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ABUNDANCE OF YOUNG BROWN SHRIMP IN NATURAL AND SEMI-IMPOUNDED MARSH NURSERY AREAS: RELATION TO TEMPERATURE AND SALINITY[1]

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ABSTRACT: Samples of brown shrimp (*Penaeus aztecus*, 10 to 130 mm in total length) were collected with otter trawls weekly from 14 March to 20 August 1971 in brackish marsh areas at Marsh Island, Louisiana. Catches were largest from 1 May to 4 June in the natural marsh and from 1 May to 4 July in the semi-impounded marsh (influenced by weirs). Total catch was four times greater in the natural than in the semi-impounded marsh. However, brown shrimp apparently stayed longer in the semi-impounded areas, and emigrated at a larger size. Water temperatures above 20°C were apparently more conducive to the growth of young brown shrimp than was a particular salinity range. The range of recorded salinities was 0.57-12.85 ‰; catch per sample was highest in salinities from 2.0 to 2.99 ‰.

Young brown shrimp (*Penaeus aztecus*) use the extensive brackish and salt marshes bordering the northern Gulf of Mexico as primary nursery areas. However, this estuarine growth phase is potentially the most vulnerable stage in their life cycle (NOAA 1980).

Factors that regulate the occurrence and development of immature shrimp play complex interactive roles, in which the importance or impact of individual factors is difficult to isolate. Although many field research efforts have considered salinity in relation to abundance and growth of young shrimp, results of these studies are ambiguous and the effects of salinity itself are difficult to determine. Various investigators have reported high abundance (*e.g., Gunter et al. 1964*) and optimal growth and survival (*e.g., St. Amant et al.* 1966; Barrett and Gillespie 1973, 1975) of young brown shrimp in water in which salinity exceeded 10 ‰. However, the occurrence of brown shrimp at salinities below 1 ‰ was reported by Gunter and Shell (1958), Gunter and Hall (1963), Parker (1970), Herke (1971), Crowe (1975), and Barrett *et al.*, 1978. Chapman *et al.* (1966) caught significantly larger numbers of young brown shrimp at salinities of 2.5-7.7 ‰ than at 12.5-22.5 ‰. Parker (1970) and Copeland and Bechtel (1974) found that juveniles were abundant throughout a broad salinity range and concluded that salinity itself had no detectable effect on their distribution. White and Boudreaux (1977) wrote that dense populations of brown shrimp have been noted in salinities below 5‰, and they detail one instance in which good production occurred in salinities bet-

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ween 1 and 3 ‰. However, they felt good production in such salinities occurred because the areas were under water level control. They stated that under normal circumstances, brown shrimp larvae recruited into low salinity regime areas do not generally respond with high production. In other field studies, Christmas *et al.* (1966) and St. Amant *et al.* (1966) noted an inhibitory effect of water temperatures below 18°C on the presence and growth of postlarval penaeids.

In laboratory studies, Zein-Eldin (1963) concluded that salinities of 2 to 40 ‰ had no appreciable effect on survival or growth of postlarval brown shrimp, and Zein-Eldin and Aldrich (1965) observed that growth increased markedly between 18° and 25°C over a broad salinity range. Results of other laboratory studies (*e.g.,* Williams 1960; Zein-Eldin and Griffith 1969) indicate that tolerance of low salinities was reduced at low temperatures. Again in laboratory studies, McFarland and Lee (1963) and Williams (1960) attributed this reduction to impairment of osmoregulatory ability, and reported that shrimp blood tended toward isosmoticity at low temperatures. Venkataramiah *et al.* (1974) reported a select salinity range of 8.5-17.0 ‰ for brown shrimp, but suggested that disagreement over salinity limits in the literature may be attributable to the fact that shrimp populations are changing: white shrimp (*P. setiferus*) may be losing part of their lower salinity territory to brown shrimp. Thus, selection of a particular salinity regime may not be influenced exclusively by physiological limits.

Though these field and laboratory studies do not agree in their conclusions about salinity optima, they do suggest that water temperature exerts greater influence than does salinity on the growth of brown shrimp.

Marsh nursery areas in Louisiana have undergone much human modification, including the installation of water-control structures. Many of these structures are weirs, which are low dams constructed across the mouths of tidal streams to stabilize water levels. The horizontal crest of the weir is set about 15 cm lower than average marsh soil surface level to allow water to flow over the weir on most incoming tides and flow out as the tide recedes. When it reaches crest level, the remaining water is impounded; Herke (1971) called the area behind a weir "semi-impounded marsh" because water in the area is truly impounded only when it falls below the weir crest level. Weir construction was discussed by Chabreck and Hoffpauir (1965), Chabreck (1968), and Herke (1968).

Little research has been directed toward assessing the relative abundance of brown shrimp in natural and semi-impounded Louisiana marshes. Indeed, Herke (1968) noted that, although over 100,000 ha of Louisiana marsh were managed with weirs, there was almost no published information on the effects of weirs on fisheries resources. Herke (1971) and Herke *et al.* (1987a) concluded that semi-impoundment tended to delay recruitment and emigration of species associated with the bottom. Herke (1979) stated that semi-impoundment appeared to adversely affect some species having saltwater affinities, and that weirs were probably an obstacle to immigration, resulting in understocking of the semi-impounded area. Similar conclusions were reached by Rogers and Herke (1985) and Herke *et al.* (1987b).

Effective management of estuarine nursery areas utilized by brown shrimp requires further exploration and understanding of the effects of weirs and environmental variables (which may be

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affected by the emplacement of weirs) on shrimp growth rates, distribution, and abundance. The objectives of our study were (1) to compare the relative abundance of brown shrimp in natural, and in semi-impounded marsh areas, within the Marsh Island estuarine system, and (2) to examine relationships of salinity and water temperature to apparent growth and abundance of brown shrimp.

STUDY AREA

Our study area was located in the 33,21O ha Marsh Island (Russell Sage) Wildlife Refuge in Iberia Parish, Louisiana. Ground elevations of Marsh Island ranged from about 15 to 30 cm above sea level, except along a south beach ridge (Yancey 1962). Over 90% of Marsh Island was composed of soft-bottomed brackish marsh, shallow brackish lakes, and tidal streams (Orton 1959). Salinity was influenced by freshwater from the Atchafalaya River, rainfall, and saltwater from the Gulf of Mexico.

Weirs were first installed at Marsh Island in the 1950's to stabilize water levels, thereby providing favorable conditions for the growth of aquatic vegetation preferred as food by waterfowl. At the time of our study, about 22,300 ha of Marsh Island were influenced by water control structures, mainly in the form of weirs (Lourd 1972).

During the study, the natural marsh area supported little submerged aquatic vegetation. However, most of the semi-impounded marsh area supported stands of baby pondweed (*Potamogeton pusillus*), common widgeonweed (*Ruppia maritima*), common hornwort (*Ceratophyllum demersum*), and filamentous blue-green algae.

The bottoms of the shallow brackish lakes and tidal streams were composed of soft, black, clayey mud mixed with *Rangia* shells, and were blanketed with detritus (Wengert 1972). The shallow lake bottoms were nearly level, bottom elevations seldom varying more than 15 cm in 400 m except in the immediate vincinity of the bank (Herke 1971). Tidal streams varied in depth from 0.3 to 3.0 m or more, depending on velocity and flow. Water depths at the sample sites were not measured when the samples were taken, but they were similar to those reported by Herke (1971). He reported average minimum water depths at the time of trawling of 53-78 cm in unimpounded areas, and 78-89 cm in semi-impounded areas. The shallow lakes not controlled by weirs were occasionally drained by strong northerly winds. At these times, water levels in the lakes controlled by weirs did not drop appreciably below weir crest level, thus accounting for the higher average depths there. The water behind the weirs was seldom impounded for 24 hours. Wind was more often responsible for extremely high or low water levels than were celestial tides. Average celestial tide range was about 30 cm.

