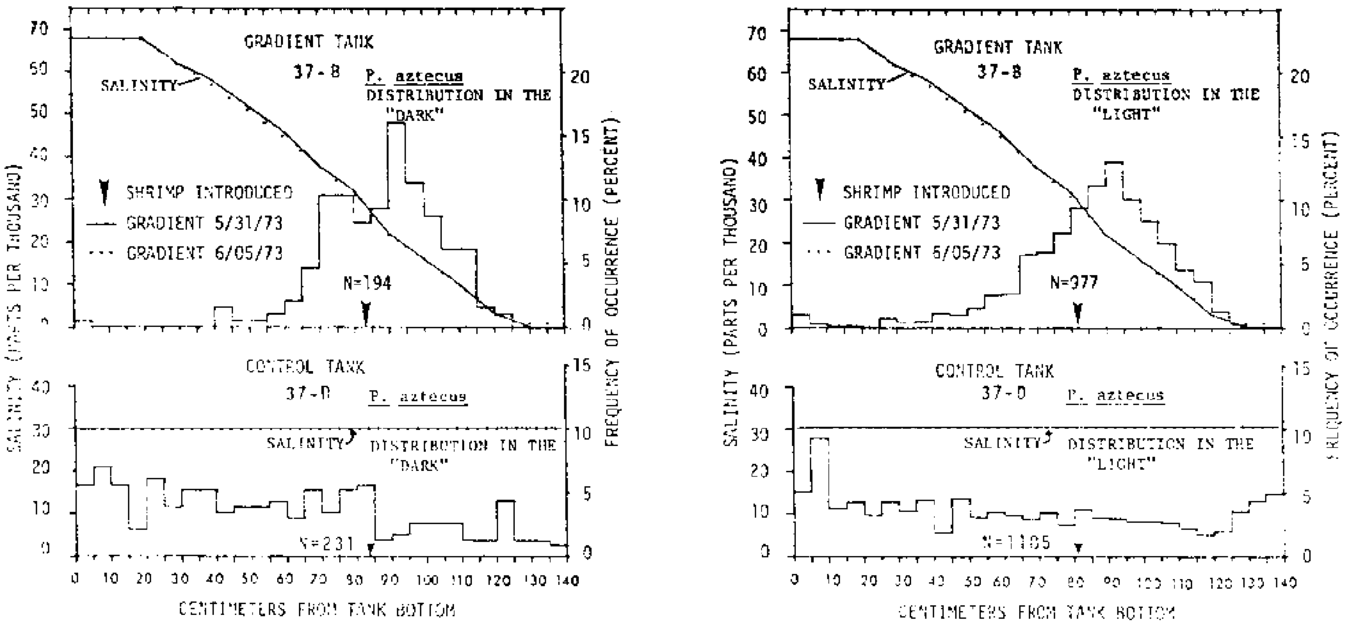


FIGURE 80.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 37 during observations made from 2.0 to 26.6 hours after shrimp were introduced. Temperature approximated 24 C during this time interval. Tanks were periodically illuminated with low level red light. "Dark" and "Light" are defined on page 73. Number of shrimp introduced into tank B = 50, tank D = 48. N = total number of shrimp counted in a series of observations.

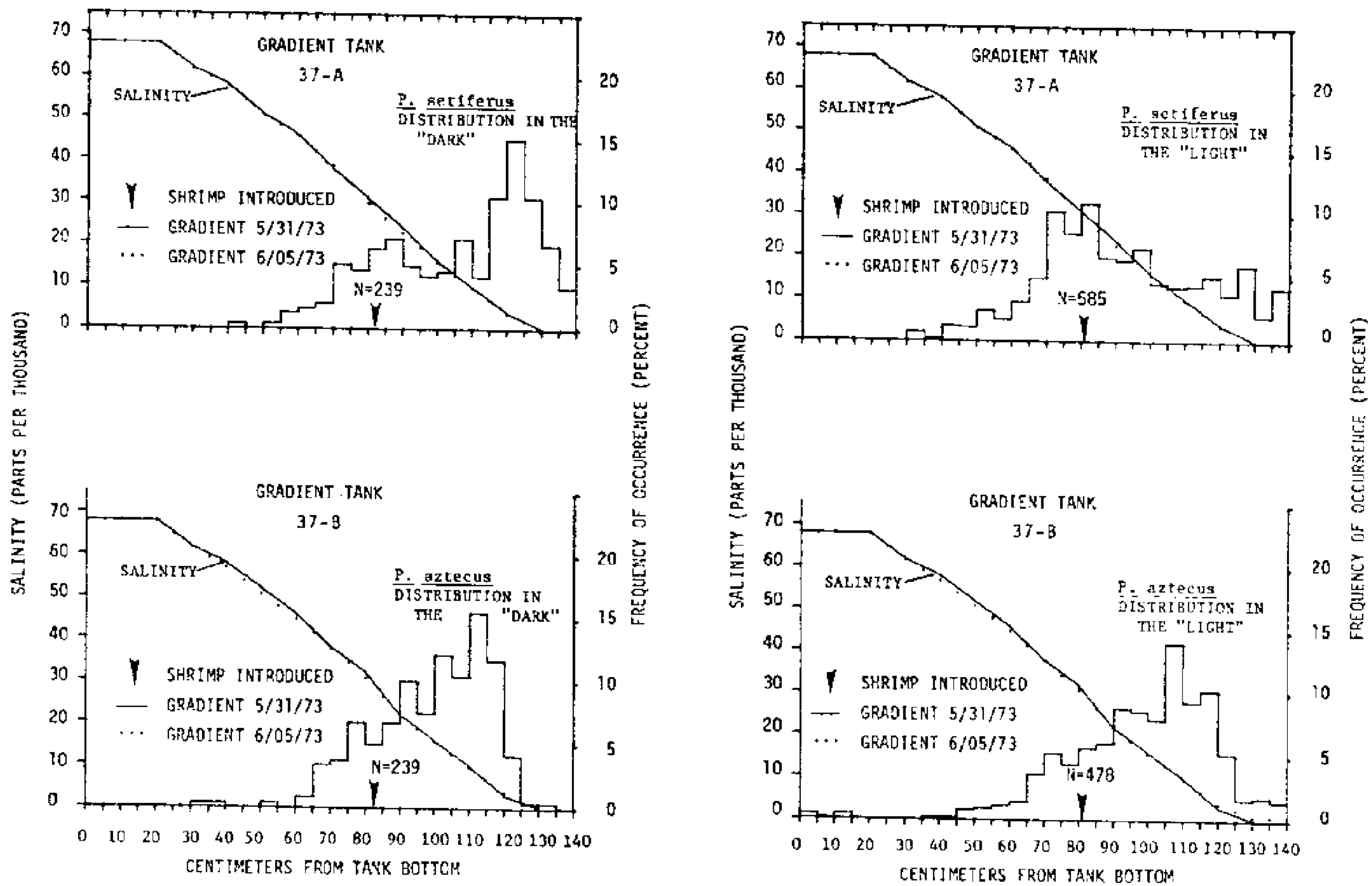
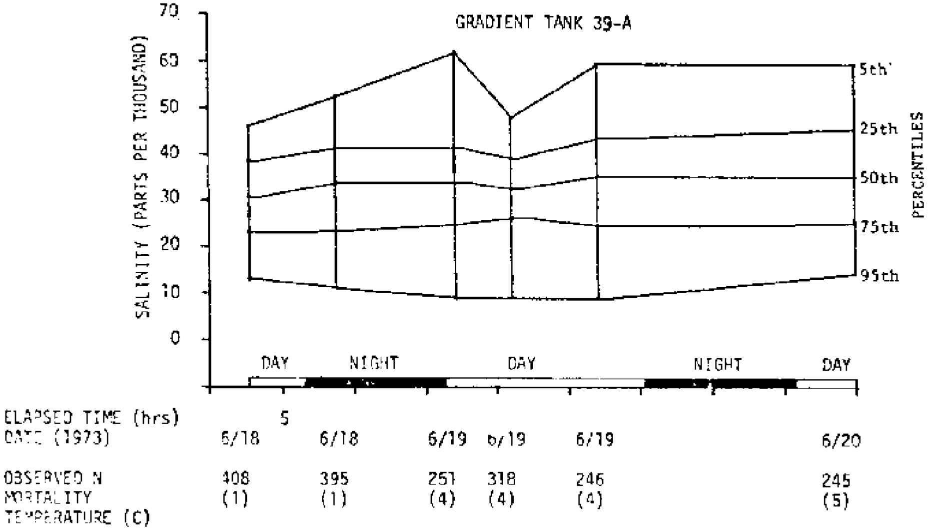
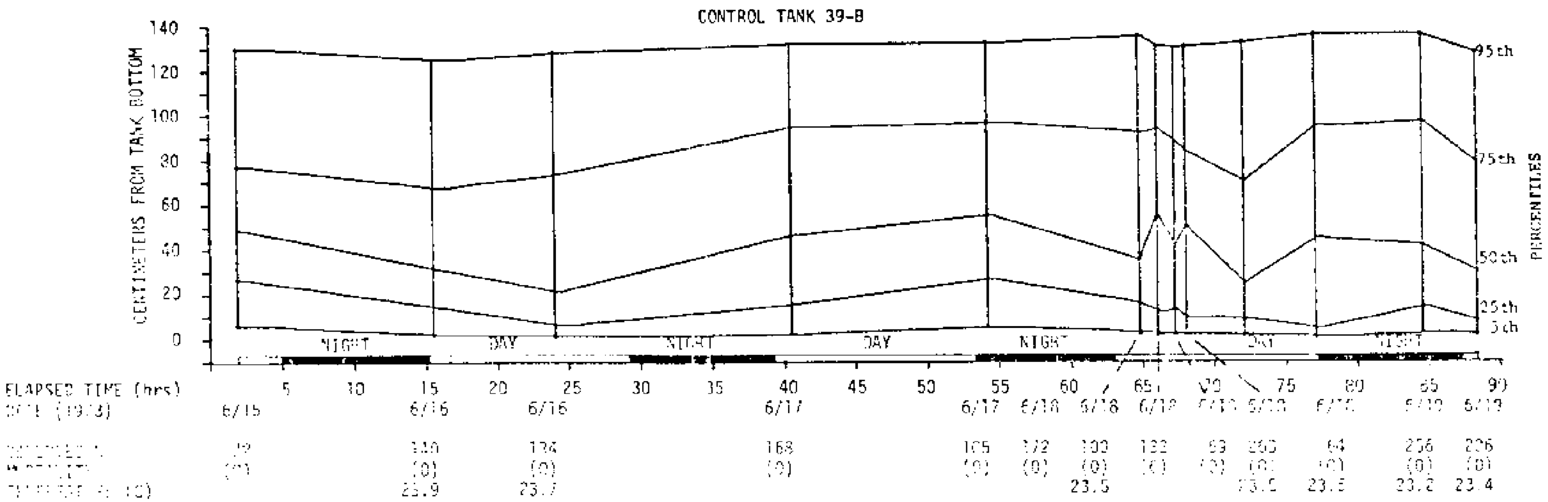


FIGURE 81.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) and salinity in experiment 37 during observations made from 43.4 to 55.0 hours after shrimp were introduced. Temperature approximated 24.0°C during this time interval. Tanks were periodically illuminated with low level red light. "Dark" and "Light" are defined on page 73. Number of shrimp introduced into tank A = 50, tank B = 50, tank C = 47, tank D = 48. N = total number of shrimp counted in a series of observations.

FIGURE 82.—Distribution of postlarval white shrimp (*P. setiferus*) under continuous low level red illumination in experiment 39. Postlarvae were collected 5/27/73 and acclimated for 22 days to 24 C and 30 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines show the 5th, 25th, 75th and 95th percentiles; percentiles oriented by tank depth. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.


GRADIENT TANK 39-A
SALINITY (PARTS PER THOUSAND)
70
60
50
40
30
20
10
0
5th
25th
50th
75th
95th
PERCENTILES
DAY
NIGHT
DAY
NIGHT
DAY
ELAPSED TIME (hrs)
5
DATE (1973)
6/18 6/18 6/19 6/19 6/19 6/20
OBSERVED N
408 395 251 318 246 245
MORTALITY
(1) (1) (4) (4) (4) (5)
TEMPERATURE (C)


CONTROL TANK 39-B
CENTIMETERS FROM TANK BOTTOM
140
120
100
80
60
40
20
0
95th
75th
50th
25th
5th
PERCENTILES
NIGHT
DAY
NIGHT
DAY
NIGHT
DAY
NIGHT
ELAPSED TIME (hrs)
5 10 15 20 25 30 35 40 45 50 55 60 65 75 80 90
DATE (1973)
6/15 6/16 6/16 6/17 6/17
134 168
(0) (0)
23.9
23.5 23.2 23.4

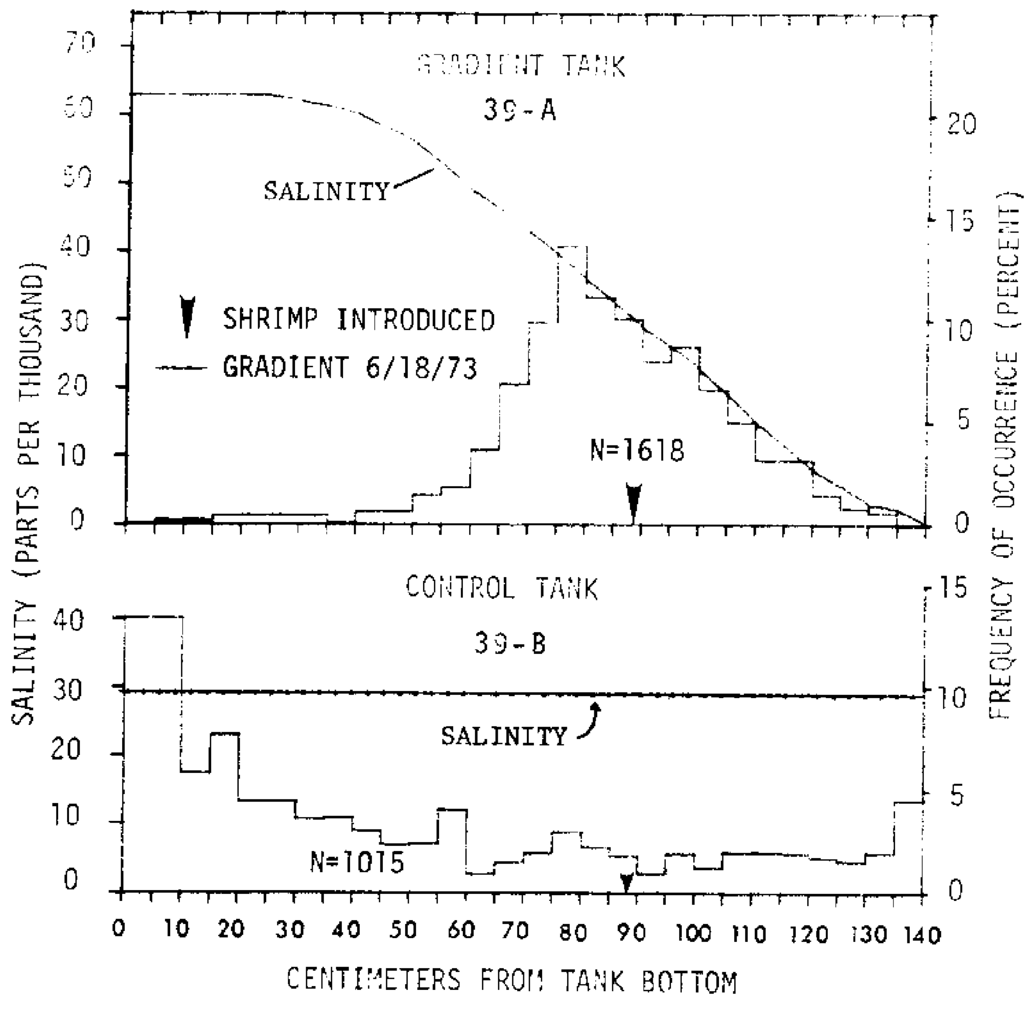
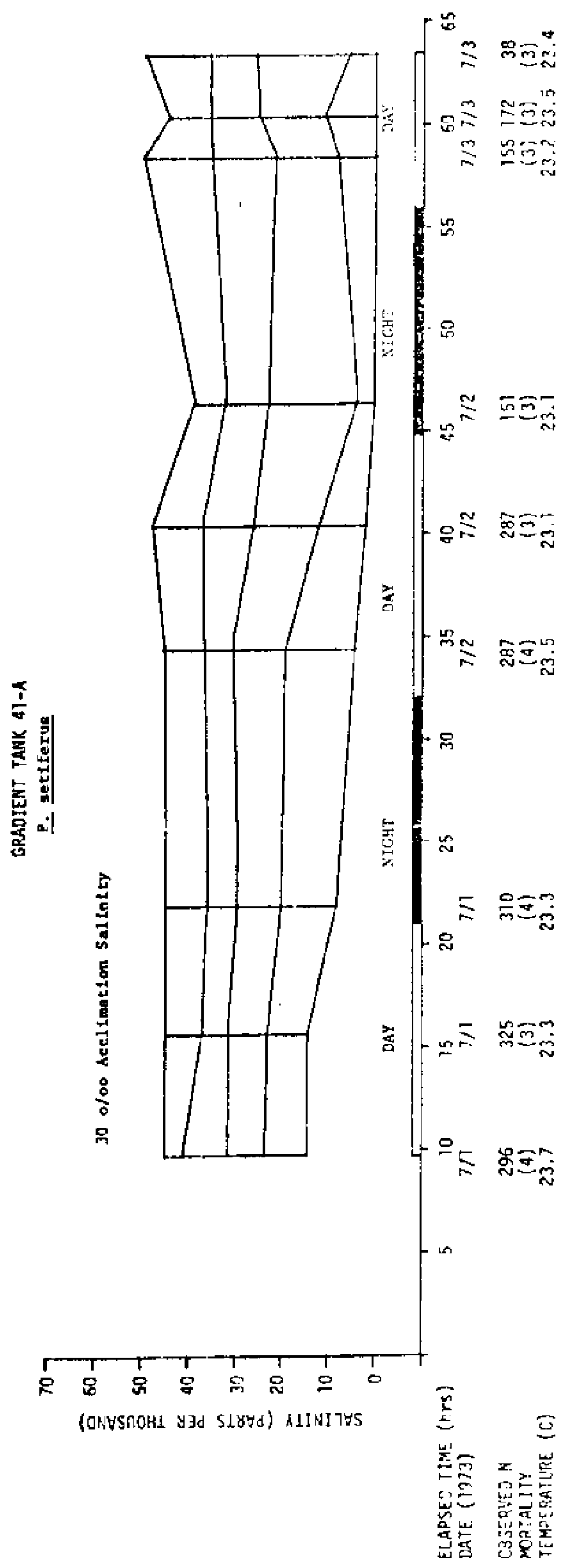


FIGURE 83.—Distribution of postlarval white shrimp (P. setiferus) and salinity in experiment 39 during observations made from 2.8 to 27.6 hours (gradient tank) and from 72.1 to 88.4 hours (control tank) after shrimp were introduced. Temperature approximated 24.5 C during this time interval. Postlarvae were collected 5/27/73 and acclimated for 22 days to 24 C and 30 o/oo. Number of shrimp introduced into tank A = 34, tank B = 35. N = total number of shrimp counted in a series of observations.

FIGURE 84.—Distribution of postlarval white shrimp (*P. setiferus*) acclimated to different salinities and tested under continuous low level red illumination in experiment 41, tanks A & C. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 84


GRADIENT TANK 41-A
P. setiferus
30 o/oo Acclimation Salinity
SALINITY (PARTS PER THOUSAND)
DAY
NIGHT
DAY
NIGHT
DAY
ELAPSED TIME (hrs)
DATE (1973)
OBSERVED N
MORTALITY
TEMPERATURE (C)

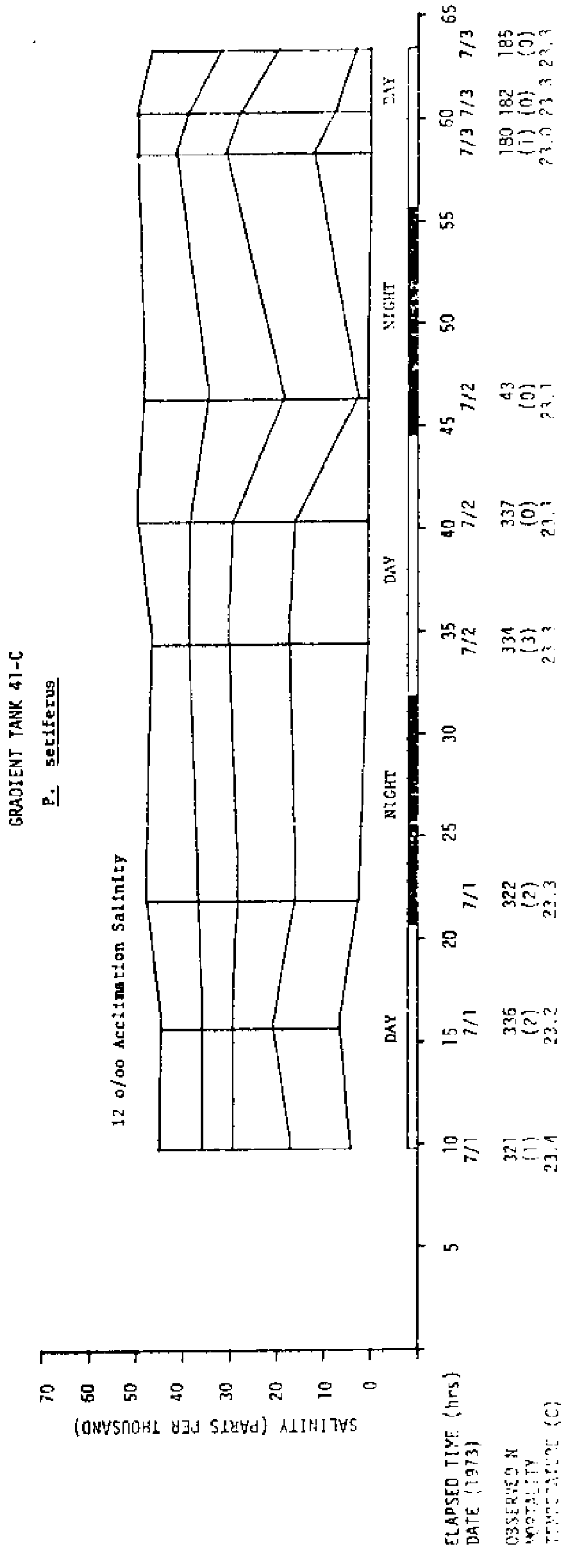
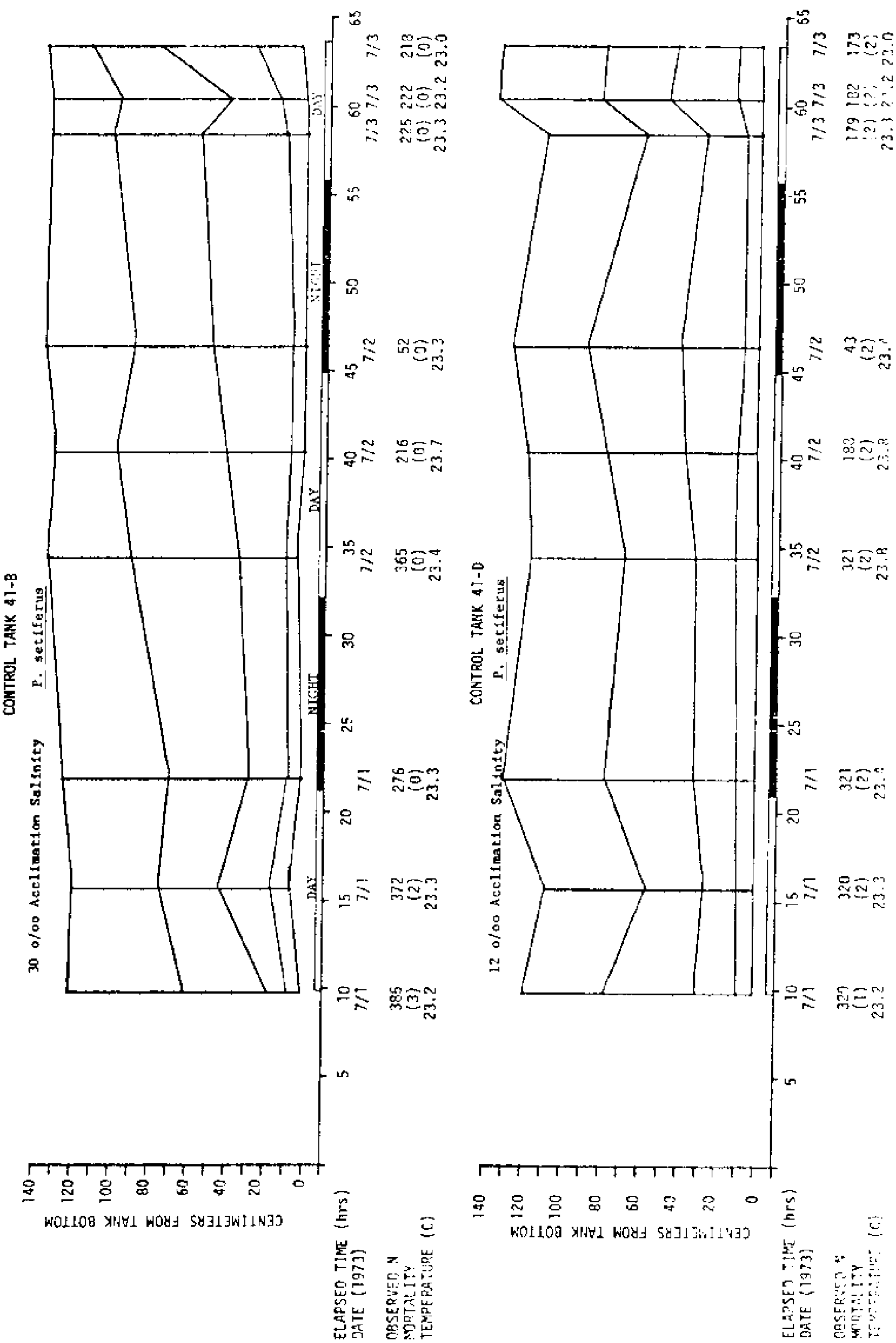

GRADIENT TANK 41-C
P. setiferus
12 o/oo Acclimation Salinity
SALINITY (PARTS PER THOUSAND)
DAY
NIGHT
DAY
NIGHT
DAY
ELAPSED TIME (hrs)
DATE (1973)

FIGURE 85.—Distribution of postlarval white shrimp (*P. setiferus*) acclimated to different salinities and tested under continuous low level red illumination in experiment 41, tanks B & D. Vertical lines indicate distributions. Midline respresents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th, and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 85


CONTROL TANK 41-B
30 o/oo Acclimation Salinity
P. setiferus
CONTROL TANK 41-D
12 o/oo Acclimation Salinity
P. setiferus
CENTIMETERS FROM TANK BOTTOM
DAY
NIGHT
ELAPSED TIME (hrs)
DATE (1973)
OBSERVED N
MORTALITY
TEMPERATURE (C)

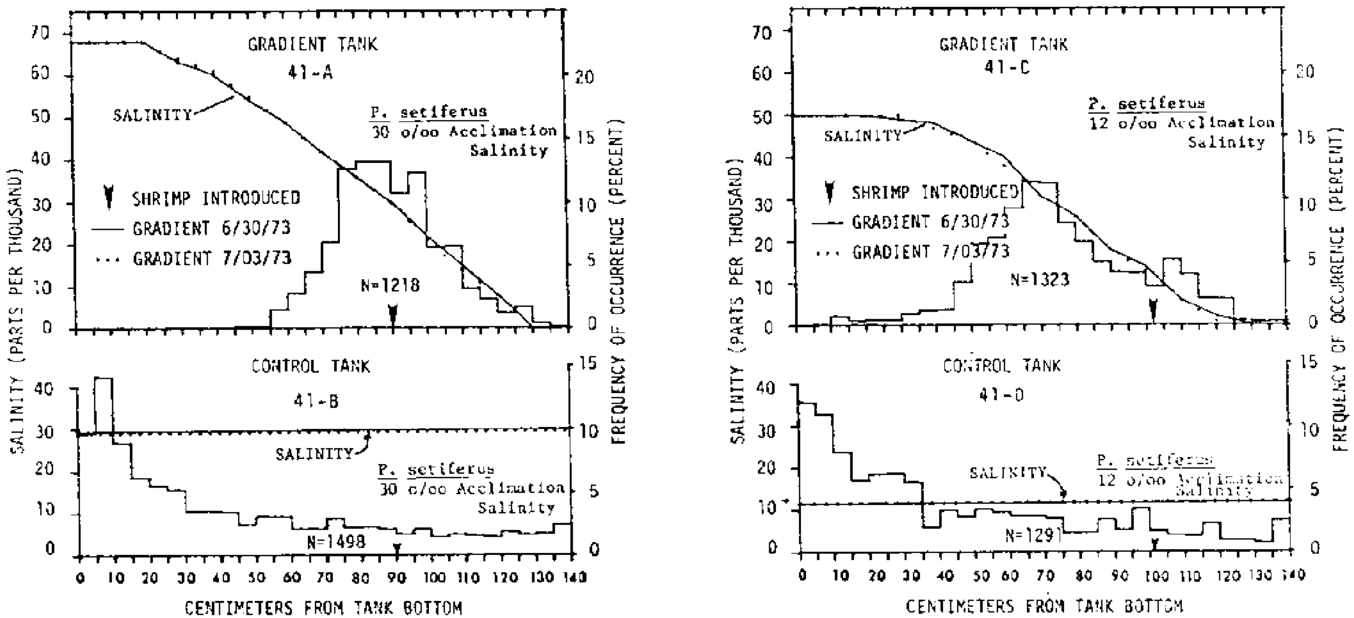
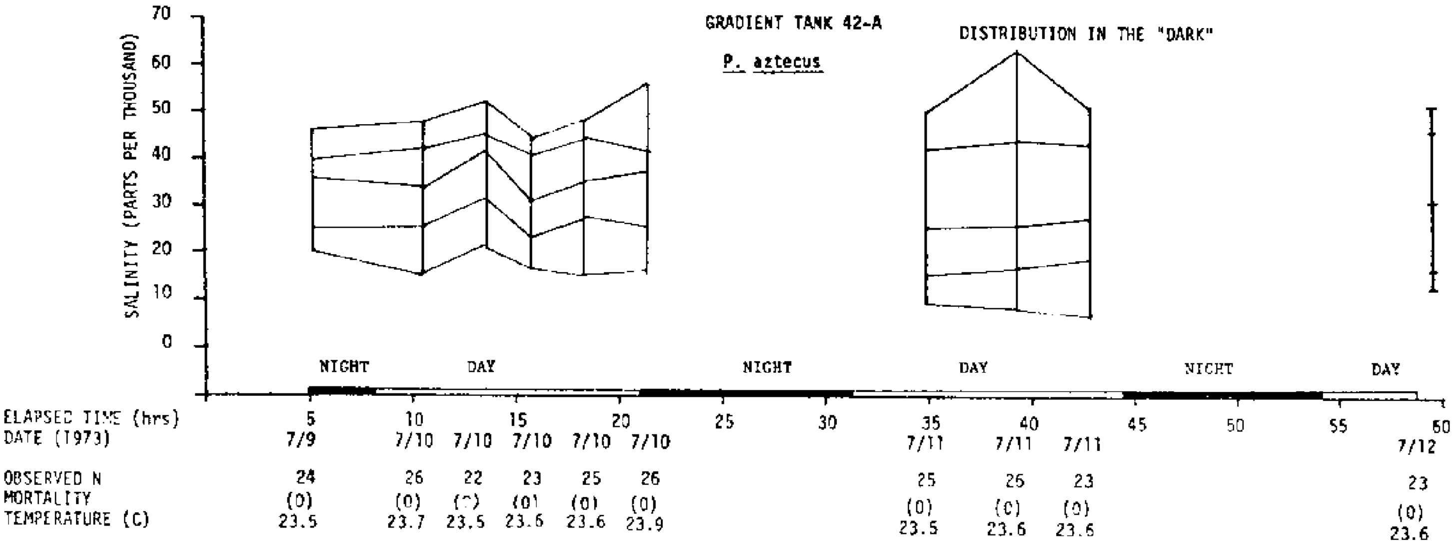


FIGURE 86.—Distribution of postlarval white shrimp (P. setiferus) and salinity in experiment 41 during observations made from 9.0 to 34.4 hours after shrimp were introduced. Temperature approximated 23.5 C during this time interval. Shrimp were acclimated for 5 days to 23 C and to different salinities. Number of shrimp introduced into tank A = 50, tank B = 56, tank C = 50, tank D = 48. N = total number of shrimp counted in a series of observations.

FIGURE 87.—Distribution of postlarval brown and white shrimp (*P. aztecus* and *P. setiferus*) under periodic low level red illumination in experiment 42, tanks A & B. "Dark" defined on page 73. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.