MATERIALS AND METHODS

Seventeen collecting stations were established in five sampling areas (Fig. 1): Areas 1 (stations 1-4) and 4 (stations 13-16) represented the natural marsh, Areas 2 (stations 5-8) and 3 (stations 9-12) the semi-impounded marsh, and Area 5 (station 17) a tidal stream in natural marsh. Stations 1-16 were either in shallow ponds or shallow flats adjoining channels. The semi-impounded marsh (Areas 2 and 3) was considered as two separate areas because they were connected only by two small, shallow streams; probably both water movement and shrimp migration through the streams was slight. Connection to the

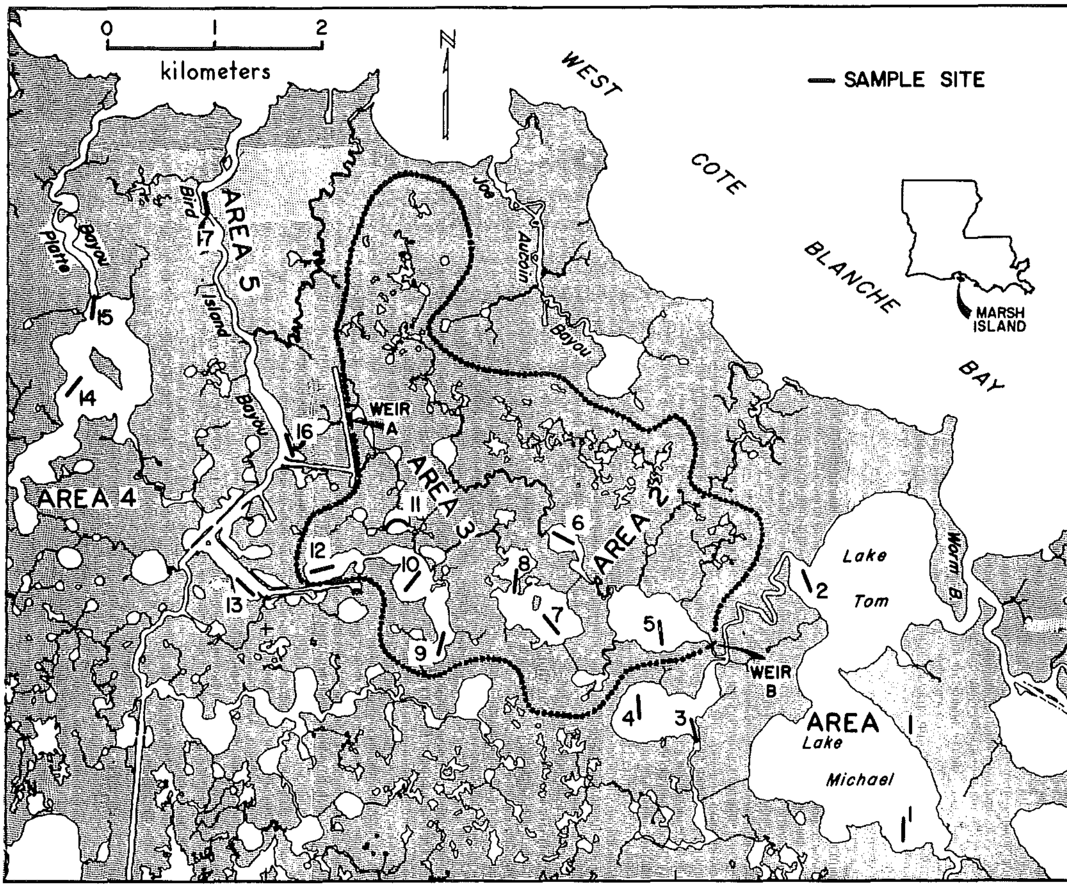

Figure 1. Locations of sampling stations and weirs in the study area at Marsh Island, Louisiana. The area enclosed by the dotted line was semi-impounded by weirs A and B, and a levee near station 12. The other stations were in the natural marsh.

bay was via weir A (Area 3) and Weir B (Area 2). Area 5 was just inside the mouth of Bird Island Bayou, a major tidal stream that drained most of Area 3 and a portion of Area 4; it was the only station located directly in a channel and was selected to intercept shrimp immigrating between West Cote Blanch Bay and Areas 3 and 4.

Collections were made from an airboat pulling a 7.6m otter trawl along transects marked with stakes set 200 m apart at each station. The otter trawl had a 16mm-mesh body and 14mm-mesh cod end (bar measure); a 3.2mm knitted mesh sock that completely surrounded the cod end was fastened 3.1 m from the tail of the trawl. Trawling time was about 2.5 minutes, but was slightly longer at vegetated stations. With some exceptions (caused mostly by airboat malfunctions), samples were obtained weekly from 14 March to 20 August 1971. All stations were sampled on the same day during each trip.

Water temperatures were recorded and water samples were collected at the time of each trawl haul. Salinity was computed from chloride values determined by the mercuric nitrate method (APHA 1965).

In the laboratory, we separated grooved shrimp postlarvae from postlarval white shrimp, using characteristics described by Williams (1953, 1959) and Ringo and Zamora (1968). All grooved

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shrimp were assumed to be brown shrimp because pink shrimp (*P. duorarum*) were relatively scarce along this section of the Louisiana coast.

All brown shrimp in each sample were counted and were individually measured unless they were too numerous. The measurements were grouped by 5mm increments designated by their highest number (e.g., shrimp 11-15mm were assigned to the 15mm group). Unusually large samples were subsampled; the subsampled shrimp were measured and the lengths of the shrimp in the total sample were then extrapolated according to procedures described by Wengert (1972).

Designations of brown shrimp life history stages were made using the length criteria suggested by Renfro (1964): postlarvae, < 25 mm; juveniles 25-89 mm; and subadults 90-139 mm. Total length measurements were made from the anterior end of rostrum to posterior end of telson.

Apparent growth rates were plotted from the increase in size of the longest individual shrimp caught each week in sampling areas 1-4 (Williams 1955; St. Amant *et al.* 1963; Loesch 1965; Ringo 1965; Jacob 1971).

RESULTS

Average number of brown shrimp caught per trawl haul was greater in the natural marsh areas (276) than in the semi-impounded areas (74) during the study. A total of 55,575 brown shrimp were collected (40,938 in natural marsh areas, 9,814 in semi-impounded areas, and 4,823 at station 17). We measured 36,800 of the shrimp (66% of the total catch, because of subsampling), ranging in length from 10 to 130 mm.

Abundance

A few postlarval brown shrimp were captured in late February 1971, while we were evaluating the performance of the sampling gear. By 14 March, most of the sampling stations had been established and postlarvae were abundant in the natural marsh. Over 900 postlarvae, 10 to 20 mm long, were caught at the eight natural marsh stations sampled; only 14 were caught at the three stations (5, 6, and 12) sampled in the semi-impounded marsh and all came from station 5, which was directly behind a weir.

Immigration of brown shrimp into the semi-impounded marsh (Areas 2 and 3) was delayed (particularly into areas farthest from a weir); this delay can be demonstrated by comparing catches by sample date for stations within Areas 1 and 2 (Tables 1, 2). Not only was recruitment delayed, but numbers were reduced, in the semi-impounded marsh and shrimp were generally recruited there as juveniles and subadults rather than as postlarvae. Although the two sites were near each other and about equidistant from West Cote Blanch Bay, catches at station 5 (behind a weir) were substantially lower than those from station 3 (in natural marsh). Even so, total catch and recruitment of postlarvae were much greater at station 5 than at stations farther from the weir within Area 2.

A summary of relative abundance and catch rate for the entire sampling period (Table 3) shows that brown shrimp average catches were largest in the natural marsh from 1 May through 4 June and in the semi-impounded marsh from 1 May through 4 July. Peak average catches occurred 2 to 3 weeks later in the semi-impounded than in the natural marsh. In addition to the lag in peak average catches in the semi-impounded areas, the average catch per trawl haul after 4 July declined more gradually than in the natural marsh, indicating a delay in emigration from the semi-impounded areas.

Table 1. Length-frequency distribution of brown shrimp caught at stations within Area 1 (natural marsh) at Marsh Island, Louisiana, during 1971. For each station, numbers above the dotted line represent catch of postlarvae; — indicates no sampling effort.

Total	March		April				May					June			July				August		
Length (mm)	14	27	3	9	17	24	1	8	15	23	28	4	12	25	4	9	18	30	8	13	20
Station 1																					
10										—			—				—				
15	60	292	159	84	6	27	29	2	6	—		3	—				—				
20	7	41	53	68	21	18	180	9	5	—	2	3	—				—				
25		6	23	27	15	42	65	40	7	—	14	15	—				—				
....																					
30				8	8	66	29	49	14	—	36	68	—	1	1		—				
35					4	44	67	28	18	—	55	104	—	10	1		—				
40						33	76	44	5	—	67	104	—	60	7		—				
45						16	74	67	3	—	139	112	—	115	5	1	—	2			
50						21	47	41	3	—	49	87	—	112	9	1	—	2			
55							74	21	5	—	20	57	—	43	17	1	—	1		1	
60							29	11	3	—	7	15	—	16	11	2	—		1	1	
65							22	7	7	—	10.	3	—	7	2	1	—	1	1		
70							9	6	1	—	7		—	4	5	2	—	6		2	
75							4	3	3	—	10	3	—	3	2	1	—	4			
80								1	1	—	4	3	—	5	2		—	7		1	
85								1	1	—	1		—	2	1		—	7			
90										—	1	1	—		1		—	4			
95										—	5		—			2	—	5			
100										—	1		—			1	—				
105										—			—				—				
110										—			—				—				
115										—			—				—				
120 Station 1										—			—				—				
125										—			—				—				
130										—			—				—				
Station 2																					
10																					
15	49	354	206	42	5	87	16	8	40	7	3	2									
20		48	77	71	4	43	52	8	26	61	6	4	3								
25		3	6	12	3	36	37	11	23	102	15	15	2	1		1		1			
....																					
30					2	38	31	10	128	92	15	15	11	3							
35					2	26	81	31	415	272	156	139	25	4	4						
40						12	89	76	336	248	522	344	32	27	4	1					
45						4	48	122	122	46	478	393	20	30	8	1					
50							29	56	33	10	161	154	6	19	7	2		1			
55						1	21	12	16	11	10	33	2	4	4	2		1			1
60							16	8	10	14		6	1	1	2			3	1		
65							6	4	2	9	3			1	3	1	3	7	2		
70							6	4	13	9	3	1		2	2	1	2	4			
75									5	8	6	3		1	1			6			
80									7	10	3	1		1	1			1			1
85									4	2	3			1	1						
90									1	6	1				1	1					
95									1	2	1				1						
100										3											
105												1			1						
110																					
115														1							
120 Station 2																					
125																					
130																					

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Table 1. Cont.

10														—				—			—	
15		69	315	188	96	48	23	59	27	92	45	6		—	1		1	—		1	—	
20		3	49	36	138	48	15	121	27	64	60	2	6	—	1			—			—	
25			3	12	28	33	62	44	123	70	165	25	7	—	1	2		—	1		—	
30				1	12	15	98	43	144	232	241	52	32	—	5	5	3	—	2	1	—	
35						15	55	150	120	165	421	143	122	—	21	2	3	—	1		—	
40						4	25	226	131	61	703	278	179	—	31	20	7	—	2	1	—	
45							18	176	95	17	323	132	56	—	26	22	11	—				
50							10	165	46	36	34	19	15	—	22	29	11	—	3		—	
55							3	137	33	31	16	11	24	—	29	33	9	—	2		—	
60							2	121	38	42	15	7	4	—	13	32	13	—	1		—	
65								103	30	39	11	12	6	—	17	31	15	—	1		—	
70								62	10	45	12	16	7	—	14	26	5	—	4	1	—	1
75								20	10	42	5	17	4	—	17	19	3	—	4	1	—	
80								4	7	17		7	3	—	10	12	4	—	2		—	
85									2	18		6	1	—	7	9	6	—	3	2	—	
90									1	7			1	—	6	10	1	—	2		—	
95										1		2	1	—	1			—	1		—	
100										1				—		1	1	—	1		—	
105										1				—	1		1	—			—	
110														—				—			—	
115														—	1			—			—	
120	Station 3													—				—			—	
125												—				—	—		—			
130														—			—				—	
10		1									—											
15		260	291	127	43	14	19	35	13	21	—			—					1	1		
20		7	59	39	24	83	12	88	13	27	—			—	2					1		
25			9	20	15	61	35	23	27	61	—	13	10	—	2	2			1			
30				3	9	23	40	49	53	160	—	29	20	—	11	2			2			
35						18	12	111	77	164	—	104	76	—	33	4						
40						5	13	75	119	99	—	205	119	—	98	17	2		1	1		
45							8	30	104	40	—	92	108	—	125	26	1		1			
50							3	18	21	11	—	4	8	—	40	19	1					
55							1	17	3	17	—	1		—	11	8	3	1	2			
60								15	3	7	—		2	—	5	3	2	1	1	1		
65								6	3	2	—	1		—	2			2	2		1	
70								2	3	3	—	2		—	2					2	1	
75									1	2	—	2	1	—	1							
80										3	—	1	2	—							2	
85											—			—	1					1	1	
90										1	—			—	1	2				1		
95										1	—			—	2						1	
100											—			—								
105											—			—							1	
110											—			—								
115											—			—								
120	Station 4										—			—								
125											—			—								
130											—			—								

Table 2. Length-frequency distribution of brown shrimp caught at stations within Area 2 (semi-impounded marsh) at Marsh Island, Louisiana, during 1971. For each station, numbers above the dotted line represent catch of postlarvae; — indicates no sampling effort.

Total	March		April				May					June			July				August		
Length (mm)	14	27	3	9	17	24	1	8	15	23	28	4	12	25	4	9	18	30	8	13	20
10										—			—								
15	14	53	13	5	1		3	1	1	—	1		—								
20		14	14	7	20		4	1	2	—			—								
25			4	4	32	10	3	3		—	1	1	—								
······																					
30			2	1	7	23	4	7	6	—	1	2	—								
35					6	26	18	4	10	—	1	3	—								
40						17	39	15	23	—	15	7	—								
45						19	67	59	14	—	67	24	—	1							
50					1	30	46	53	29	—	76	103	—	7	3						
55						6	41	45	33	—	23	149	—	30	12	1					
60						3	30	12	8	—	4	21	—	55	59	2	1				
65							22	5	4	—	3	2	—	24	87	14	1				
70							14	1	3	—		1	—	5	54	10	2				
75							4	4	2	—	1	4	—	2	16	3	4	1			
80							2		1	—	3	1	—	1	7	1		5	1		
85							1		3	—			—		1	1		3	1		1
90										—		1	—		1		1			3	
95										—			—	1					1	2	1
100										—			—		1	1	1				
105										—			—								
110										—			—								
115										—			—								
120 Station 5										—			—								
125										—			—								
130										—			—								
10				—						—			—				—			—	
15				—		1	4	1		—			—				—			—	
20				—		2	1			—			—				—			—	
25				—	1		3	3	2	—			—				—			—	
······																					
30				—		7		5	12	—		1	—				—			—	
35				—		5	5	7	13	—	1	4	—				—			—	
40				—		1	4	2	8	—	3	5	—				—			—	
45				—			14	8		—	11	5	—	3			—			—	
50				—			8	21	1	—	13	9	—	3			—			—	
55				—			4	19	2	—	15	25	—	10	2	1	—			—	
60				—			1	19	5	—	5	27	—	14	2	4	—			—	
65				—				10	13	—	8	19	—	16	7	10	—			—	
70				—				8	7	—	4	12	—	14	4	10	—			—	
75				—				3	10	—	8	9	—	26	9	13	—	1		—	
80				—				2	4	—	3	2	—	15	14	10	—	5		—	
85				—						—	3	4	—	1	2	7	—	7		—	
90				—						—	2	2	—		1	1	—	21	3	—	
95				—						—	2		—				—	12	2	—	
100				—						—			—	1	1		—	9		—	
105				—						—			—				—	1		—	
110				—						—			—				—			—	
115				—						—			—				—			—	
120 Station 6				—						—			—				—			—	
125				—						—			—				—			—	
130				—						—			—				—			—	

Table 2. Cont.