GRADIENT TANK 42-A
P. aztecus
DISTRIBUTION IN THE "DARK"
SALINITY (PARTS PER THOUSAND)
70 60 50 40 30 20 10 0
NIGHT DAY NIGHT DAY NIGHT DAY
ELAPSED TIME (hrs) 5 10 15 20 25 30 35 40 45 50 55 60
DATE (1973) 7/9 7/10 7/10 7/10 7/10 7/10 7/11 7/11 7/11 7/12
OBSERVED N 24 26 22 23 25 26 25 26 23 23
MORTALITY (0) (0) (0) (0) (0) (0) (0) (0) (0) (0)
TEMPERATURE (C) 23.5 23.7 23.5 23.6 23.6 23.9 23.5 23.6 23.6 23.6

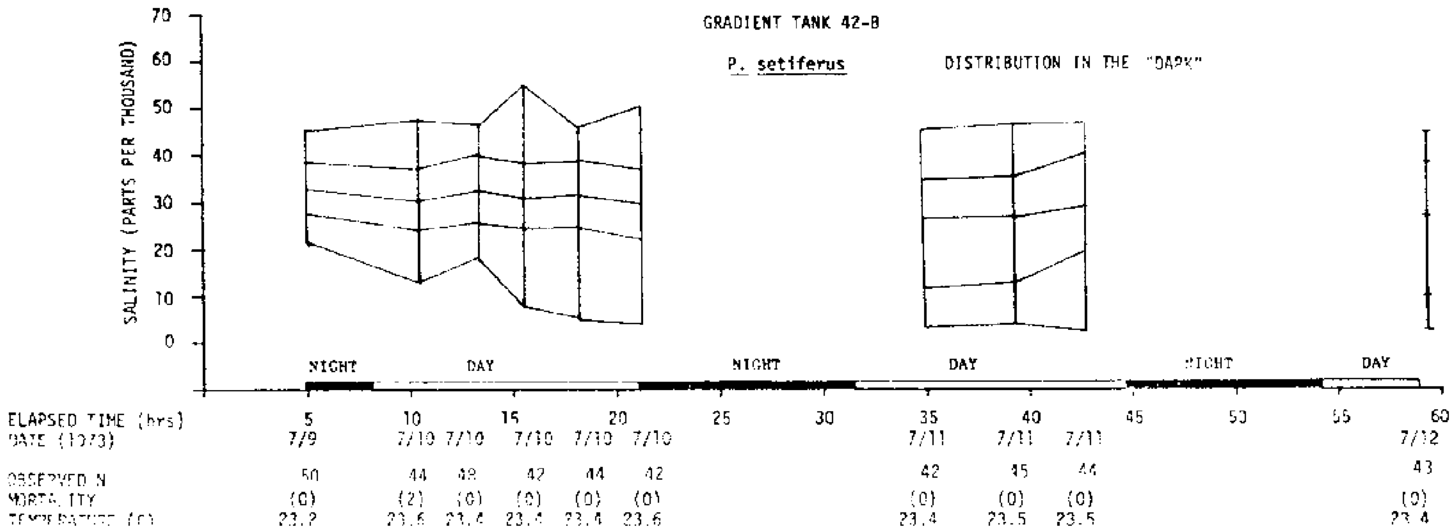
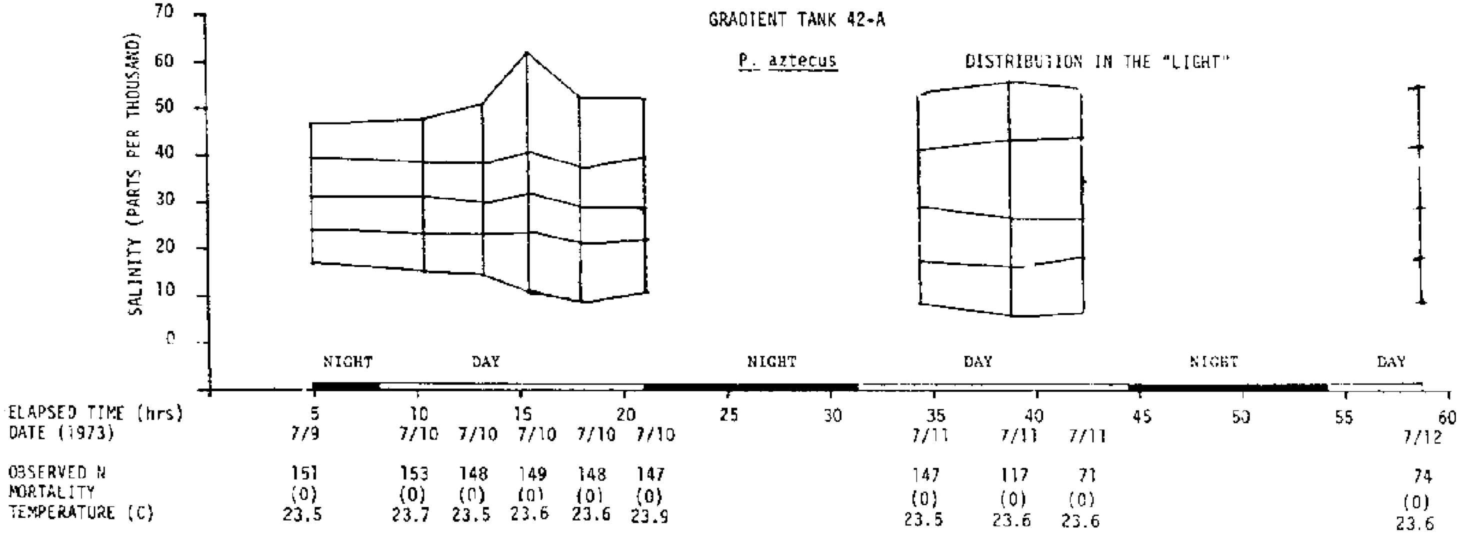

GRADIENT TANK 42-B
P. setiferus
DISTRIBUTION IN THE "DARK"
SALINITY (PARTS PER THOUSAND)
70 60 50 40 30 20 10 0
NIGHT DAY NIGHT DAY NIGHT DAY
ELAPSED TIME (hrs) 5 10 15 20 25 30 35 40 45 50 55 60
DATE (1973) 7/9 7/10 7/10 7/10 7/10 7/10 7/11 7/11 7/11 7/12
OBSERVED N 50 44 48 42 44 42 42 45 44 43
MORTALITY (0) (2) (0) (0) (0) (0) (0) (0) (0) (0)
TEMPERATURE (C) 23.2 23.6 23.4 23.4 23.4 23.6 23.4 23.5 23.5 23.4

FIGURE 38.—Distribution of postlarval brown and white shrimp (*P. aztecus* and *P. setiferus*) under periodic low level red illumination in experiment 42, tanks A & B. "Light" defined on page 73. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.


GRADIENT TANK 42-A
P. aztecus
DISTRIBUTION IN THE "LIGHT"
SALINITY (PARTS PER THOUSAND)
70 60 50 40 30 20 10 0
NIGHT DAY NIGHT DAY NIGHT DAY
ELAPSED TIME (hrs) 5 10 15 20 25 30 35 40 45 50 55 60
DATE (1973) 7/9 7/10 7/10 7/10 7/10 7/10 7/11 7/11 7/11 7/12
OBSERVED N 151 153 148 149 148 147 147 117 71 74
MORTALITY (0) (0) (0) (0) (0) (0) (0) (0) (0) (0)
TEMPERATURE (C) 23.5 23.7 23.5 23.6 23.6 23.9 23.5 23.6 23.6 23.6

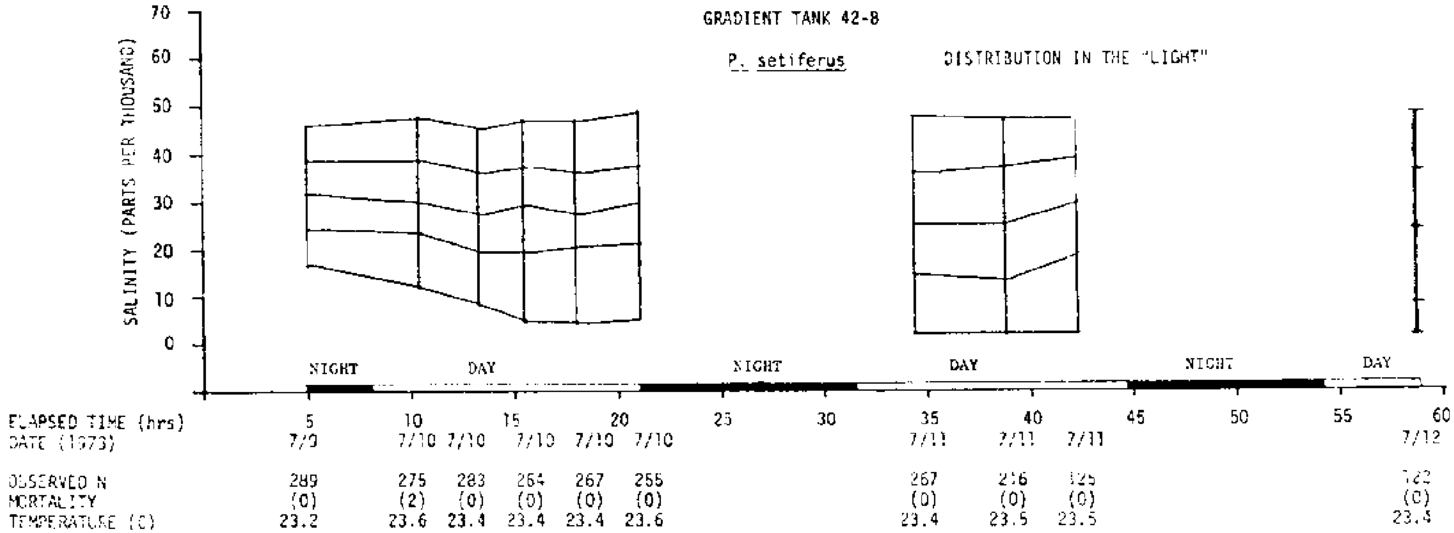
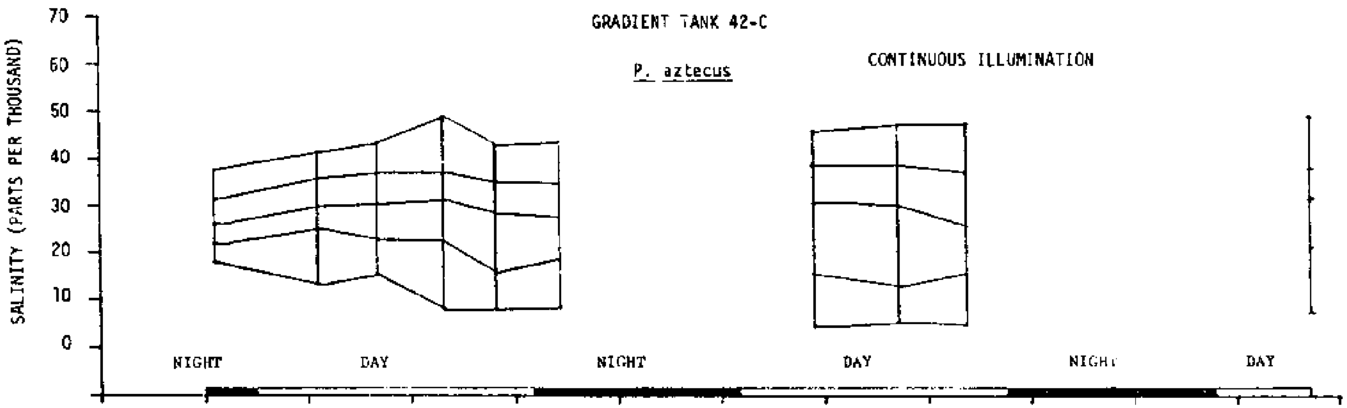
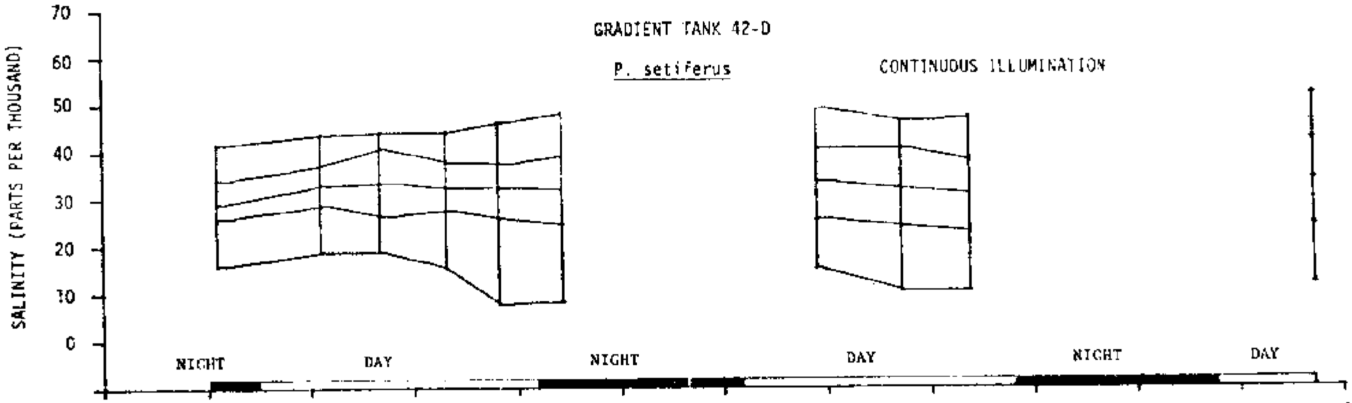

GRADIENT TANK 42-B
P. setiferus
DISTRIBUTION IN THE "LIGHT"
SALINITY (PARTS PER THOUSAND)
70 60 50 40 30 20 10 0
NIGHT DAY NIGHT DAY NIGHT DAY
ELAPSED TIME (hrs) 5 10 15 20 25 30 35 40 45 50 55 60
DATE (1973) 7/9 7/10 7/10 7/10 7/10 7/10 7/11 7/11 7/11 7/12
OBSERVED N 289 275 283 264 267 255 267 216 125 122
MORTALITY (0) (2) (0) (0) (0) (0) (0) (0) (0) (0)
TEMPERATURE (C) 23.2 23.6 23.4 23.4 23.4 23.6 23.4 23.5 23.5 23.4

FIGURE 89.—Distribution of postlarval brown and white shrimp (*P. aztecus* and *P. setiferus*) under continuous low level red illumination in experiment 42, tanks C & D. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom show the 5th, 25th, 75th and 95th percentiles. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.



ELAPSED TIME (hrs) DATE (1973)	7/9	7/10	7/10	7/10	7/10	7/10	7/11	7/11	7/11	7/12
OBSERVED N	160	163	160	167	168	164	162	90	111	85
MORTALITY	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
TEMPERATURE (C)	21.3	22.6	22.8	23.1	22.0	23.3	23.4	23.3	23.0	23.5



ELAPSED TIME (hrs) DATE (1973)	7/9	7/10	7/10	7/10	7/10	7/10	7/11	7/11	7/11	7/12
OBSERVED N	360	335	318	320	303	301	303	171	178	169
MORTALITY	(1)	(5)	(5)	(6)	(7)	(8)	(6)	(6)	(6)	(5)
TEMPERATURE (C)	21.0	22.4	22.8	22.9	22.8	23.0	23.3	23.1	22.0	23.3

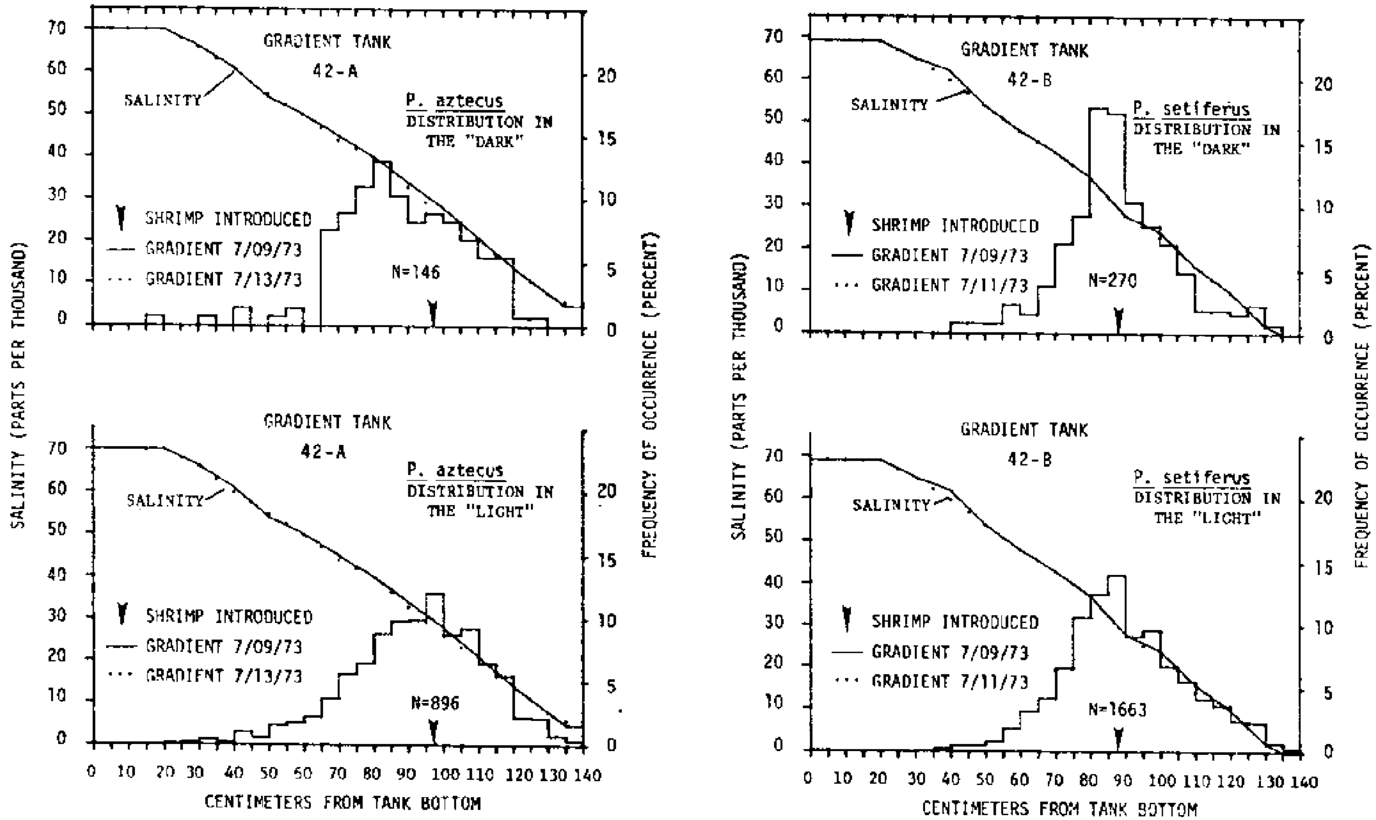


FIGURE 90.—Distribution of postlarval brown and white shrimp (P. aztecus and P. setiferus) and salinity in experiment 42 during observations made from 5.0 to 26.1 hours after shrimp were introduced. Temperature approximated 23.5 C during this time interval. Tanks were periodically illuminated with low level red light. "Dark" and " Light" are defined on page 73. Number of shrimp introduced into tank A = 25. tank B = 48. N = total number of shrimp counted in a series of observations.

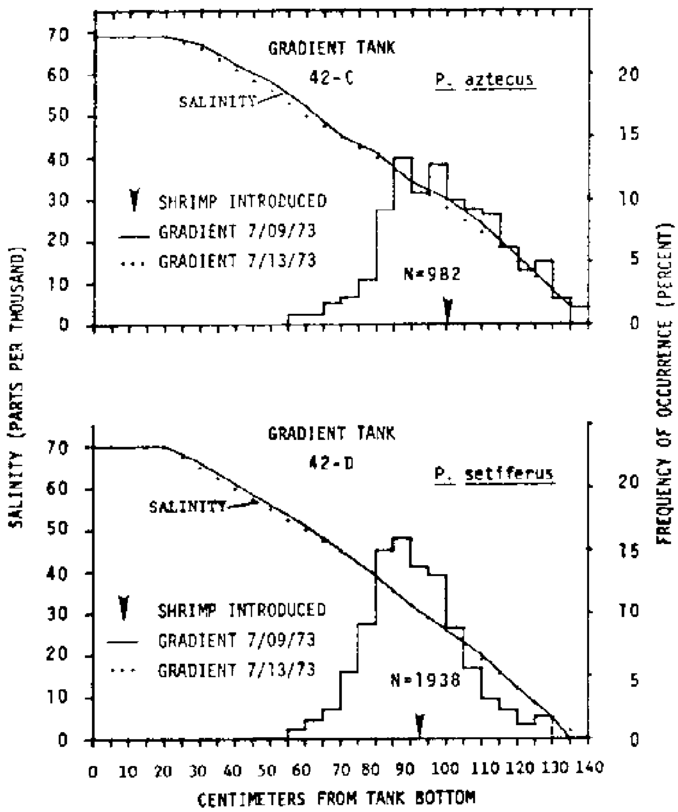
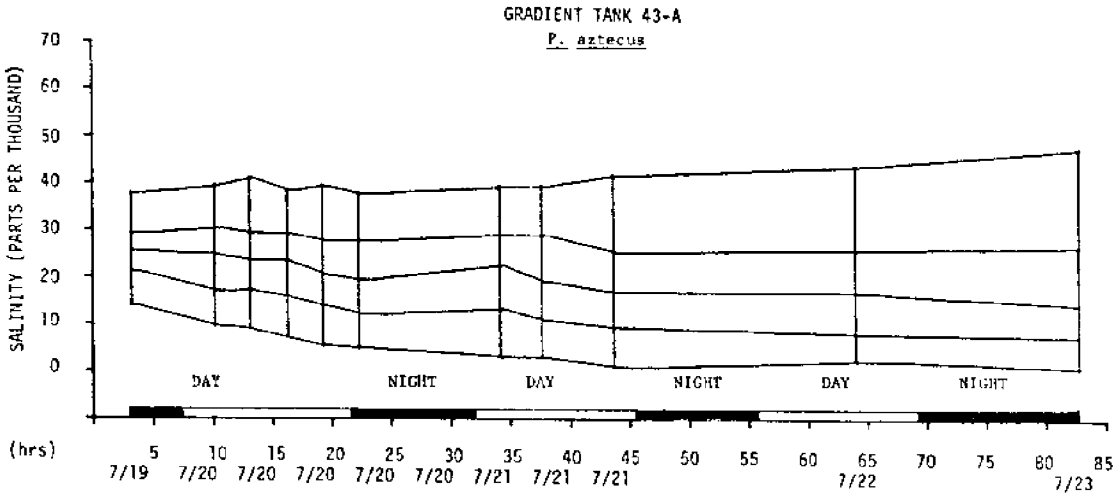
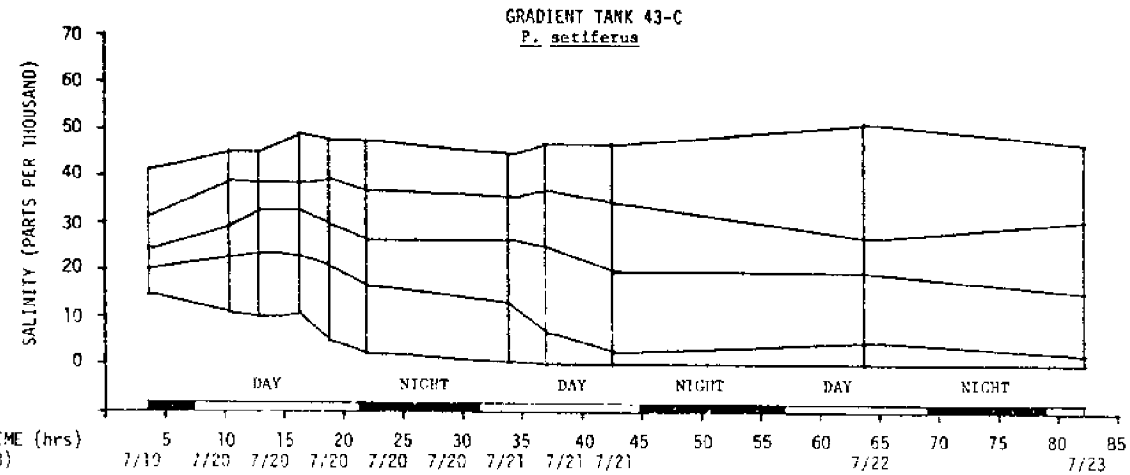


FIGURE 91.—Distribution of postlarval brown and white shrimp (P. aztecus and P. setiferus) and salinity in experiment 42, tanks C & D during observations made from 5.5 to 27.7 hours after shrimp were introduced. Temperature approximated 23.0 C during this time interval. Tanks were continuously illuminated with low level red light. Number of shrimp introduced into tank C = 23, tank D = 49. N = total number of shrimp counted in a series of observations.

FIGURE 92.—Distribution of postlarval brown and white shimp (*P. aztecus* and *P. setiferus*) under continuous low level red illumination in experiment 43, tanks A & C. Postlarvae were collected 7/15/73 and acclimated for 4 days to 26 C and 33 o/oo. Vertical lines indicate distributions. Midline represents medians and other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.



DATE (1973)	7/19	7/20	7/20	7/20	7/20	7/20	7/21	7/21	7/21	7/22	7/23
OBSERVED N	188	332	188	316	183	200	198	93	93	46	44
MORTALITY	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1)	(1)
TEMPERATURE (C)	26.1	26.5	26.4	26.2	26.5	26.6	26.4	26.3	26.3	25.2	

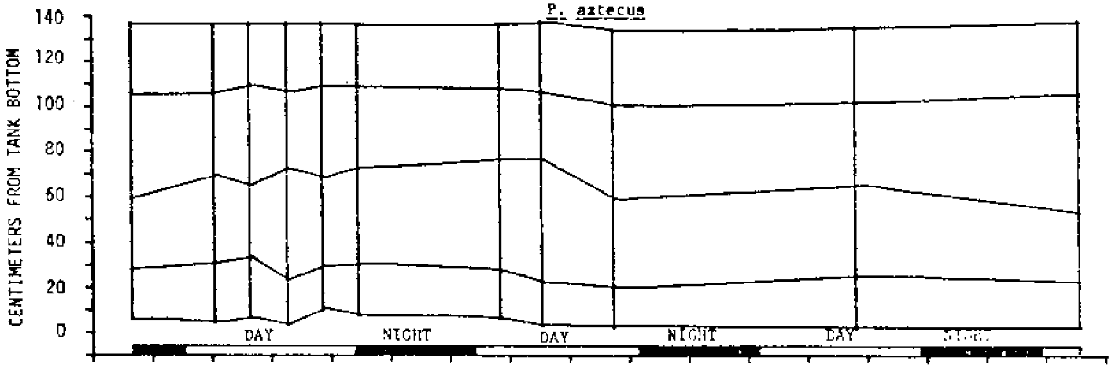


DATE (1973)	7/19	7/20	7/20	7/20	7/20	7/20	7/21	7/21	7/21	7/22	7/23
OBSERVED N	200	334	183	328	186	193	199	98	98	44	47
MORTALITY	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
TEMPERATURE (C)	25.7	25.9	24.8	24.6	25.7	25.7	25.3	25.2	25.3	25.5	25.9

FIGURE 93.—Distribution of postlarval brown and white shrimp (*P. aztecus* and *P. setiferus*) under continuous low level red illumination in experiment 43, tanks B & D. Postlarvae were collected 7/15/73 and acclimated for 4 days to 26 C and 33 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

CONTROL TANK 43-B

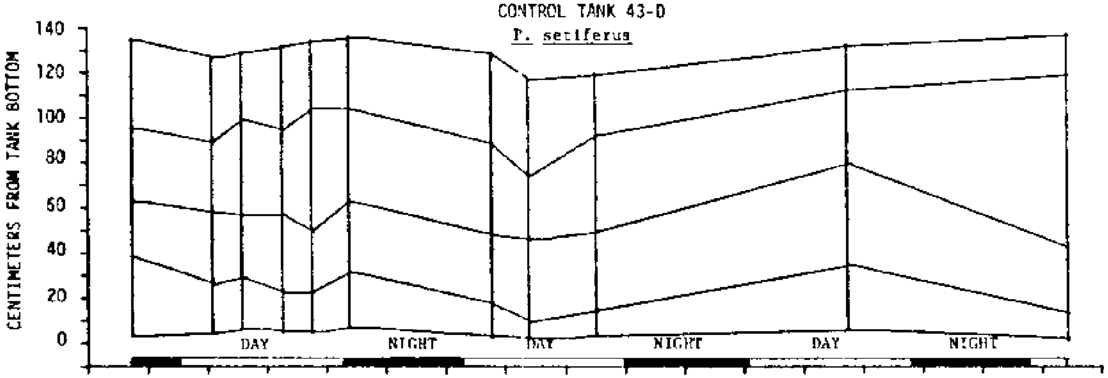
P. aztecus



ELAPSED TIME (hrs)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
DATE (1973)	7/19	7/20	7/20	7/20	7/20	7/20	7/21	7/21	7/21				7/22			7/23	
OBSERVED N	210	369	211	261	202	214	209	106	110				49			46	
MORTALITY	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)				(0)			(0)	
TEMPERATURE (C)	26.2	26.4	26.6	26.3	26.6	26.5	26.6	26.3	26.3				26.2				

CONTROL TANK 43-D

P. setiferus



ELAPSED TIME (hrs)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
DATE (1973)	7/19	7/20	7/20	7/20	7/20	7/20	7/21	7/21	7/21				7/22			7/23	
OBSERVED N	184	304	179	300	174	172	171	83	84				48			40	
MORTALITY	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)				(0)			(0)	
TEMPERATURE (C)	25.9	26.1	26.0	25.8	25.9	25.9	25.3	25.3	25.3				25.3			25.2	

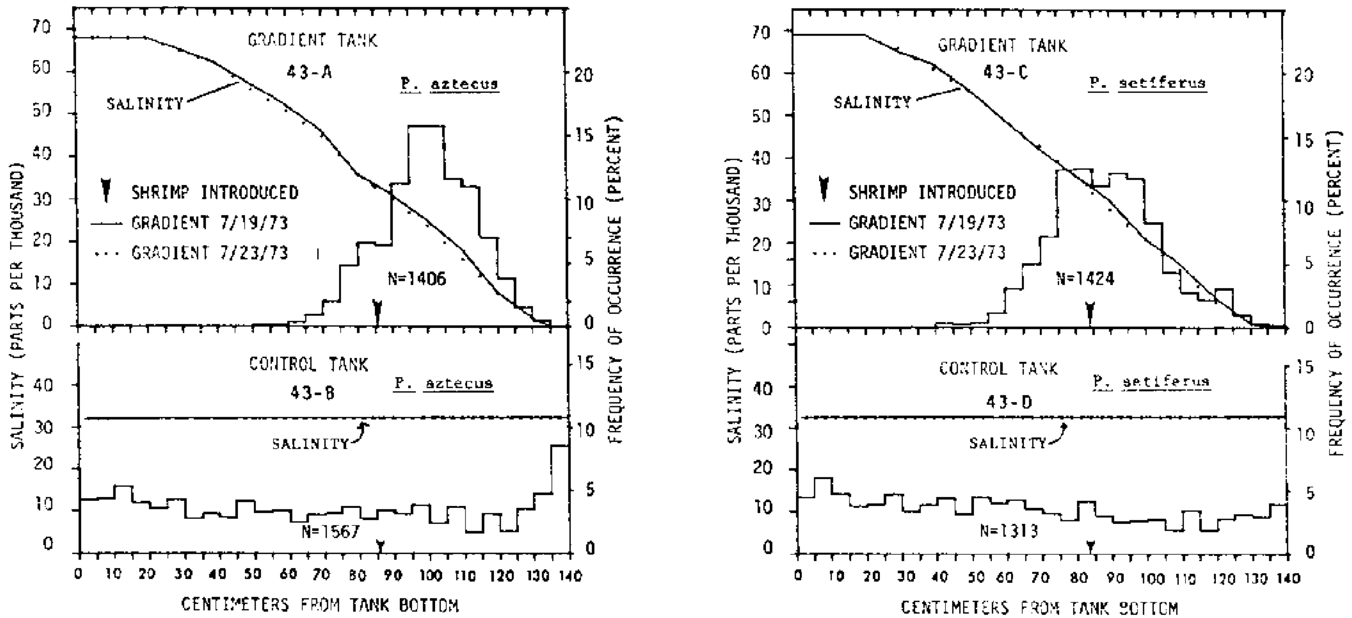
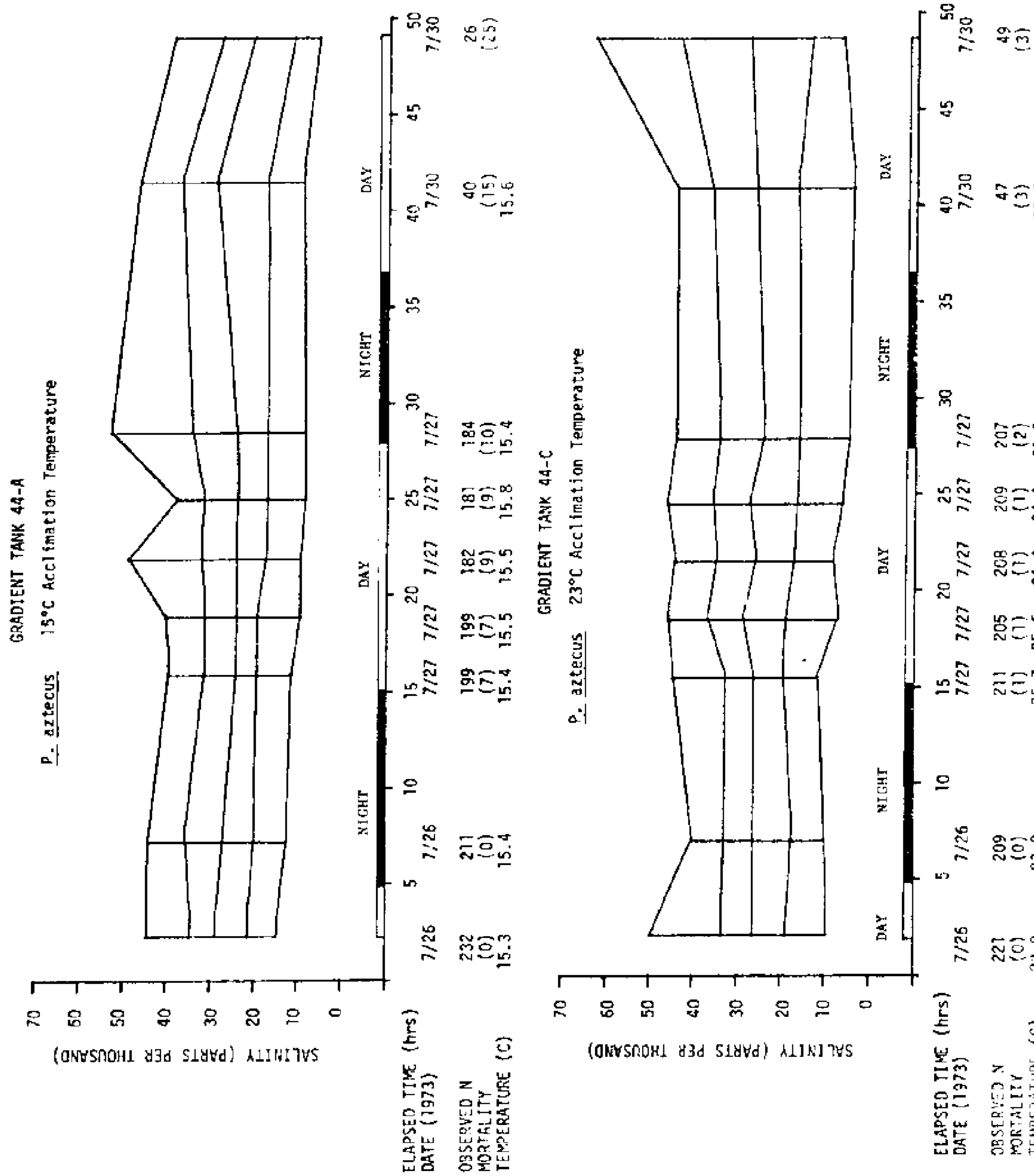


FIGURE 94.—Distribution of postlarval brown and white shrimp (P. aztecus and P. setiferus) and salinity in experiment 43 during observations made from 3.3 to 25.6 hours after shrimp were introduced. Temperature approximated 26.0 C during this time interval. Shrimp were collected 7/15/73 and acclimated for 4 days to 26 C and 33 o/oo. Number of shrimp introduced into tank A = 48, tank B = 51, tank C = 49, tank D = 44. N = total number of shrimp counted in a series of observations.