10		—			—						—			—								
15		—	2	1	—						—			—								
20			—		—	1		2			—			—								
25		—	1		—	2		7			—		—									
30		—			—	2		1	1		—			—								
35		—			—		2	2	1	2	—	1		—								
40		—			—		2	13	1	3	—			—								
45		—			—			19	3	4	—		1	—								
50		—			—			25	2	6	—	4	2	—								
55		—			—			18	1	5	—	6	16	—	4	1						
60		—			—			25	1	6	—	7	19	—	8	1	3					
65		—			—			6	7	11	—	5	32	—	7	2	5	2				
70		—			—			6	2	14	—	5	39	—	14	4	9					
75		—			—			3	3	15	—	7	16	—	16	8	14	3	1			
80		—			—			2	7	1	—	1	19	—	26	17	27	7	2			
85		—			—			1	1	6	—	4	11	—	18	25	31	8	10			
90		—			—				1	10	—	3	7	—	15	33	61	11	10	1	1	
95		—			—					4	—	1	1	—	2	22	18	14	24	4	4	
100		—			—						—	1	2	—	3	21	7	14	23	18	7	3
105		—			—					1	—			—	1	6	1	4	16	19	5	2
110		—			—						—			—		3	1		17	24	18	4
115		—			—						—			—		1			9	10	17	2
120	Station 7	—			—						—			—					1	6	3	1
125		—			—						—			—							3	2
130		—			—						—			—								

10		—	—		—						—			—				—				
15		—	—	1	—		2				—			—				—				
20		—	—		—						—			—				—				
25		—	—		—		1		1		—			—				—				
30		—	—		—						—			—				—				
35		—	—		—		2		2	1	—			—				—				
40		—	—		—			1	2	6	—			—				—				
45		—	—		—		1	3		11	—		4	—				—				
50		—	—		—			6	8	5	—	11	2	—								
55		—	—		—		1	13	27	8	—	15	13	—	1			—				
60		—	—		—			15	22	15	—	19	12	—	2			—				
65		—	—		—			4	45	15	—	21	13	—	5	2	2	—				
70		—	—		—			1	23	33	—	9	18	—	13	6	9	—				
75		—	—		—			2	24	49	—	20	21	—	19	10	6	—				
80		—	—		—			1	7	43	—	16	11	—	25	18	15	—				
85		—	—		—				11	40	—	13	14	—	22	42	17	—	2			1
90		—	—		—				2	24	—	20	11	—	33	48	29	—	6	1	1	
95		—	—		—				1	13	—	6	2	—	23	52	19	—	12	2	5	
100		—	—		—					1	—		1	—	14	30	9	—	14	6	9	
105		—	—		—						—	1		—	3	10	2	—	26	13	16	1
110		—	—		—						—	1		—		5		—	10	15	40	5
115		—	—		—						—			—		2		—	6	8	23	5
120	Station 8	—	—		—						—			—				—	3	4	19	2
125		—	—		—						—			—				—			10	3
130		—	—		—						—			—				—			2	

Salinity and Abundance

Over 95% of the trawl hauls were made at salinities of less than 7.0 ‰ (Table 4) Percentages of sample effort and total catch, within salinity classes less than 7.0‰, follow.

Salinity (‰)	Trawl hauls (% of total)	Catch (% of total)
0.0-0.99	2	7.7
1.0-1.99	14	27.9
2.0-2.99	33	45.9
3.0-6.99	46	18.3

Although nearly 5% of all hauls were made at salinities ≥7.0 ‰, these samples contributed only about 0.2% of the total brown shrimp catch. The lowest salinity at which a sample was taken was 0.57 ‰ (3 April, station 17); 89 postlarvae were in that sample.

Brown shrimp in every 5mm size class from 15 to 130 mm were caught in salinities ranging from 3.00 to 3.99 ‰.

Temperature, Salinity, and Apparent Growth

All data for each sample (only summarized here), on salinity, temperature, and brown shrimp length frequency, were listed by Wengert (1972).

Average water depths in our study area were about 65 cm at natural marsh sites and 85 cm at semi-impounded sites.

Table 3. Relative abundance and catch rate of brown shrimp at Marsh Island, Louisiana, 14 March to 20 August 1971.

	Area 1[a]			Area 2[b]			Area 3[b]			Area 4[a]			Station 17		Total — All Stations		
Date	No. of Trawls	No. Caught	Avg. Catch	No. of Trawls	No. Caught	Avg. Catch	No. of Trawls	No. Caught	Avg. Catch	No. of Trawls	No. Caught	Avg. Catch	No. of Trawls	No. Caught	No. of Trawls	No. Caught	Avg. Catch
14/3	4	456	114	2	14	7	1	0	0	4	457	114	—	—	11	927	84
27/3	4	1,470	368	3	70	23	4	8	2	4	1,330	333	1	221	16	3,099	194
03/4	4	950	238	4	35	9	4	26	7	4	1,221	305	1	89	17	2,321	137
09/4	4	677	169	1	17	17	—	—	—	—	—	—	—	—	5	694	139
17/4	4	437	109	4	73	18	4	98	25	4	1,210	303	1	657	17	2,475	146
24/4	4	968	242	4	161	40	4	301	75	4	1,426	357	1	317	17	3,173	187
01/5	4	3,037	759	4	518	130	4	588	147	4	2,100	525	1	1,537	17	7,780	458
08/5	4	1,964	491	4	524	131	4	170	43	4	1,536	384	1	288	17	4,482	264
15/5	4	2,864	716	4	568	142	4	581	145	4	2,698	675	1	461	17	7,172	422
23/5	2	2,963	1,482	—	—	—	—	—	—	—	—	—	—	—	2	2,963	1,482
28/5	4	3,003	751	4	471	118	4	549	37	4	2,044	511	1	382	17	6,449	379
04/6	4	2,503	626	4	730	183	4	792	198	4	1,872	468	1	551	17	6,448	379
12/6	1	102	102	—	—	—	—	—	—	—	—	—	—	—	1	102	102
25/6	4	1,034	256	4	503	126	4	469	117	4	1,110	278	1	53	17	3,169	186
04/7	4	440	110	4	652	163	4	405	101	4	395	96	1	114	17	2,006	118
09/7	4	125	31	4	374	94	4	174	43	4	185	46	1	206	17	1,064	63
18/7	2	9	5	2	74	37	2	44	22	2	42	21	—	—	8	169	21
25/7	—	—	—	—	—	—	1	24	24	4	34	9	—	—	5	58	12
30/7	4	104	26	4	257	64	4	90	23	4	74	19	1	4	17	529	31
08/8	4	20	5	4	139	35	4	36	9	4	29	7	—	—	16	224	14
13/8	3	12	4	3	188	63	3	34	11	2	29	15	—	—	11	263	24
20/8	4	3	1	4	33	8	4	24	6	4	5	1	1	3	17	68	4
TOTALS	76	23,141	304	67	5,401	81	67	4,413	66	72	17,797	247	14	4,823	296	55,575	188

— no sampling effort

[a] natural marsh

[b] semi-impounded marsh

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The wide range of water temperatures sometimes recorded during a single sampling trip (Fig. 2) reflected the rapid changes in temperature in the relatively shallow water.

Average water temperature was above 20 °C on 14 March, but declined to a low of 17.2 °C on 3 April (Fig. 2). Average water temperature was again above 20 °C on 9 April and generally increased during the rest of the study. After 12 June, average temperatures generally exceeded 30 °C, except for a period in late July. Apparent growth rates of maximum-sized shrimp in Areas 1-4 generally increased with increasing water temperatures, and peaked near 1 May (Fig. 2).