FIGURE 95.—Distribution of postlarval brown shrimp (*P. aztecus*) acclimated to different temperatures and tested under continuous low level red illumination in experiment 44, tanks A & C. Postlarvae were collected 7/15/73 and acclimated for 11 days to 33 o/oo and to either 15 C or 23 C Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

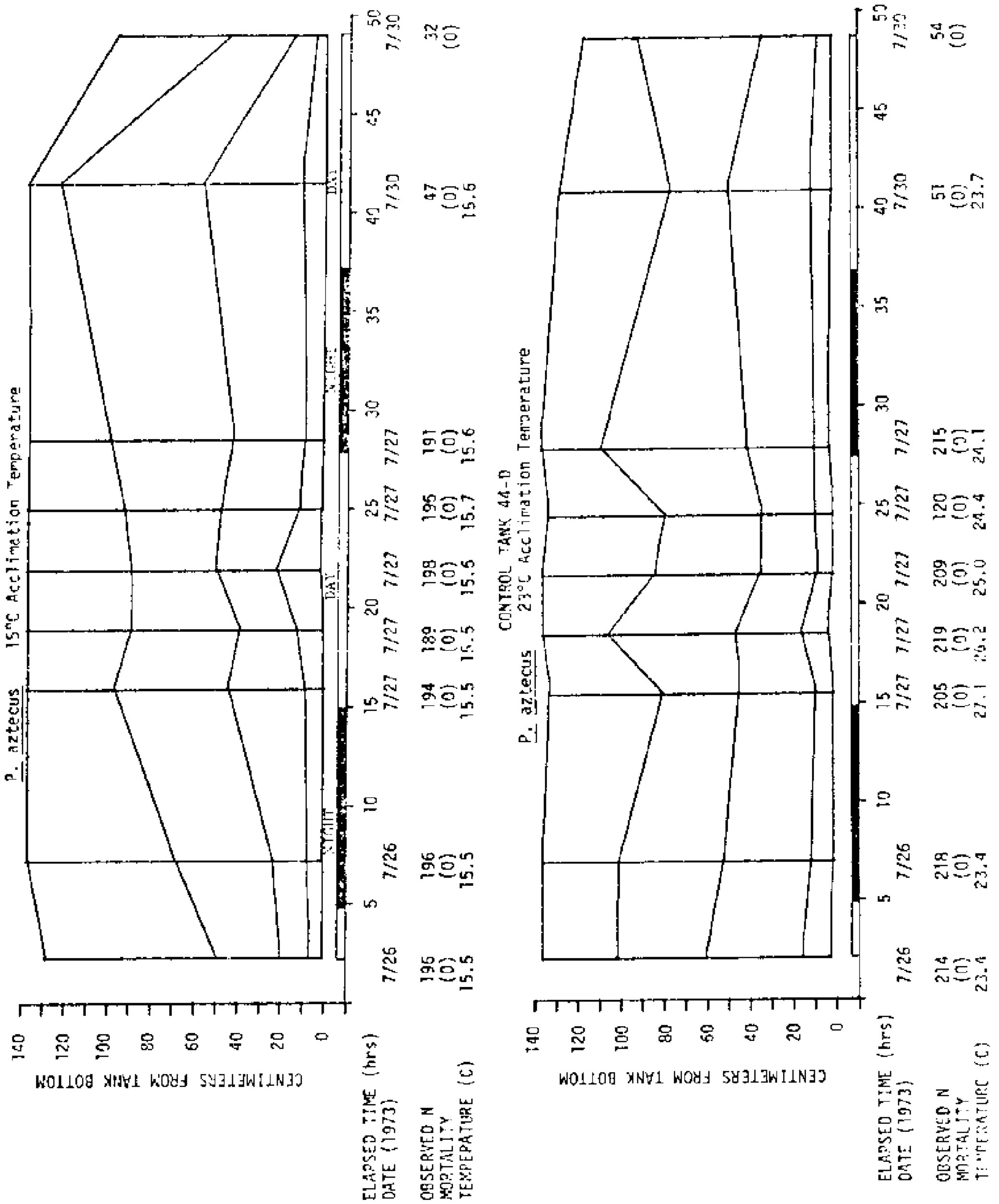
FIGURE 95



GRADIENT TANK 44-A
P. aztecus 15°C Acclimation Temperature
GRADIENT TANK 44-C
P. aztecus 23°C Acclimation Temperature
SALINITY (PARTS PER THOUSAND)
ELAPSED TIME (hrs)
DATE (1973)
OBSERVED N
MORTALITY
TEMPERATURE (C)
DAY
NIGHT
7/26 232 (0) 15.3
7/26 211 (0) 15.4
7/27 199 (7) 15.4
7/27 199 (7) 15.5
7/27 182 (9) 15.5
7/27 181 (9) 15.8
7/27 184 (10) 15.4
7/30 40 (15) 15.6
7/30 26 (25)
7/26 221 (0) 22.0
7/26 209 (0) 23.0
7/27 211 (1) 26.7
7/27 205 (1) 25.6
7/27 208 (1) 24.4
7/27 209 (1) 24.1
7/27 207 (2) 23.8
7/30 47 (3) 23.6
7/30 49 (3)

FIGURE 96.—Distribution of postlarval brown shrimp (*P. aztecus*) acclimated to different temperatures and tested under continuous low level red illumination in experiment 44, tanks B & D. Postlarvae were collected 7/15/73 and acclimated for 11 days to 33 o/oo and to either 15 C or 23 C. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

FIGURE 96


P. aztecus CONTROL TANK 44-B
15°C Acclimation Temperature
P. aztecus CONTROL TANK 44-D
23°C Acclimation Temperature
CENTIMETERS FROM TANK BOTTOM
ELAPSED TIME (hrs)
DATE (1973)
OBSERVED N
MORTALITY
TEMPERATURE (C)
DAY
NIGHT

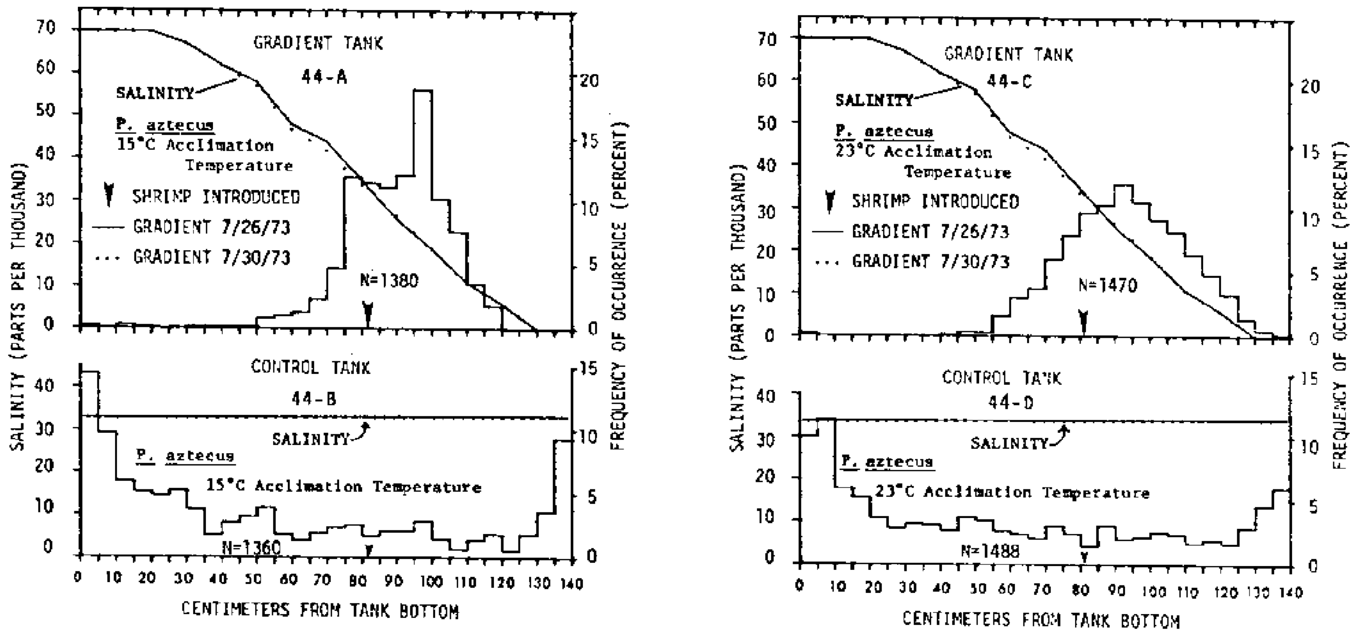


FIGURE 97.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 44 during observations made from 2.1 to 28.5 hours after shrimp were introduced. Postlarvae were collected 7/15/73 and acclimated for 11 days to 33 o/oo and to either 15 C or 23 C. Number of shrimp introduced into tank A = 50, tank B = 50, tank C = 53, tank D = 52. N = total number of shrimp counted in a series of observations.

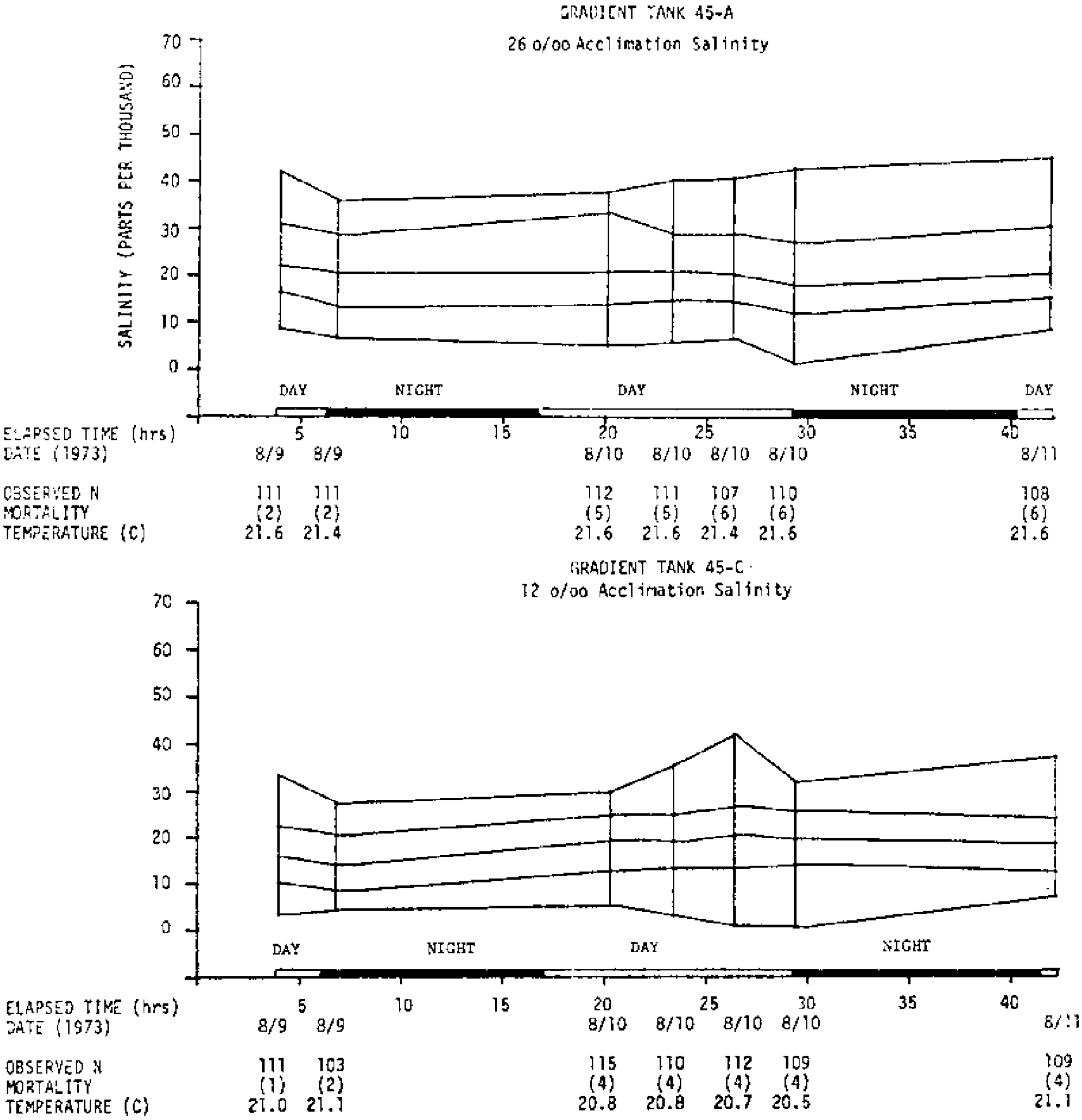


FIGURE 98.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 45, tanks A & C. Shrimp were collected 7/15/73 and acclimated for 25 days to 22 C and to either 12 o/oo or 26 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th 75th and 95th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

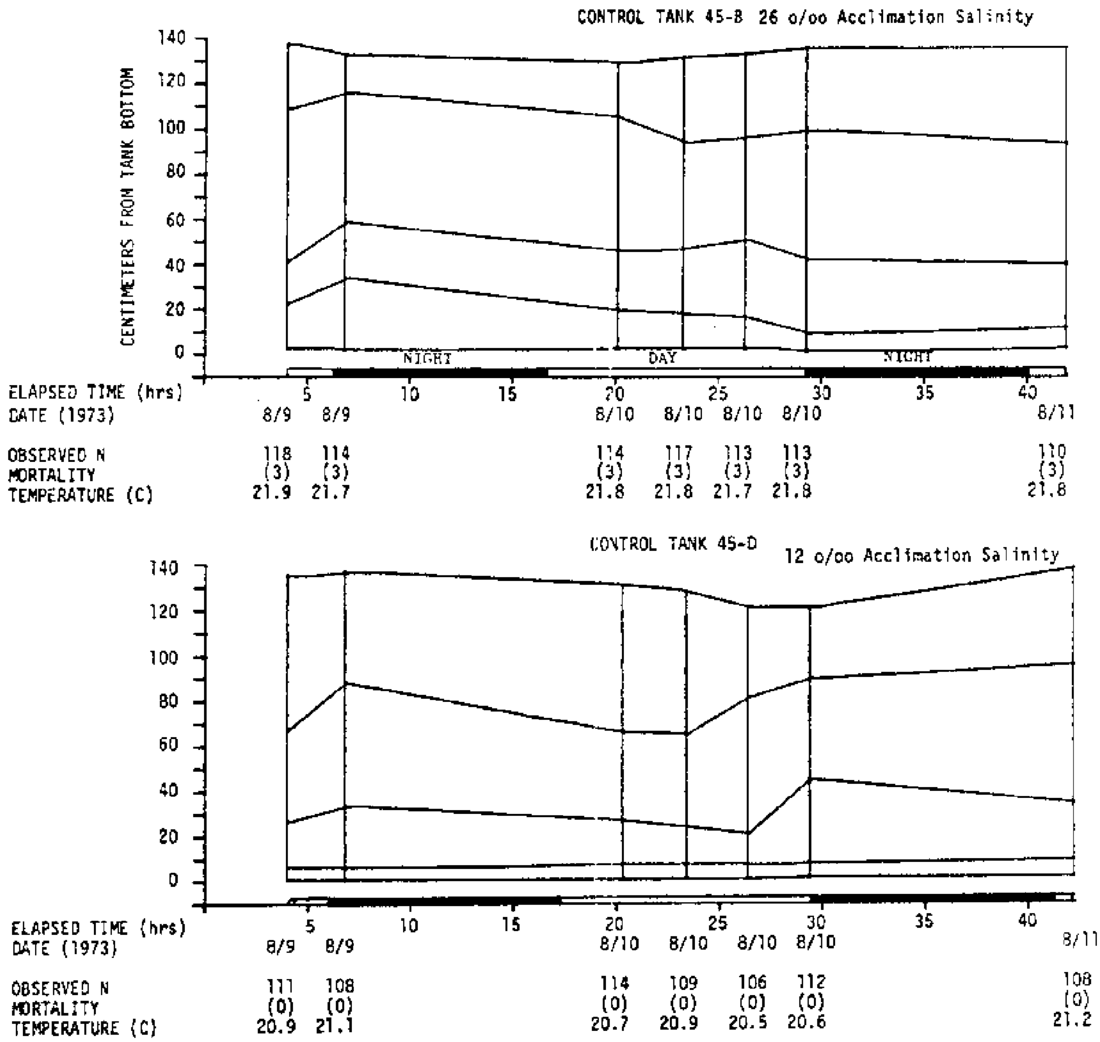


FIGURE 99.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level illumination in experiment 45, tanks B & D. Shrimp were collected 7/15/73 and acclimated for 25 days to 22 C and to either 12 o/oo or 26 o/oo. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th and 5th percentiles for each distribution. Observed N = total number of shrimp counted in a series of observations. Mortality = number of observations of dead shrimp during an observation period; dead shrimp not removed.