Recorded salinities ranged from 0.57 ‰ (Fig. 3) to 12.85 ‰; both extremes occurred in the natural marsh. In the semi-impounded marsh, the minimum recorded salinity was 1.11 ‰ at station 5 and the maximum was 5.81 ‰ at station 11; these were the stations nearest the two weirs, and thus were most affected by conditions in the natural marsh. Like water temperatures, salinities also decreased from 14 March to 3 April. As water temperatures increased, however,

Table 4. Relationship of length-frequency distribution and mean catch/tow of brown shrimp to salinity at Marsh Island, Louisiana, from 14 March to 20 August 1971.

Total Length (mm)	Salinity (‰)														
	<0.80	0.80-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99	10-10.99	11-11.99	12-12.99	Totals
10						1									1
15	983	255	1,784	993	1,754	975	376								7,120
20	465	832	1,324	1,611	668	97	2	1							5,000
25	101	853	1,378	1,744	227	13		1		1					4,318
30	28	269	1,944	1,916	193	7	1	1					1		4,360
35	2	85	2,348	2,991	283	2	3	4							5,718
40		153	2,235	4,396	406	7	6	38					1		7,242
45		106	1,749	3,331	355	36	18	141							5,736
50		76	1,182	1,774	271	98	43	277							3,721
55		17	681	1,221	239	87	106	171	1	1	1	1			2,526
60		17	359	915	250	77	165	80				1			1,864
65		4	210	862	239	55	155	47	2	2		2	2	2	1,582
70			133	753	189	45	94	29	1	3	1	5	2	2	1,257
75			81	723	140	34	59	22		9	2	10	9	4	1,093
80			33	609	159	37	47	9	2	6		14	3	3	922
85			19	545	216	46	19	9		2		16		2	874
90			9	492	220	39	7	3	2				1		773
95			2	259	127	56	4	3				1	1		453
100				154	117	42	6	1					1		321
105				72	100	28	8								208
110				52	119	15	7								193
115				23	79	3	1								106
120				10	36	3	5								54
125					21		1								22
130					2										2
Totals	1,579	2,667	15,471	25,446	6,410	1,803	1,133	837	8	24	4	50	21	13	55,466[a]
Number of trawls	3	3	40	98	67	45	19	5	5	1	1	3	2	2	294
Mean Catch per tow	526.3	889.0	386.8	259.7	95.7	40.1	59.6	167.4	1.6	24.0	4.0	16.7	10.5	6.5	188.7

[a] Missing salinity values for 2 samples (from Station 13) prevent the classification of their catches by salinity; therefore this number does not reflect the actual total catch (55,575).

salinities continued to decrease, reaching lowest levels in early May in Areas 1, 2, and 3; in Area 4, the lowest salinity was recorded on 3 April, but salinities were still less than 2.00 ‰ on 8 May. Unlike with temperature, salinity appeared to be unrelated to apparent growth rate.

DISCUSSION

Abundance

Catch results in any study may reflect sampling efficiency more than abundance of organisms. However, the combination of the otter trawl and knitted mesh sock that was used during our study seemed reasonable effective in capturing shrimp longer than 10 mm, because the catch of 15mm (11-15mm) shrimp was substantial (3% of the total catch); only the catch of 40mm (36-40mm) shrimp was greater. In heavily vegetated areas in the semi-impounded marsh, the trawl sometimes filled quickly with aquatic vegetation, perhaps reducing the trawl's sampling efficiency in those areas.

As indicated by our catch data, the weirs apparently interfered with the natural tidal process that carries postlarvae into the marsh. Bradshaw (1985) reached the same conclusion. Hebert (1968) also noticed an immigration delay (of 2 weeks) of postlarval brown and white shrimp into a semi-impounded area in south central Louisiana; however, he attributed the delay to heavy freshwater drainage into his study area. In our study, it appears that brown shrimp were more abundant in the natural marsh areas except in the latter part of the growing season, which could be attributed to a lag in emigration for semi-impounded areas. Such a lag has been indicated for a number of species (Herke 1971; Herke *et al.* 1987a, b).

Salinity and Abundance

Although limited numbers of brown shrimp have been collected at salinities less than 1 ‰ (e.g., Gunter and Shell 1958; Gunter and Hall 1963; Herke 1971), most of the pertinent literature indicates that brown shrimp are more abundant at considerably higher salinities. For example, Gunter et al. (1964) observed that young brown shrimp were most abundant within a salinity range of 10-30 ‰ and that 0.80 ‰ was the lower salinity limit of brown shrimp on the northern coast of the Gulf of Mexico. This observation differs considerable from results of our study, in which nearly all (99.8%) brown shrimp were captured in salinities less than 7.0 ‰, and many were caught at salinities lower than 0.80 ‰ (Table 4).

Our average catch of 276 brown shrimp per trawl in the natural marsh areas, versus 74 per trawl in the semi-impounded areas, strongly contradicts the opinion expressed by White and Boudreaux (1977) that brown shrimp recruited into a low salinity regime area do not generally respond with high production unless the area is under water level control.

The effects of salinity on the distribution of brown shrimp may be inaccurately assessed from catch data when data are compiled and averaged by salinity class, unless equal sampling effort is expended within each class (Parker 1970) and temporal variations in both salinity range and brown shrimp abundance are considered. In our study, equal sampling effort was made in salinities of 6.0 to 6.99 ‰ and 7.0 to 7.99 ‰; however, salinities recorded within our study area did not exceed 7.0 ‰ until 25 July, after relative abundance had peaked and emigration had begun. Therefore, although many more shrimp were captured in the 6.0 to 6.99 ‰ than in the 7.0 to 7.99 ‰ range (837 versus 8), a preference of brown shrimp for salinities less than 7.0 ‰ cannot be inferred from this relation. However, we can deduce that brown shrimp at Marsh Island were able to tolerate the relatively low salinities at which they were captured (in substantial numbers) throughout most of the study period.

Conflicting conclusions about the effect of salinity on brown shrimp distribution, as inferred in field studies, may result from inadequate sampling of the entire area occupied by brown shrimp in each estuarine system; that is, sampling that does not encompass in a representative manner the full range of salinities tolerated by young shrimp during their stay in each system. Also, previous work has suggested that tolerance or preference of a particular salinity by young brown shrimp changes within the salinity gradient of the estuary and is influenced by the age and size and salinity acclimation history of the shrimp (Gunter 1961; Venkataramiah et at. 1974; Biesiot 1975; Bishop et al. 1980); therefore, salinity optima inferred from specific field studies may not reflect salinity optima of brown shrimp in other nursery areas.

Temperature, Salinity, and Apparent Growth

A laboratory study by Zein-Eldin and Aldrich (1965) indicated that combinations of low temperature and low salinity were detrimental to the survival of postlarval and juvenile brown shrimp (12.1-50.0 mm long). Postlarvae survived temperatures as low as 11 °C for one month at salinities above 15 ‰, but significant growth did not occur until water temperatures reached the interval between 11° and 18 °C. Their 24-hour survival tests revealed that tolerance to salinities below 10 ‰ was reduced at water temperatures of 7° and 15 °C. Growth of postlarvae increased markedly at temperatures of 11 to 25 °C; temperatures above 25 °C affected growth less. In other laboratory work (Zein-Eldin and Griffith 1969), brown shrimp postlarvae grew equally well at water temperatures of 24.5-26 °C and salinities of 2-40 ‰. St. Amant *et al.* (1966) prescribed water temperatures of 20 °C and salinities greater than 15 ‰ for optimum growth and survival of young brown shrimp. Williams (1960) also wrote that the osmoregulatory ability of brown shrimp (42-150 mm) decreased with decreasing water temperatures (to 8.8 °C).

St. Amant *et al.* (1966) wrote that brown shrimp growth rates were almost nil at water temperatures below 16 °C, < 1.00 mm/day at temperatures below 20 °C, and <1.5 mm/day at temperatures from 20 to 25 °C; rates decreased as temperatures reached 29-33 °C. Zein-Eldin and Aldrich (1965) and Ringo (1965) wrote that growth approached a maximum at about 25 °C. Zein-Eldin and Griffith (1966) observed that at 35 °C, growth decreased and all shrimp died within 15 days.

In our study, the growth of brown shrimp seemed to be affected more by water temperature than by salinity. Compared with other growth estimates in the literature, growth rate of our shrimp appeared to respond in the "normal" manner to changes in temperature. Apparent growth rate for all areas (Fig. 2) was less than 1.00 mm/day from 14 March to 9 April, when temperature had decreased to about 17 °C and salinities were decreasing. Water temperature had risen by 9 April, and by 17 April, despite still-decreasing salinities, apparent growth rate had increased to at least 1.00 mm/day at all locations except Area 4.

Length-frenquency distributions of organisms collected in periodic samples

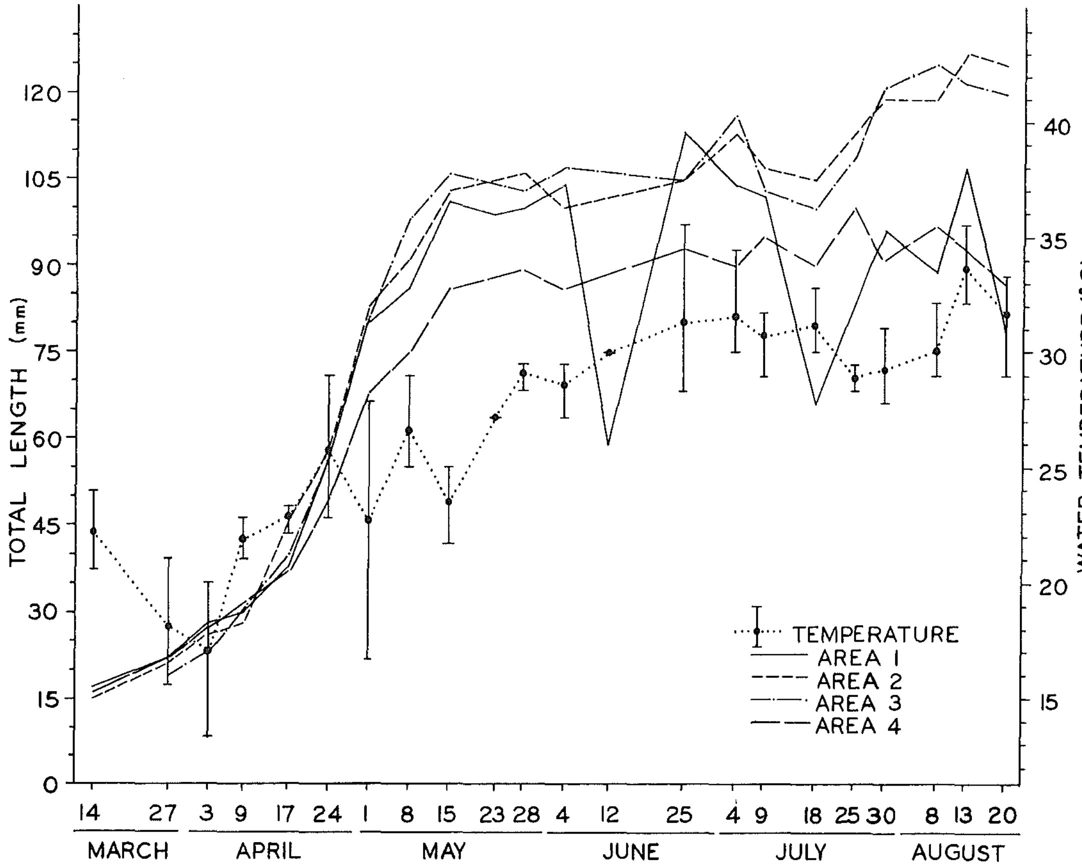

Figure 2. Change in maximum total lengths of brown shrimp in relation to water temperature (average and range) in natural (Areas 1 and 4) and semi-impounded (Areas 2 and 3) marsh areas of Marsh Island, Louisiana, March through August 1971.

have often been used to estimate growth rates. Some factors that may confound the interpretation of these length-frequency distributions for growth rate estimates are (1) changing susceptibility of an organism to capture with growth, thereby biasing the sample's length-frequency distribution in favor of the most readily captured length-classes in the population sampled, (2) size-selective mortality, and (3) transience, recruitment, and emigration within the population since the previous sample. These and other factors may cumulatively produce a significant effect on the length-frequency distributions in samples from open systems such as estuaries (Herke 1971, 1977). Moreover, for some species it has been either inferred or demonstrated that primarily the larger individuals are leaving the nursery at any specific time (Herke 1971; Yakupzack et al. 1977). As explained by Knudsen and Herke (1978), this size-related emigration tends to give a downward bias to the regression of length on time, resulting in an underestimate of growth rate.

Our samples were probably subject to all of the previously mentioned confounding factors. For example, on the basis of reasoning detailed by Herke (1971, 1977), emigration took place on numerous occasions between one sample period and the next. This was especially obvious between the 1 May and 8 May samples, when average catch

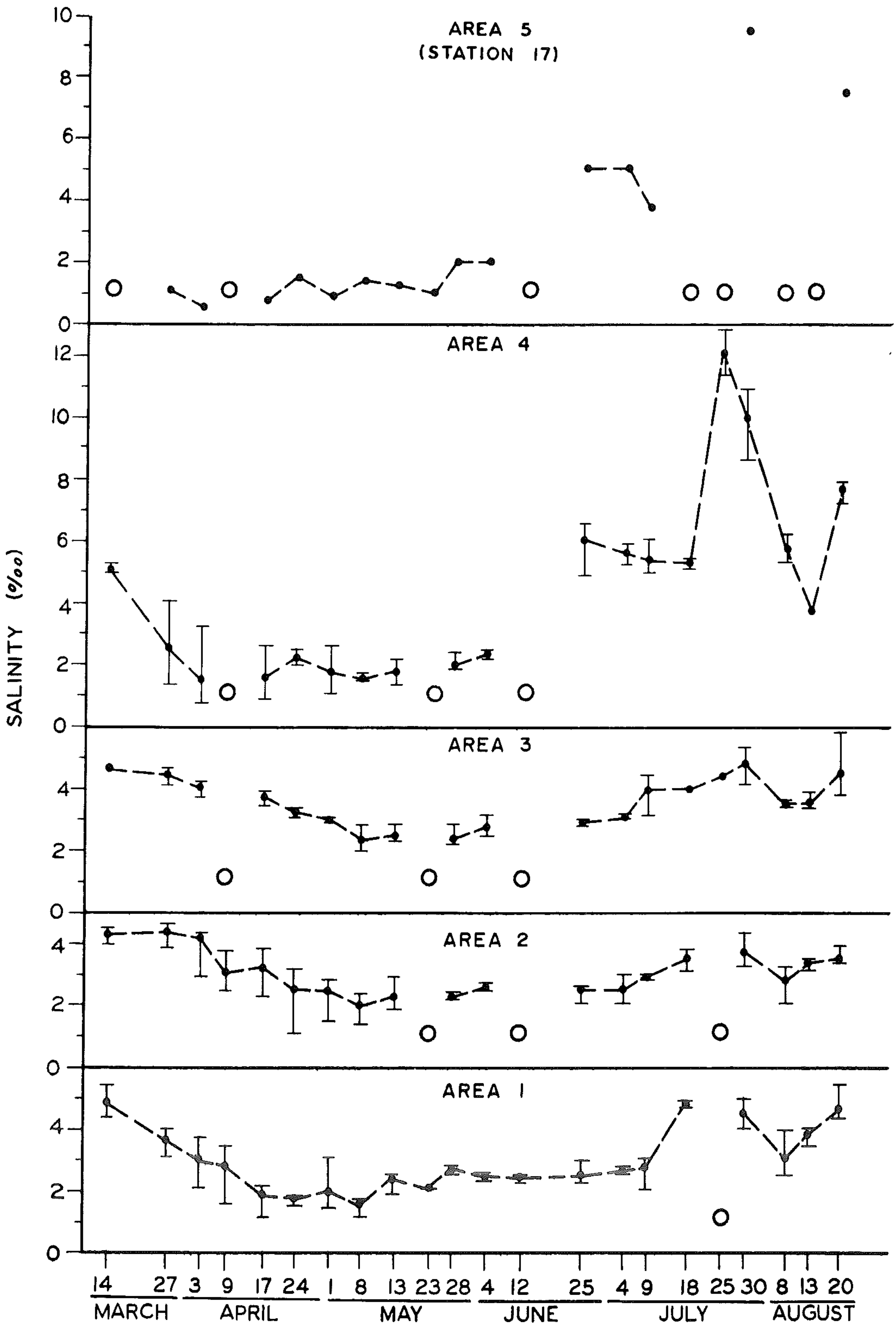

Figure 3. Average and range of salinities at five study areas on Marsh Island, Louisiana, by sampling date, from March through August 1971. Open circles represent missing salinity values.