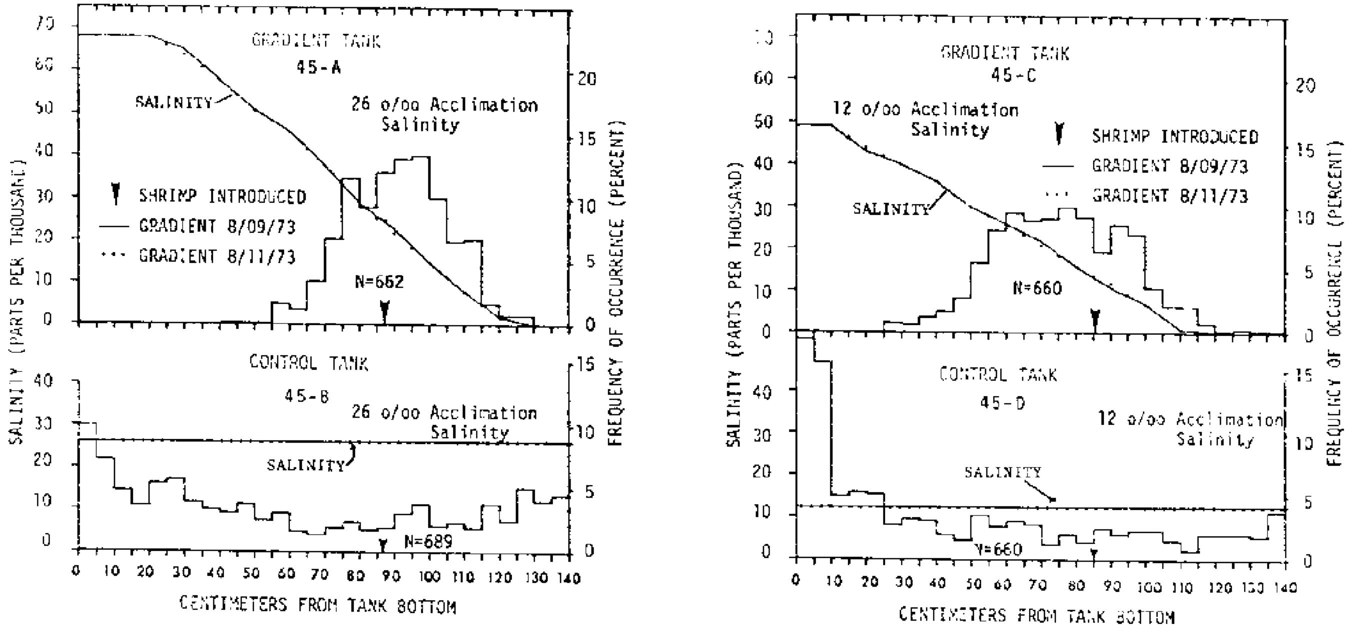


FIGURE 100.—Distribution of postlarval brown shrimp (P. aztecus) and salinity in experiment 45 during observations made from 4.0 to 29.4 hours after shrimp were introduced. Temperature approximated 21.0 C during this time interval. Postlarvae were collected 7/15/73 and acclimated for 25 days to 22 C and to either 12 o/oo or 26 o/oo. Number of shrimp introduced into tank A = 30, tank B = 33, tank C = 30, tank D = 29. N = total number of postlarvae counted in a series of observations.

B - Predicted tides and tidal currents plotted for selected shrimp distributions in experimental tanks
Figures 1 through 13

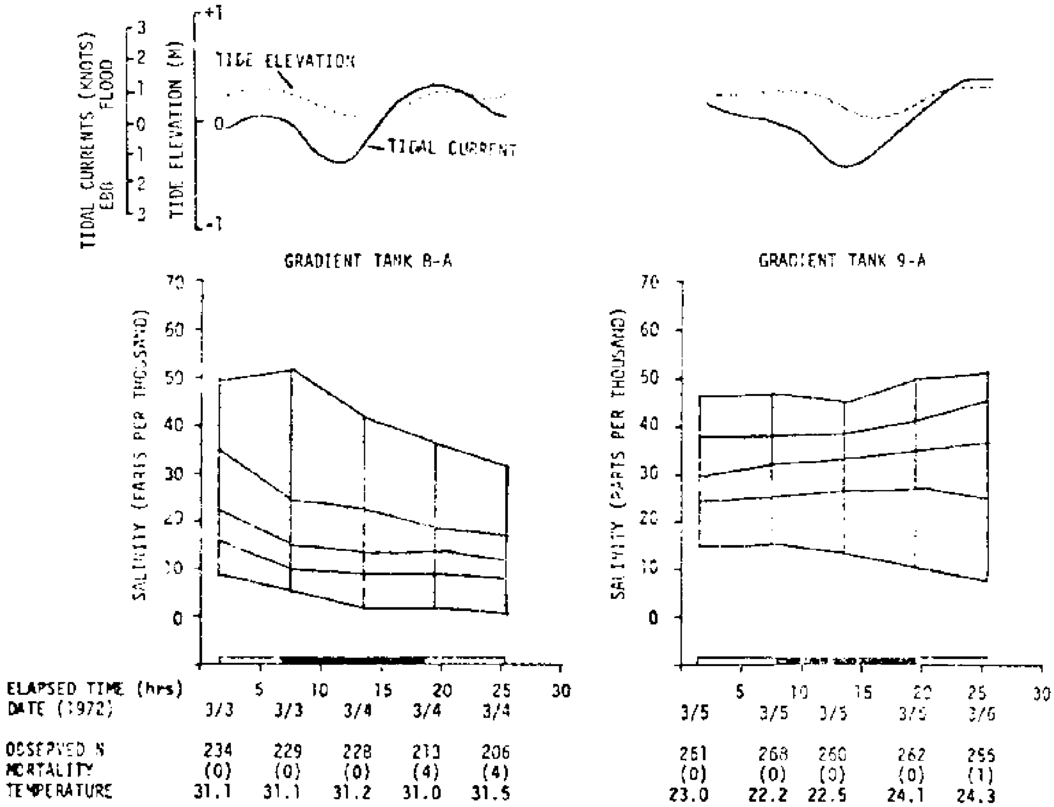


FIGURE 1.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiments 8 & 9 (gradient tanks) with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, indicate the 5th, 25th, 75th, and 95th percentiles for each distribution.

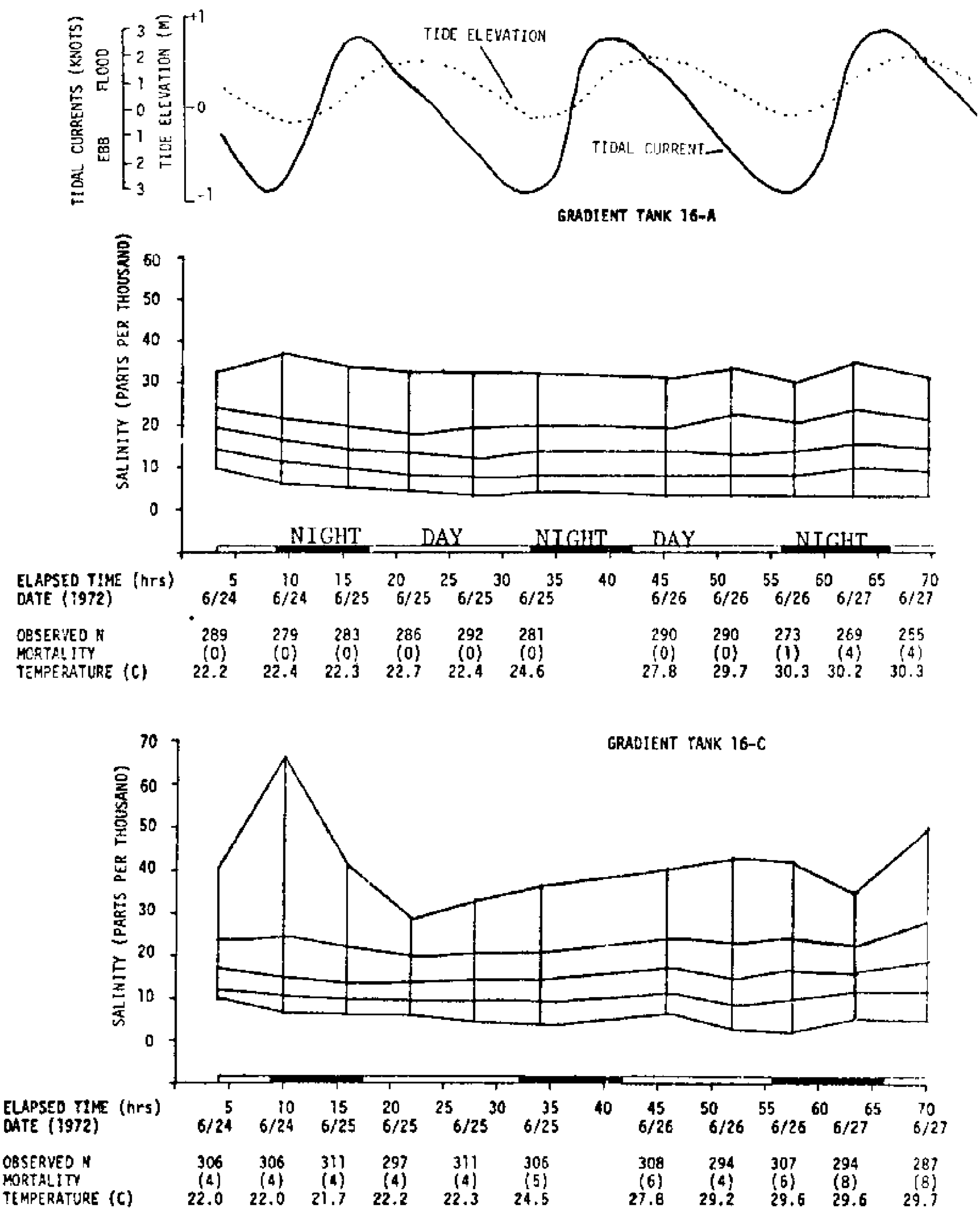


FIGURE 2.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 16, tanks A & C, with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th, and 95th percentiles for each distribution.

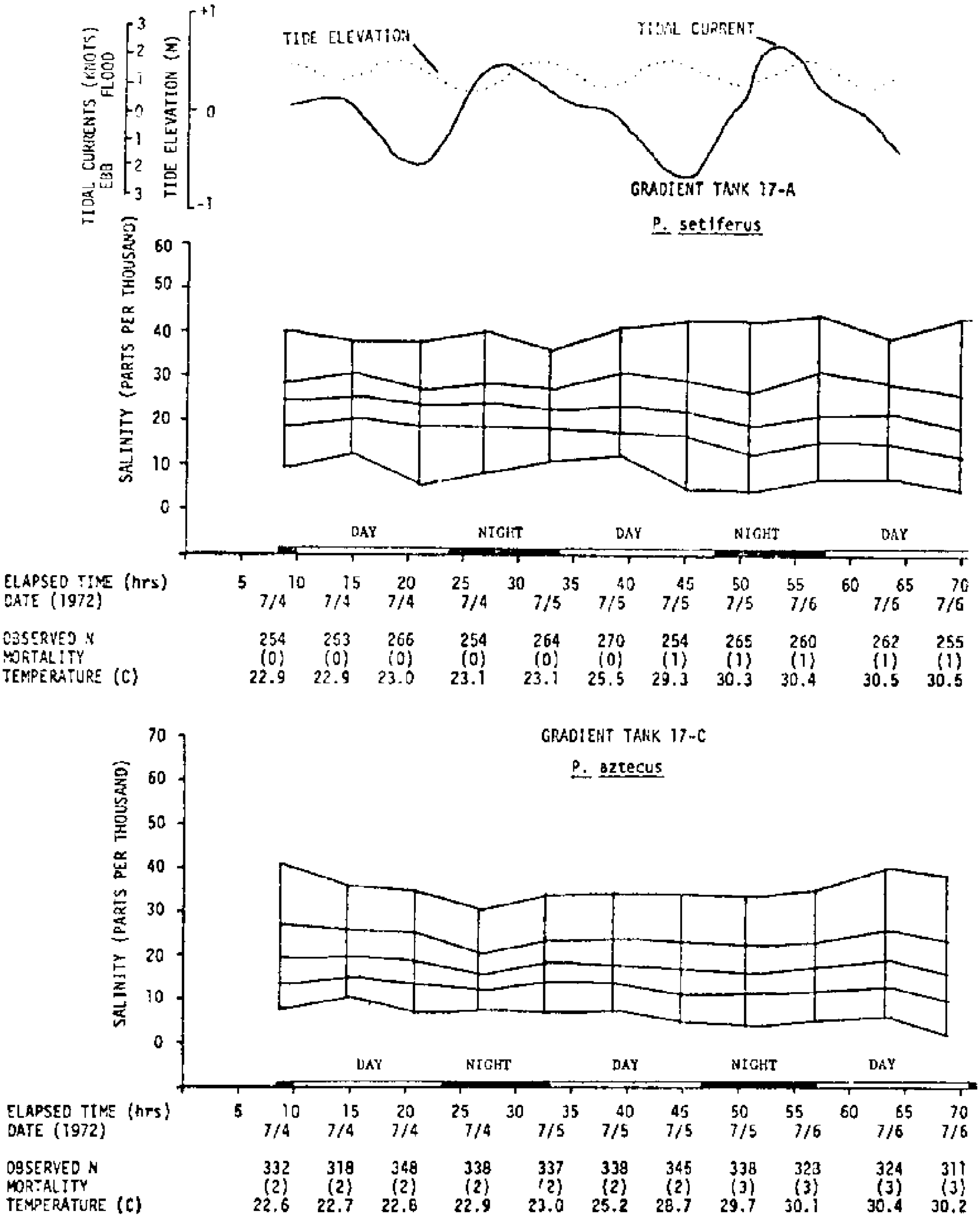


FIGURE 3.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under continuous low level red illumination in experiment 17, tanks A & C, with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th, and 95th percentiles for each distribution.