dropped sharply in all areas except Area 2, where the average catch per trawl haul was similar to that of the previous week (Table 3). We agree with Knudsen *et al.* (1977) that: "To date, no study of brown shrimp growth rates, including ours, can be considered conclusive. The subject of shrimp growth rate, from postlarval to adult stages, deserves further study, preferably by methods other than length frequency analysis." Thus, we refrain here from attempting to quantify growth. Instead we have presented an "apparent" growth rate (Fig. 2), based on the increase in maximum lengths of shrimp caught each week. By this standard, our brown shrimp seem to have grown rapidly throughout April, even though salinity was well below that usually considered optimal and was generally declining.

Emigration

The emigration that occurred between 1 and 8 May might have been in response to the temperature drop recorded on 1 May (Fig. 2) and the concomitant drop of salinities to near their lowest levels (Fig. 3).

Overall, the shrimp in the semi-impounded areas grew to a larger size and probably stayed longer before emigrating. Most brown shrimp apparently emigrated from the natural marsh before reaching 60 mm, because less than 10% of those captured there exceeded this length; in the semi-impounded marsh, most apparently stayed until they were considerably larger because nearly 10% were over 100 mm long when captured there (Wengert 1972).

The larger brown shrimp size at emigration from the semi-impounded marsh may have been due to factors such as: (1) reduced intraspecific or interspecific competion as a result of poor recruitment, as suggested by St. Amant *et al.* (1966), Parker (1970), and Barrett and Ralph (1976); (2) reduced fluctuation in environmental factors, resulting in delayed emigration, as inferred by Herke (1971); or (3) an abundant supply of food and cover associated with submergent vegetation (at all semi-impounded stations except 5 and 10), as discussed by Heck and Wetstone (1977).

SUMMARY AND CONCLUSIONS

Total brown shrimp catch in the semi-impounded marsh was only about 1/4 of that from the natural marsh. Peak catches of brown shrimp in the semi-impounded marsh lagged about 2 to 3 weeks behind peak catches in the natural marsh.

Salinity fluctuated less in the semi-impounded areas than in the natural marsh areas. Our data indicated a relation between temperature and apparent growth in estuarine nursery areas, but no such relation was found between apparent growth and salinity. Brown shrimp were abundant at salinities much lower than the optimal salinities reported in most of the literature.

Brown shrimp in semi-impounded areas apparently stayed longer and emigrated at a larger size than did those in the natural marsh.

Our data indicated that semi-impoundment decreased the total numbers of brown shrimp that used the Marsh Island estuarine area, delayed their recruitment, and influenced the life history stage at which they were able to enter the semi-impounded areas. The weirs apparently interfered with the natural stocking process in the marsh by reducing tidal exchange. Although the water behind the weirs was seldom actually impounded for a 24-hour period, the density to which an area was stocked was apparently limited by this reduced water exchange. By reducing tidal flushing, weirs may lessen the total number of postlarval brown shrimp recruited into the marsh. Reductions in the size of the nursery area available for postlarval and juvenile brown shrimp may cause crowding that could significantly affect their growth and survival.

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LITERATURE CITED

APHA (American Public Health Association). 1965. Standard methods for the examination of water and wastewater. 12th edition. New York, New York. 769 p.

Barrett, B. B., and M. C. Gillespie. 1973. Primary factors which influence commercial shrimp production in coastal Louisiana. La. Wildl. Fish. Comm. Tech. Bull. No. 9. 28 p.

__________. 1975. 1975 environmental conditions relative to shrimp production in coastal Louisiana. La. Wildl. Fish. Comm. Tech. Bull. No. 15, 22 p.

__________, and E. J. Ralph. 1976. 1976 Environmental conditions relative to shrimp production in coastal Lousiana. La. Wildl. Fish. Comm. Tech. Bull. No. 21. 20 p.

__________, J.L. Merrell, T.P. Morrison, M.C. Gillespie, E.J. Ralph, and J.F. Burdon. 1978. A study of Louisiana's major estuaries and adjacent offshore waters. La. Dept. Wildl. Fish. Tech. Bull. No. 27, 197 p.

Biesiot, P. 1975. Salinity tolerance of postlarval brown shrimp *Penaeus aztecus* in relation to age and acclimation salinity. M.S. Thesis, Bowling Green State Univ., Bowling Green, Ohio. 63 p.

Bishop, J. M., J. G. Gosselink, and J. H. Stone. 1980. Oxygen consumption and hemolymph osmolality of brown shrimp, *Penaeus aztecus*. Nat. Oceanic Atmos. Adm. (U.S.), Fish. Bull. 78(3):741-757.

Bradshaw, W.H. 1985. Relative abundance of small brown shrimp as influenced by semi-impoundment. M.S. Thesis, La. State Univ., Baton Rouge. 61 p.

Chabreck, R. H. 1968. Weirs, plugs and artificial potholes for the management of wildlife in coastal marshes. Pages 178-192 *in*: J. D. Newsom, editor. Proc. Marsh Estuary Manage. Symp. La. State Univ., Div. Continuing Education, Baton Rouge.

__________, and C. M. Hoffpauir. 1965. The use of weirs in coastal marsh management in Louisiana. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 16:103-112.

Chapman, C. R., W. L. Trent, C. R. Mock, E. J. Pullen, and R. D. Ringo. 1966. Ecology of western Gulf estuaries. U.S. Fish Wildl. Serv. Circ. 268:21-28.

Christmas, J. Y., G. Gunter, and P. Musgrave. 1966. Studies of annual abundance of postlarval penaeid shrimp in the estuarine waters of Mississippi, as related to subsequent commercial catches. Gulf Res. Rep. 2(2):177-212.

Copeland, B. J., and T. J. Bechtel. 1974. Some environmental limits of six Gulf coast estuarine organisms. Contrib. Mar. Sci. 18:169-204.

Crowe, A. L. 1975. Population dynamics of two species of commercial shrimp in Caminada Bay, Louisiana. Proc. La. Acad. Sci. 38:86-91.

Gunter, G. 1961. Some relations of estuarine organisms to salinity. Limnol. Oceanogr. 6(2):182-190.

__________, J. Y. Christmas, and R. Killibrew. 1964. Some relations of salinity to population distributions of motile estuarine organisms, with special reference to penaeid shrimp. Ecology 45(1):181-185.

__________, and G. E. Hall. 1963. Biological investigations of the St. Lucie estuary (Florida) in connection with Lake Okeechobee discharges through the St. Lucie Canal. Gulf Res. Rep. 1(5):189-307.

__________, and W. E. Shell, Jr. 1958. A study of an estuarine area with water-level control in the Louisiana marsh. Proc. La. Acad. Sci. 21:5-34.

Hebert, H. F. 1968. Abundance and size distribution of white and brown shrimp in the north lake area of Redfish Point, Vermilion Bay, Louisiana, 1965-1967. M.S. Thesis, Univ. Southwestern La., Lafayette. 75 p.

Heck, K. L., Jr., and G. S. Wetstone. 1977. Habitat complexity and invertebrate species richness and abundance in tropical seagrass meadows. J. Biogeogr. 4(2):135-142.