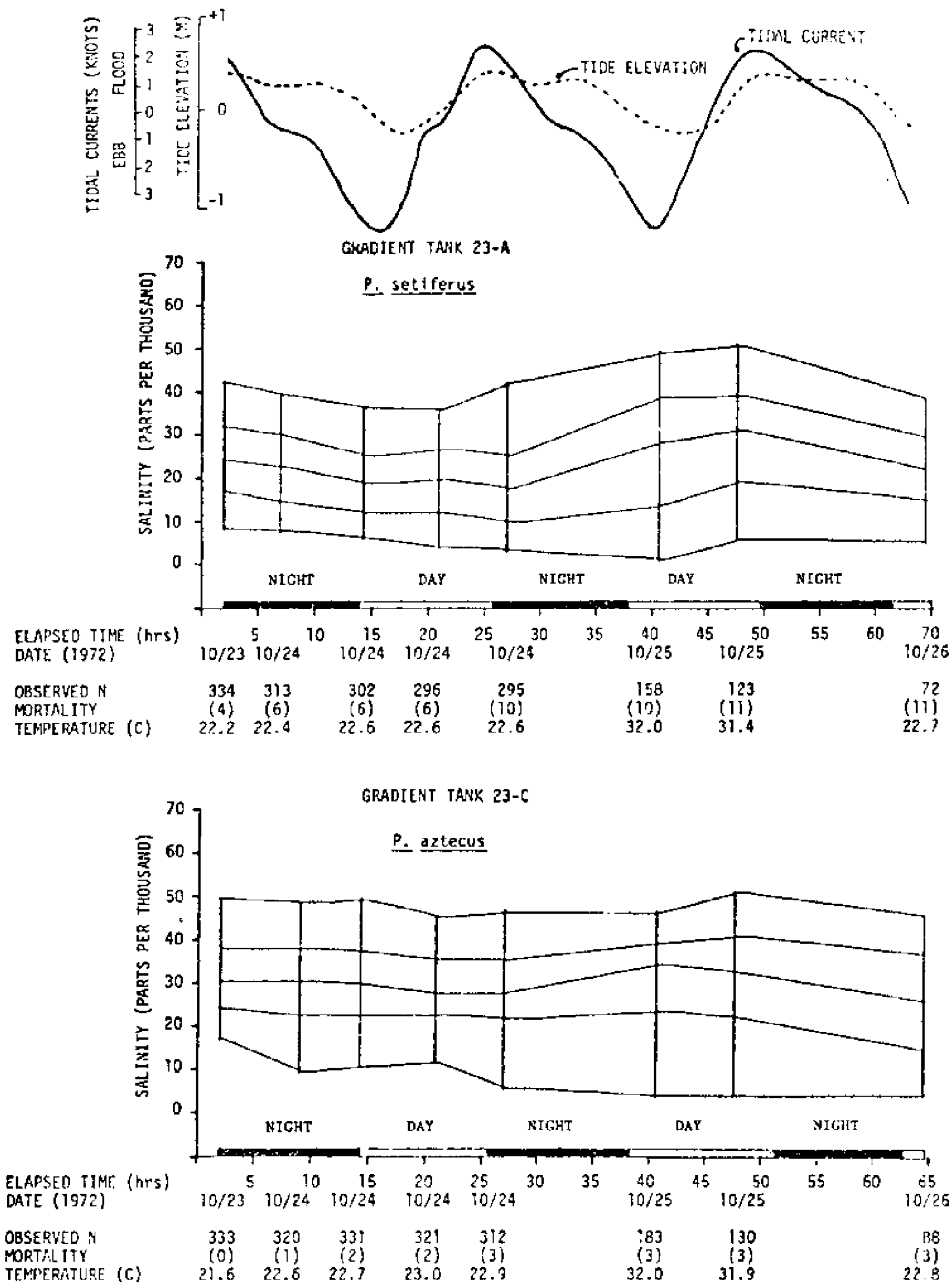


FIGURE 4.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under continuous low level red illumination in experiment 23, tanks A & C, with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th, and 95th percentiles for each distribution.

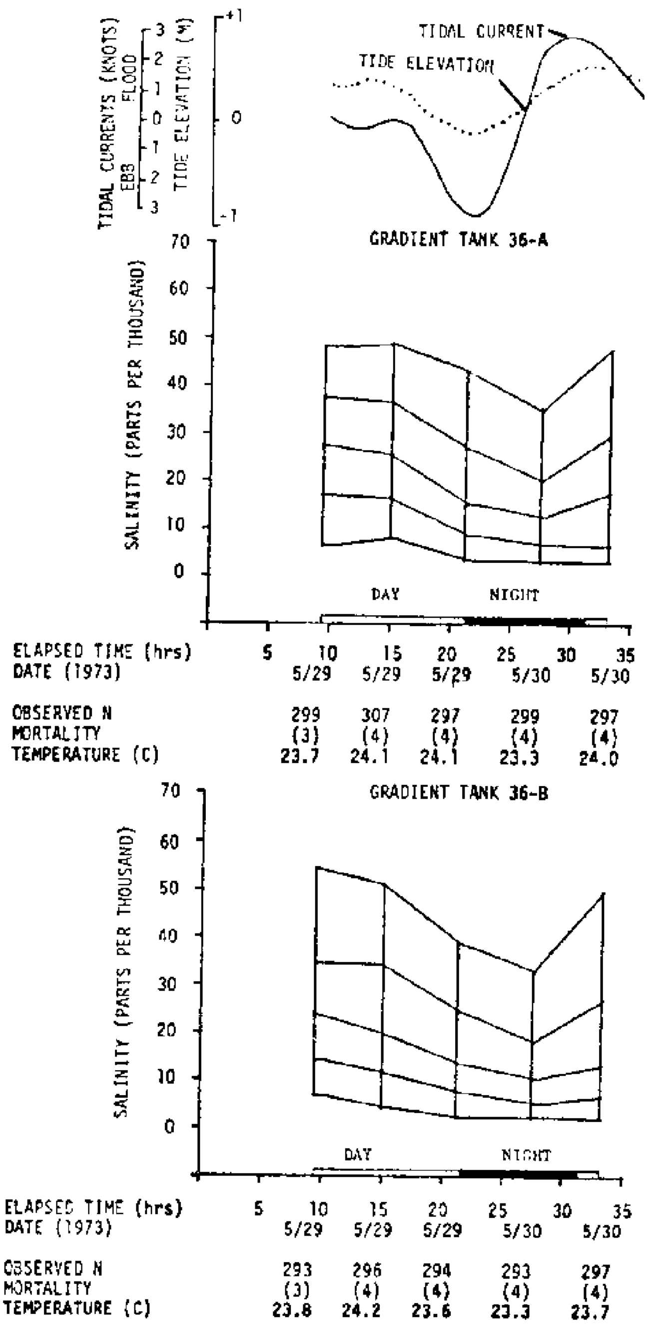


FIGURE 5.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiment 36, tanks A & B, with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th, and 95th percentiles.

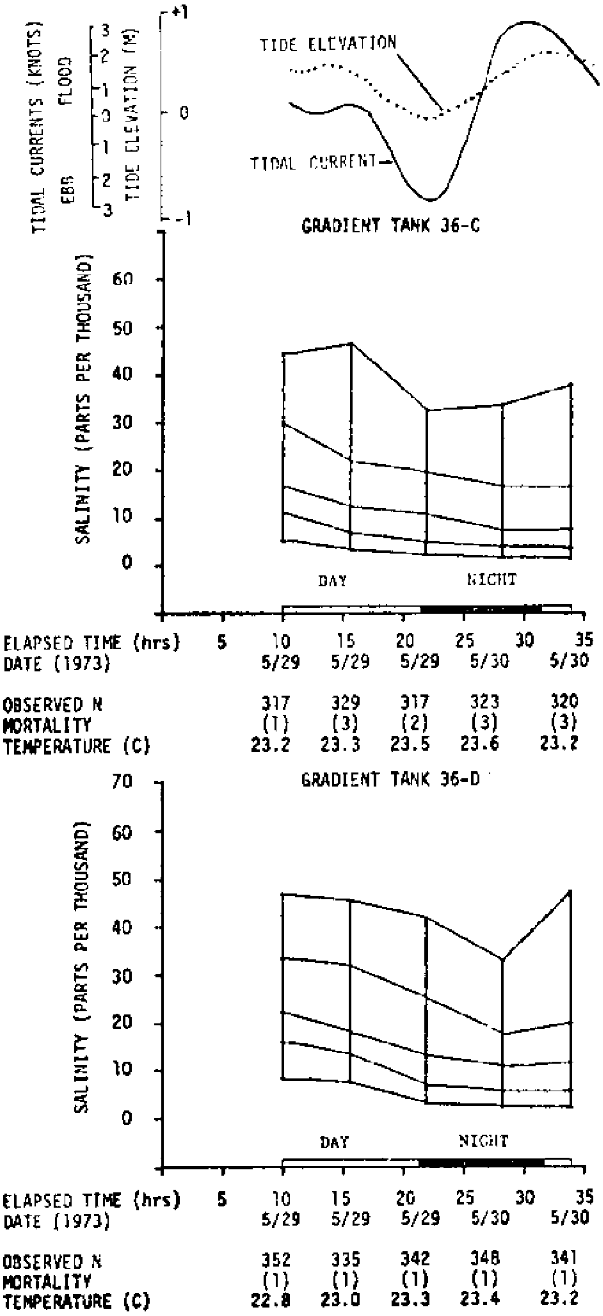


FIGURE 6.—Distribution of postlarval brown shrimp (*P. aztecus*) under continuous low level red illumination in experiment 36, tanks C & D, with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th, and 5th percentiles.

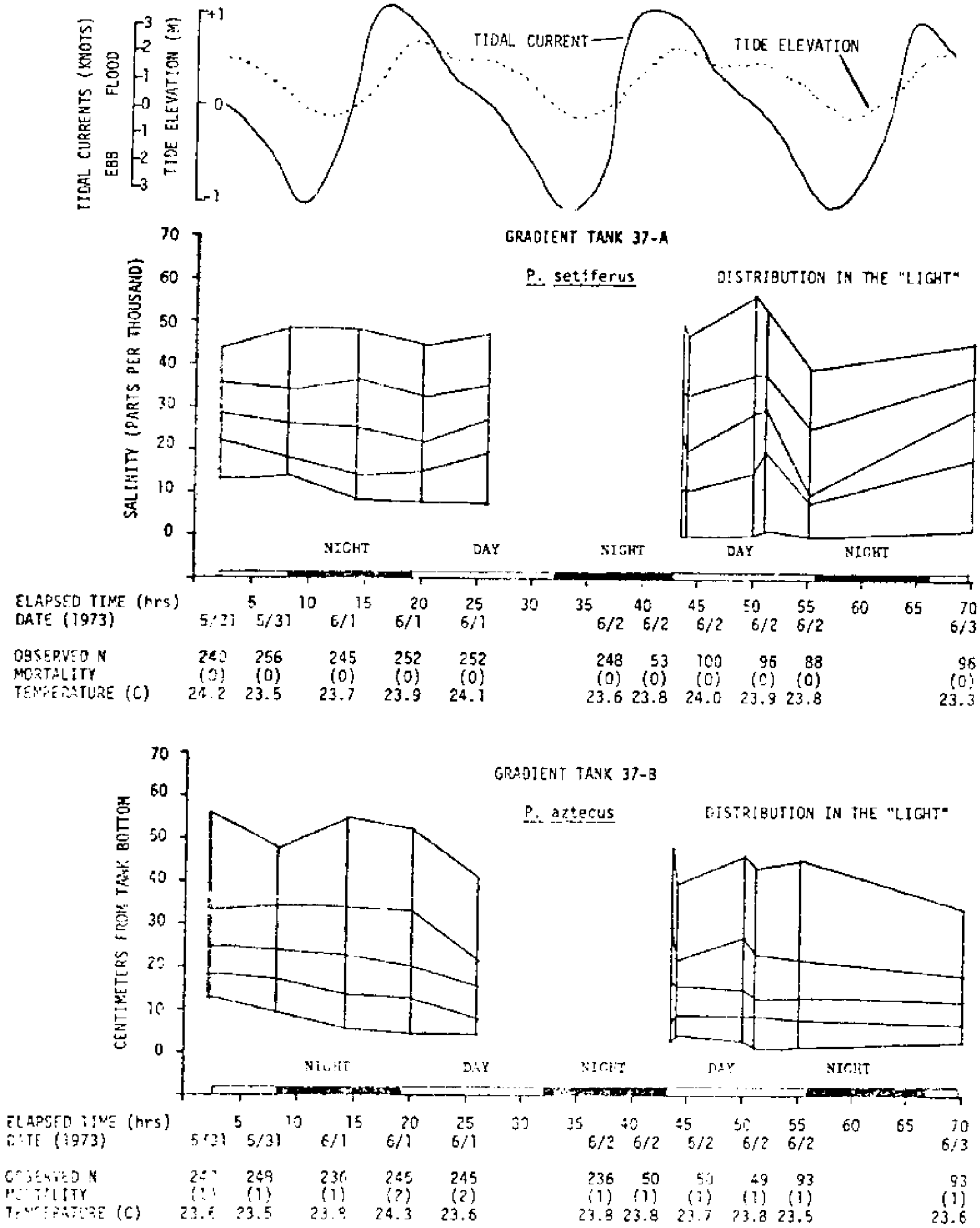


FIGURE 7.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under periodic low level red illumination in experiment 37, tanks A & B, with predicted tides and tidal currents. "Light" defined on page 73. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 5th, 25th, 75th, and 95th percentiles.

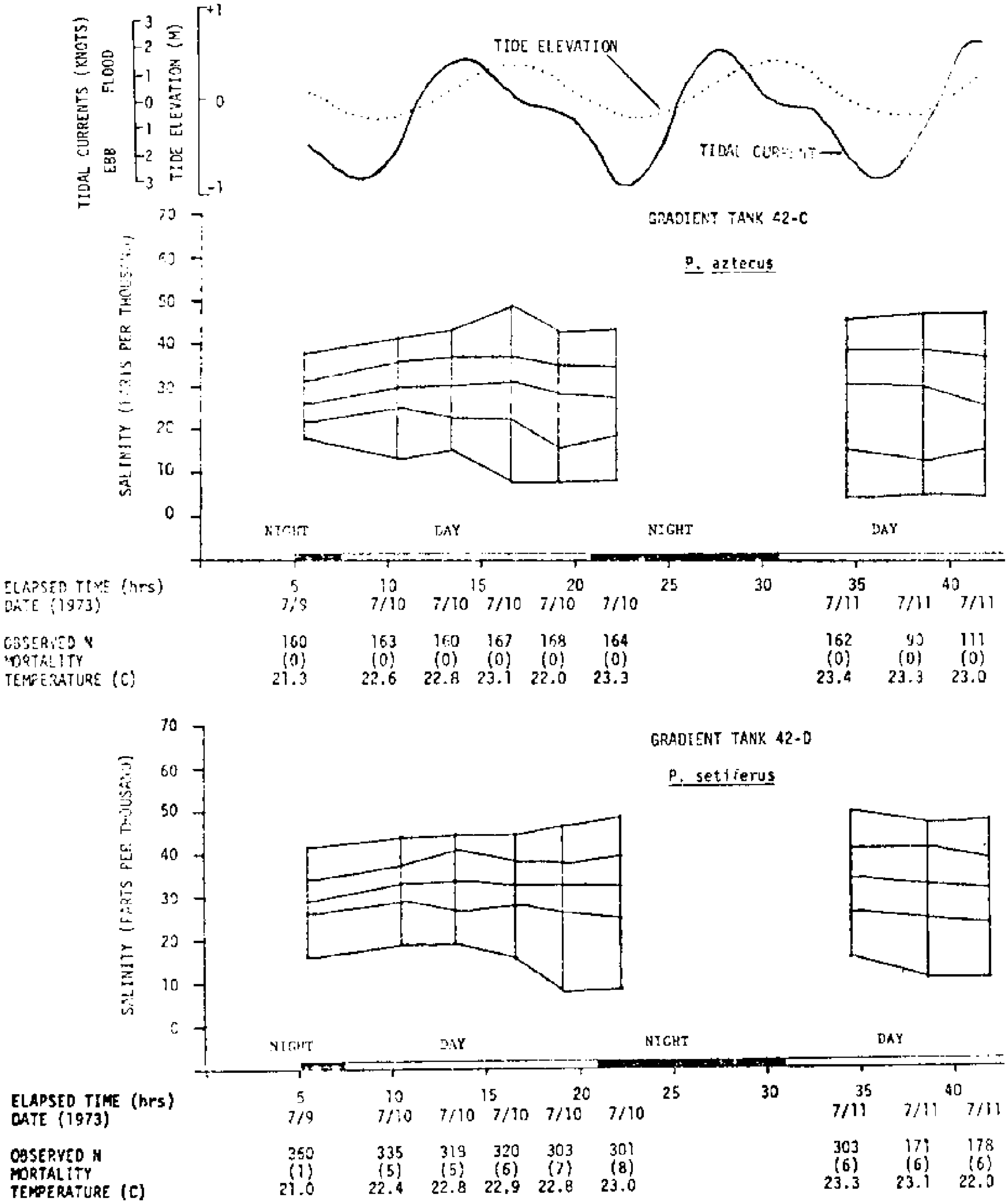


FIGURE 8.—Distribution of postlarval brown and white shrimp (P. aztecus and P. setiferus) under continuous low level red illumination in experiment 42, tanks C & D, with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians, and the other four lines, from top to bottom, show the 5th, 25th, 75th, and 95th percentiles for each distribution.

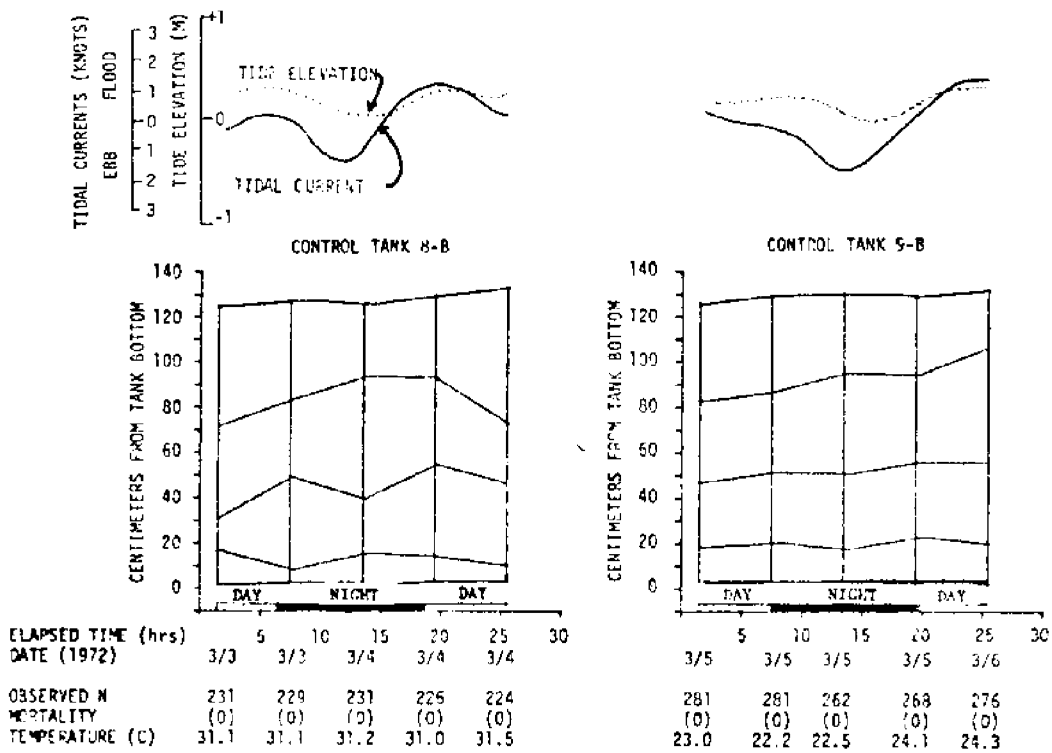


FIGURE 9.—Distribution of postlarval brown shrimp (P. aztecus) under continuous low level red illumination in experiments 8 & 9 (control tanks) with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, indicate the 95th, 75th, 25th, and 5th percentiles for each distribution.

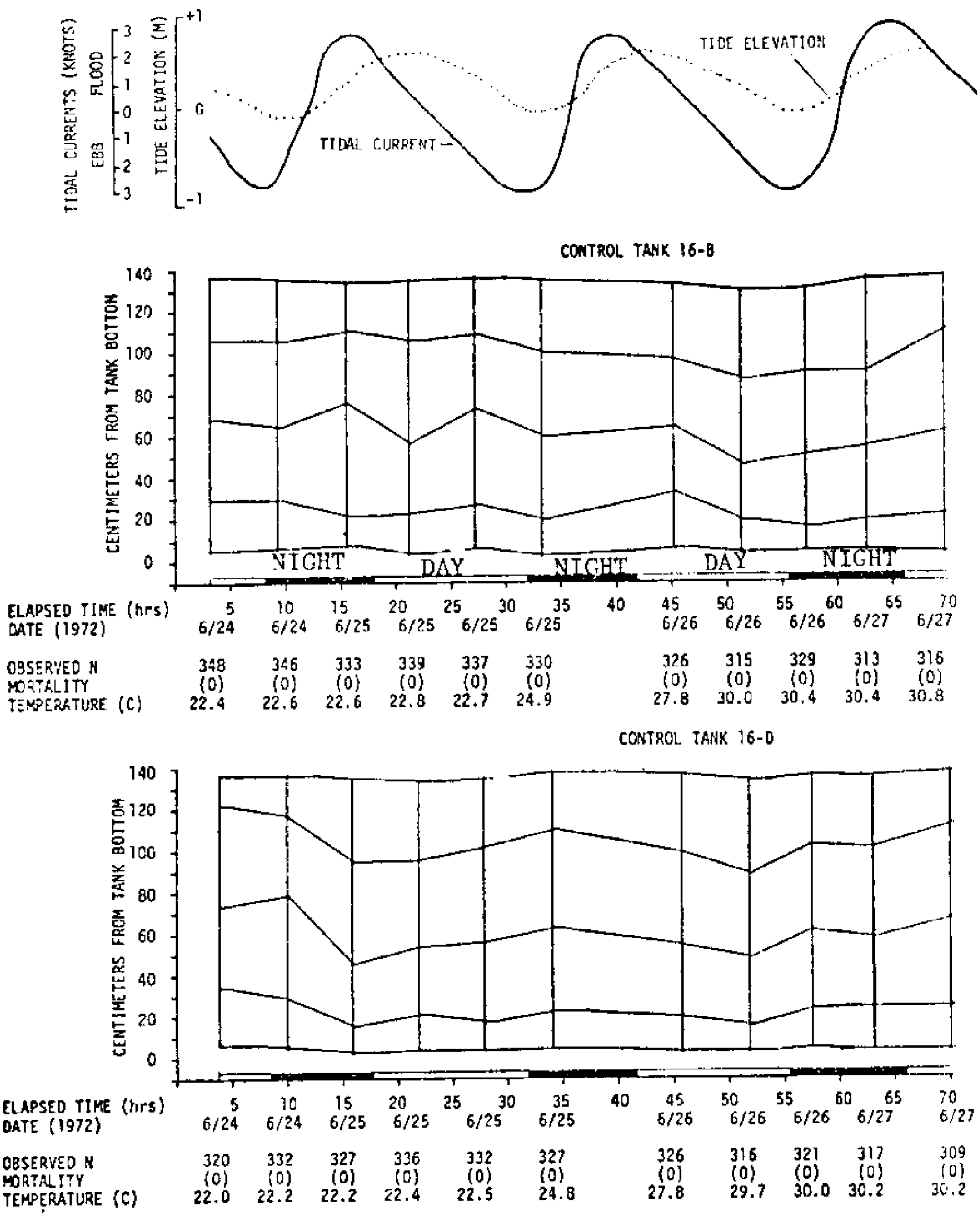


FIGURE 10.—Distribution of postlarval brown shrimp under continuous low level red illumination in experiment 16, tanks B & D, with predicted tides and tidal currents. Vertical lines indicate distributions and the other four lines, from top to bottom, shows the 95th, 75th, 25th, and 5th percentiles for each distribution.

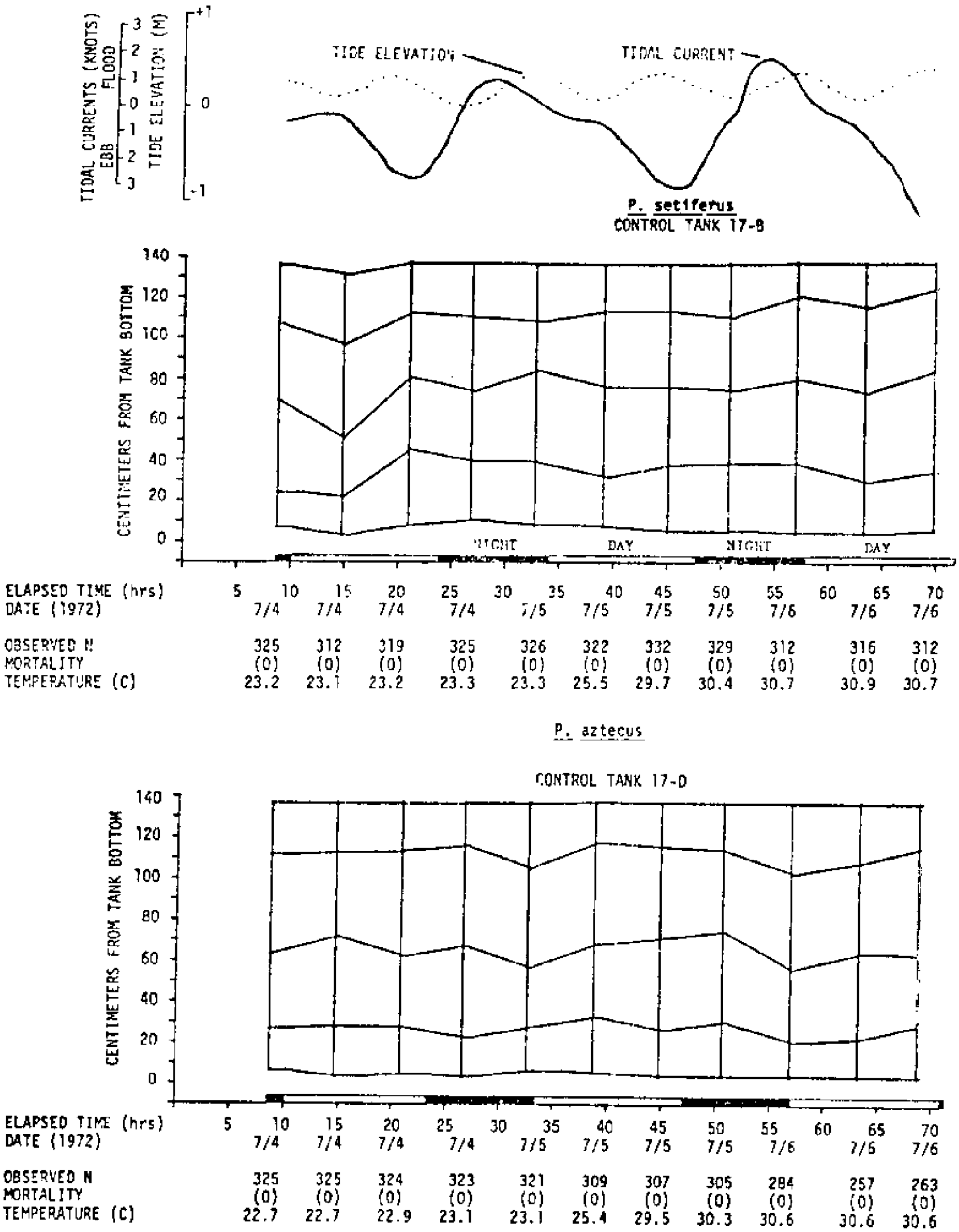


FIGURE 11.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under continuous low level red illumination in experiment 17, tanks B & D, with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th, and 5th percentiles for each distribution.

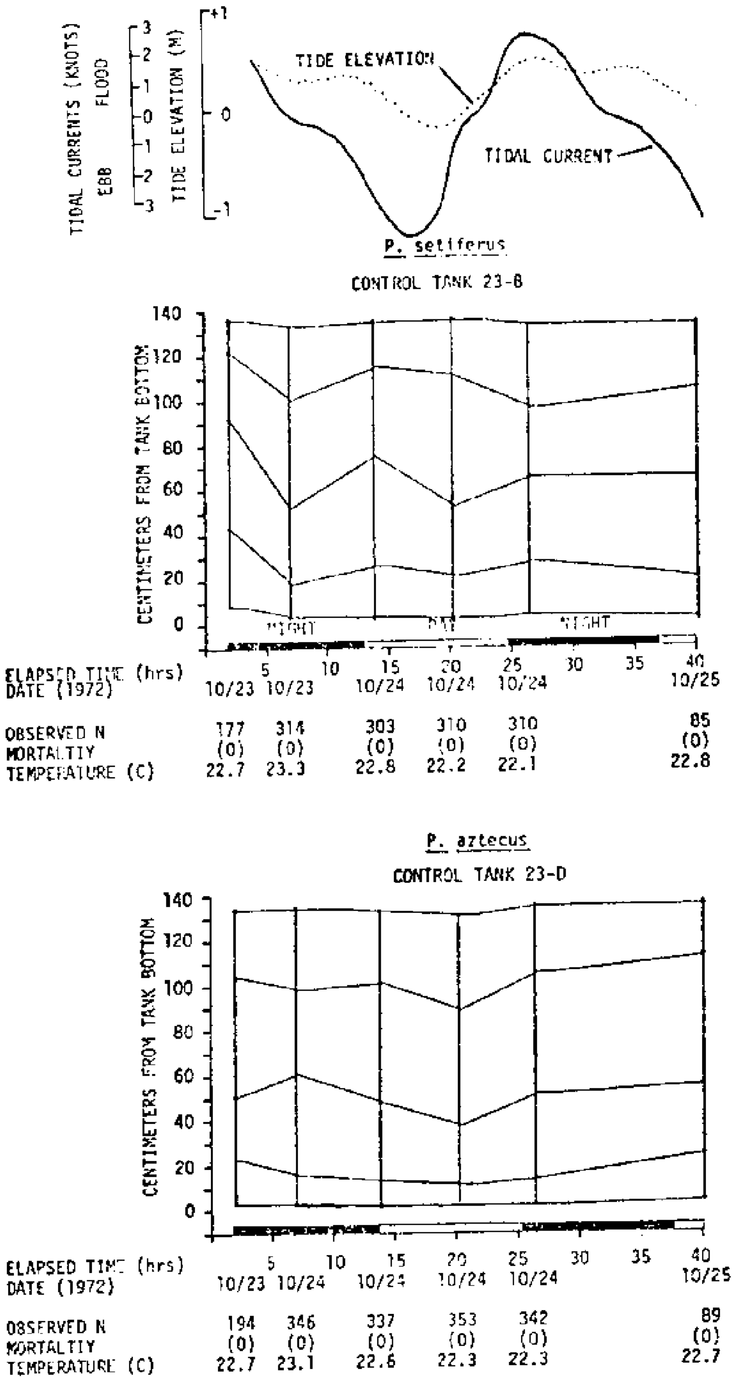


FIGURE 12.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under continuous low level red illumination in experiment 23, tanks B & D, with predicted tides and tidal currents. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th, and 5th percentiles for each distribution.

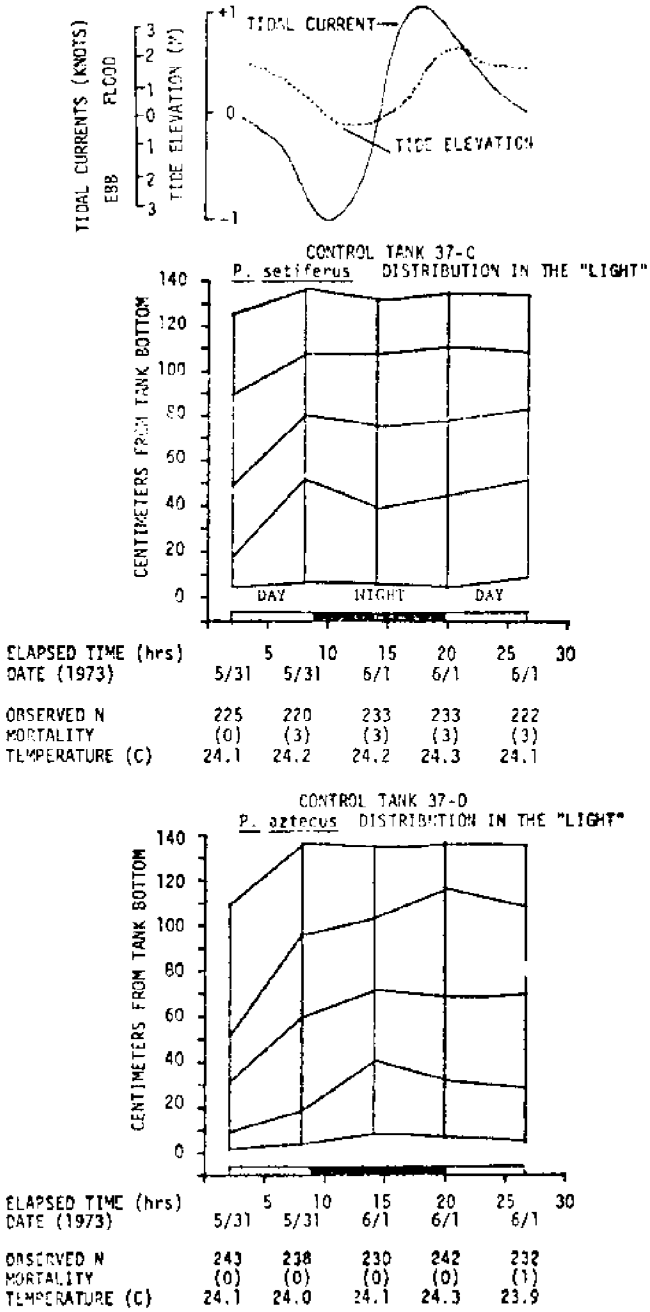


FIGURE 13.—Distribution of postlarval white and brown shrimp (P. setiferus and P. aztecus) under periodic low level red illumination in experiment 37, tanks C & D. "Light" defined on page 73. Vertical lines indicate distributions. Midline represents medians and the other four lines, from top to bottom, show the 95th, 75th, 25th, and 5th percentiles for each distribution.