Herke, W. H. 1968. Weirs, potholes and fishery management. Pages 193-211 *in*: J. D. Newsom, editor. Proc. Marsh Estuary Manage. Symp. La. State Univ., Div. of Continuing Education, Baton Rouge.

__________ 1971. Use of natural, and semi-impounded, Louisiana tidal marshes as nurseries for fishes and crustaceans. Ph.D. Dissertation, La. State Univ., Baton Rouge. 242 p.

__________ 1977. Life history concepts of motile estuarine-dependent species should be re-evaluated. W. H. Herke, 555 Staring Ln., Baton Rouge, La. (Library of Congress Catalog Card Number 77-90015.) 97 p.

__________ 1979. Some effects of semi-impoundment on coastal Louisiana fish and crustacean nursery usage. Pages 325-346 *in*: J. W. Day, Jr., D. D. Culley, Jr., R. E. Turner, and A. J. Mumphrey, Jr., editors. Proc. Coastal Marsh and Estuary Manage. Symp. La. State Univ., Div. of Continuing Education, Baton Rouge.

__________, E.E. Knudsen, P.A. Knudsen, and B.D. Rogers. 1987a. Effects of semi-impoundment on fish and crustacean nursery use: evaluation of a "solution." *In* O.T. Magoon, H. Converse, D. Clark, and L.T. Tobin, editors. Proceedings of Coastal Zone 87, the Fifth Symposium on Coastal and Ocean Management, Amer. Soc. Civil Engineers. [In press].

____________________, B.D. Rogers, and P.A. Knudsen. 1987b. Effects of Louisiana semi-impoundments on estuarine-dependent fisheries. *In* W.R. Whitman and W.H. Meredith, editors. Proceedings of the Waterfowl and Wetlands Symposium: the symposium on waterfowl and wetlands management in the coastal zone of the Atlantic flyway, Wilmington, DE, September 16-19, 1986. Coastal Management Program, Delaware Department of Natural Resources and Environmental Control, Dover. [In press].

Jacob, J. S. 1971. Observations on the distribution, growth, survival and biomass of juvenile and subadult *Penaeus aztecus* in southern Louisiana. M.S. Thesis, La. State Univ., Baton Rouge. 68 p.

Knudsen, E. E., and W. H. Herke. 1978. Growth rate of marked juvenile Atlantic croakers, *Micropogon undulatus*, and length of stay in a coastal marsh

DOI: 10.18785/negs.0901.02

nursery in southwest Louisiana. Trans. Am. Fish. Soc. 107(1):12-20.

__________, W. H. Herke, and J. M. Mackler. 1977. The growth rate of marked juvenile brown shrimp, *Penaeus aztecus*, in a semi-impounded Louisiana coastal marsh. Gulf Caribb. Fish. Inst., Univ. Miami, Proc. 29:144-159.

Loesch, H. 1965. Distribution and growth of penaeid shrimp in Mobile Bay, Alabama. Publ. Inst. Mar. Sci., Univ. Texas 10:41-58.

Lourd, H. H. 1972. Marsh Island Wildlife Refuge. La. Wildl. Fish. Comm., Biennial Rep. 14:42-44.

NOAA (National Oceanic and Atmospheric Administration [U.S.]). 1980. Shrimp fishery of the Gulf of Mexico; plan approval and proposed regulations. 7 November 1980. Federal Register 45(218,III):74178-74308.

McFarland, W. N., and B. D. Lee. 1963. Osmotic and ionic concentrations of penaeidean shrimps of the Texas coast. Bull. Mar. Sci. Gulf Caribb. 13(3):391-417.

Orton, E. W. 1959. A geological study of Marsh Island, Iberia Parish, Louisiana. La. Wildl. Fish. Comm. Tech. Rep., Refuge Div., New Orleans, 36 plates + 28 p.

Parker, J. C. 1970. Distribution of juvenile brown shrimp (*Penaeus aztecus* Ives) in Galveston Bay, Texas, as related to certain hydrographic features and salinity. Contrib. Mar. Sci. 15:1-12.

Renfro. W. C. 1964. Life history stages of Gulf of Mexico brown shrimp. U.S. Fish Wildl. Serv. Circ. 183:94-98.

Ringo, R. D. 1965. Dispersion and growth of young brown shrimp. U.S. Fish Wildl. Serv. Circ. 230:68-70.

__________, and G. Zamora, Jr. 1968. A penaeid postlarval character of taxonomic value. Bull. Mar. Sci. 18(2):471-476.

Rogers, B.D., and W.H. Herke. 1985. Estuarine-dependent fish and crustacean movements and weir management. Pages 201-219 *in* C.F. Bryan, P.J. Zwank, and R.H. Chabreck, editors. Proc. Fourth Coastal Marsh and Estuary Manage. Symp., La. Coop. Fish. and Wildl. Res. Unit., La. State Univ. Agric. Center, Baton Rouge.

St. Amant, L. S., K. C. Corkum, and J. G. Broom. 1963. Studies on growth dynamics of the brown shrimp, *Penaeus aztecus*, in Louisiana waters. Gulf Caribb. Fish. Inst., Univ. Miami, Proc. 15:14-26.

__________, J. G. Broom, and T. B. Ford. 1966. Studies of the brown shrimp, *Penaeus aztecus*, in Barataria Bay, Louisiana, 1962-1965. Gulf Caribb. Fish. Inst., Univ. Miami, Proc. 18:1-17.

Venkataramiah, A., G. J. Lakshmi, and G. Gunter. 1974. Studies on the effects of salinity and temperature on the commercial shrimp, *Penaeus aztecus* Ives, with special regard to survival limits, growth, oxygen consumption and ionic regulation. Publ. No. AD 777794, National Technical Information Service, Springfield, Va.

Wengert, M. W. 1972. Dynamics of the brown shrimp, *Penaeus aztecus aztecus* Ives 1891, in the estuarine area of Marsh Island, Louisiana in 1971. M.S. Thesis, La. State Univ., Baton Rouge. 94 p.

White, C.J., and C.J. Boudreaux. 1977. Development of an areal management concept for gulf penaeid shrimp. La. Wildl. Fish. Comm. Tech. Bull. No. 22. 77 p.

Williams, A. B. 1953. Identification of juvenile shrimp (*Penaeidae*) in North Carolina. J. Elisha Mitchell Sci. Soc. 69(2):156-160.

__________ 1955. A contribution to the life histories of commercial shrimps (*Penaeidae*) in North Carolina. Bull. Mar. Sci. Gulf Caribb. 5(2):116-146.

_____________ 1959. Spotted and brown shrimp postlarvae (*Penaeus*) in North Carolina. Bull. Mar. Sci. Gulf Caribb. 9(3):281-290.

_____________ 1960. The influence of temperature on osmotic regulation in two species of estuarine shrimps (*Penaeus*). Biol. Bull. 119(3):560-571.

Yakupzack, P. M., W. H. Herke, and W. G. Perry. 1977. Emigration of juvenile Atlantic croakers, *Micropogon undulatus*, from a semi-impounded marsh in southwestern Louisiana. Trans. Am. Fish. Soc. 106(6):538-544.

Yancey, R. 1962. Marsh Island Wildlife Refuge. La. Conserv. 14(3):14-16.

Zein-Eldin, Z. P. 1963. Effect of salinity on growth of postlarval penaeid shrimp. Biol. Bull. 125(1):188-196.

_____________, and D. V. Aldrich. 1965. Growth and survival of postlarval *Penaeus aztecus* under controlled conditions of temperature and salinity. Biol. Bull. 129(1):199-216.

_____________, and G. W. Griffith. 1966. The effect of temperature upon the growth of laboratory-held postlarval *Penaeus aztecus*. Biol. Bull. 131(1):186-196.

_____________ _____________ 1969. An appraisal of the effects of salinity and temperature on growth and survival of postlarval penaeids. FAO Fish. Rep. No. 57, 3:1015-1026.

DOI: 10.18785/negs.0901.02