WHITE SHRIMP EMIGRATION IN RELATION TO SIZE, SEX, TEMPERATURE AND SALINITY

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Abstract

This study was conducted on juvenile and subadult white shrimp, Penaeus setiferus (Linnaeus), emigrating from Galveston Bay, Texas, to the Gulf of Mexico. Surface, midwater, and bottom tows were made with a 3-m otter trawl on ebbing tides from 1 August 1966 to 27 January 1967. Sampling was usually conducted during the day. Five peaks of emigration occurred from 19 October through 25 December, coinciding with water temperatures between 19° and 8° C in the tidal pass. The catch per unit of effort increased significantly from the surface to the bottom of the water column. Sharp drops in water temperature appeared to stimulate shrimp emigration. The mean lengths of shrimp caught were similar between water depths and sexes on a given sampling date, but decreased with progress of the season and decreasing temperature; there was no obvious relation between length and salinity. Of 2,964 white shrimp caught in the tidal pass, 55.1 percent were females, but the sex ratio was not significantly different from 1:1.

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EMIGRATION DE LA CREVETTE Penaeus setiferus (LINNAEUS) EN FONCTION DE LA TAILLE, DU SEXE, DE LA TEMPERATURE ET DE LA SALINITE

Résumé

Les auteurs ont étudié les stades juvéniles et sub-adultes de "crevette blanche" - Penaeus setiferus (Linnaeus) -, qui émigrent de la baie de Galveston (Texas) à destination du golfe du Mexique. Du 1er août 1966 au 27 janvier 1967, des traits ont été effectués durant le jusant, en surface, entre deux eaux, et sur le fond au moyen d'un chalut (de 3 mètres) à panneaux. Le prélèvement a généralement eu lieu de jour. On a constaté cinq "pointes" d'émigration, s'échelonnant du 19 octobre au 25 décembre, et coïncidant avec des températures de l'eau du chenal situées entre 19° et 8°C. Les captures par unité d'effort ont accusé une nette progression à mesure que l'on allait de la surface vers le fond. Les chutes brusques de la température de l'eau ont paru stimuler l'émigration des crevettes. Pour une même date d'échantillonage, la taille moyenne des animaux capturés était identique aux différentes profondeurs et pour les deux sexes, mais elle a diminué à mesure qu'avançait la saison et que baissait la température. On n'a pas relevé de rapport évident entre longueur des animaux et taux de salinité. Sur 2 964 crevettes pêchées dans le chenal, le pourcentage des femelles était de 55,1 p. 100, mais la sex-ratio ne s'écartait guère de 1/1.

LA EMIGRACION DEL CAMARON BLANCO EN RELACION CON EL TAMAÑO, EL SEXO, LA TEMPERATURA Y LA SALINIDAD

Extracto

Se estudió el camarón blanco, Penaeus setiferus (Linnaeus), en su forma juvenil y subadulta, al emigrar de la Bahía de Galveston, en Texas, al Golfo de México. Desde el 1 de agosto de 1966 hasta el 27 de enero de 1967, se efectuaron lances en la superficie, entre dos aguas y en el fondo, con una red de arrastre de puertas de 3 m, con marea descendente. Por lo general, el muestreo se hizo durante el día. Desde el 19 de octubre hasta el 25 de noviembre, coincidiendo con temperaturas del agua entre 19° y 8°C hubo cinco emigraciones máximas en el canal de paso de la marea. La captura por unidad de esfuerzo aumentó mucho desde la superficie al fondo. Los bruscos descensos de la temperatura del agua estimulaban, al parecer, la emigración de los camarones. Las tallas medias de los camarones capturados, así como el sexo eran similares a ciertas profundidades en una fecha dada de muestreo, pero disminuían al avanzar la estación y bajar la temperatura; no existía ninguna relación clara entre la talla y la salinidad. De los 2.964 camarones capturados en el canal de paso de la marea, el 55,1 por ciento eran hembras, pero la proporción de sexos no se alejó mucho de 1:1.

1 INTRODUCTION

Adult white shrimp, Penaeus setiferus (Linnaeus), which contribute to the Texas commercial fishery, spawn offshore in the Gulf of Mexico. Peak postlarval immigration into Galveston Bay, Texas, occurs in the summer (Baxter and Renfro, 1967), and juveniles are most abundant from August to December (Chin, 1960; Baxter and Renfro, 1967). In general, juvenile and subadult white shrimp emigrate from the bay in the autumn as temperatures decrease. Shrimp that emigrate to outside waters appear to remain adjacent to the estuaries until adverse environmental changes force them offshore or possibly until water temperature in the estuary rises enough to allow the shrimp to move back into the bays (Lindner and Anderson, 1956).

Specific information on causes of emigration is needed to gain a clear understanding of the life history. In addition, information on the size and time of emigration can be used in regulating the shrimp fishery. The objectives of this study are to determine for juvenile and subadult white shrimp emigrating from Galveston Bay: (1) vertical distribution; (2) peaks of emigration; (3) sex ratio; (4) size at emigration; and (5) the effects of temperature and salinity on size and abundance.

2 METHODS

2.1 Study Area

Galveston Bay in southeast Texas is connected with the Gulf of Mexico by three tidal passes (Fig. 1a and 1b). The Bolivar Roads tidal pass was chosen for studying white shrimp emigration because about 85 percent of the tidal exchange occurs through it (Trent, 1967b). Water depths (mean low tide) at sampling stations 1 and 2 (Fig. 1c) were about 8 and 10 m respectively.

2.2 Gear and Sampling Procedure

Sampling for shrimp was conducted in the tidal pass from 1 August 1966 to 27 January 1967. Intervals between sampling dates were usually 3 or 4 days, but were shorter during periods when water temperature dropped rapidly in Galveston Bay.

An otter trawl with an opening of 1.2 by 3.0 m was used for sampling. Five corks were attached to the float line and a chain to the foot line of the trawl. The cotton webbing had stretched mesh of 38 mm in the body and 28 mm in the cod end.

Samples were taken at three depths in the water column. Fishing depth of the trawl was controlled by making slight alterations in the otter boards or length of towing line. Standard otter boards were used for sampling at the bottom and in midwater, and converted otter boards (Trent, 1967a) for sampling at the surface. To sample in midwater, only enough towing rope was paid out to permit the trawl to fish 3.7 to 4.9 m below the surface.

The samples were taken by towing the trawl from a 12-m vessel at a constant engine speed. Most samples were taken during the day within 2 h of maximum ebb tide or during ebb tides within 24 h after strong northerly winds. Catch per effort reported here included all white shrimp caught per 8-min tow against ebbing tides. Three tows were made at each depth on each collecting date.

In the Gulf (station 2), bottom tows were made on days following high catches in the tidal pass. Towing time varied from 10 to 30 min. Shrimp from these tows were measured for comparison with the length of shrimp caught in the tidal pass.

2.3 Measurements

Total length (tip of rostrum to tip of telson) of all shrimp caught was measured to the nearest half-centimeter immediately after capture. Mean total lengths were calculated from length-frequency distributions. Sex was determined for all shrimp caught in the tidal pass.

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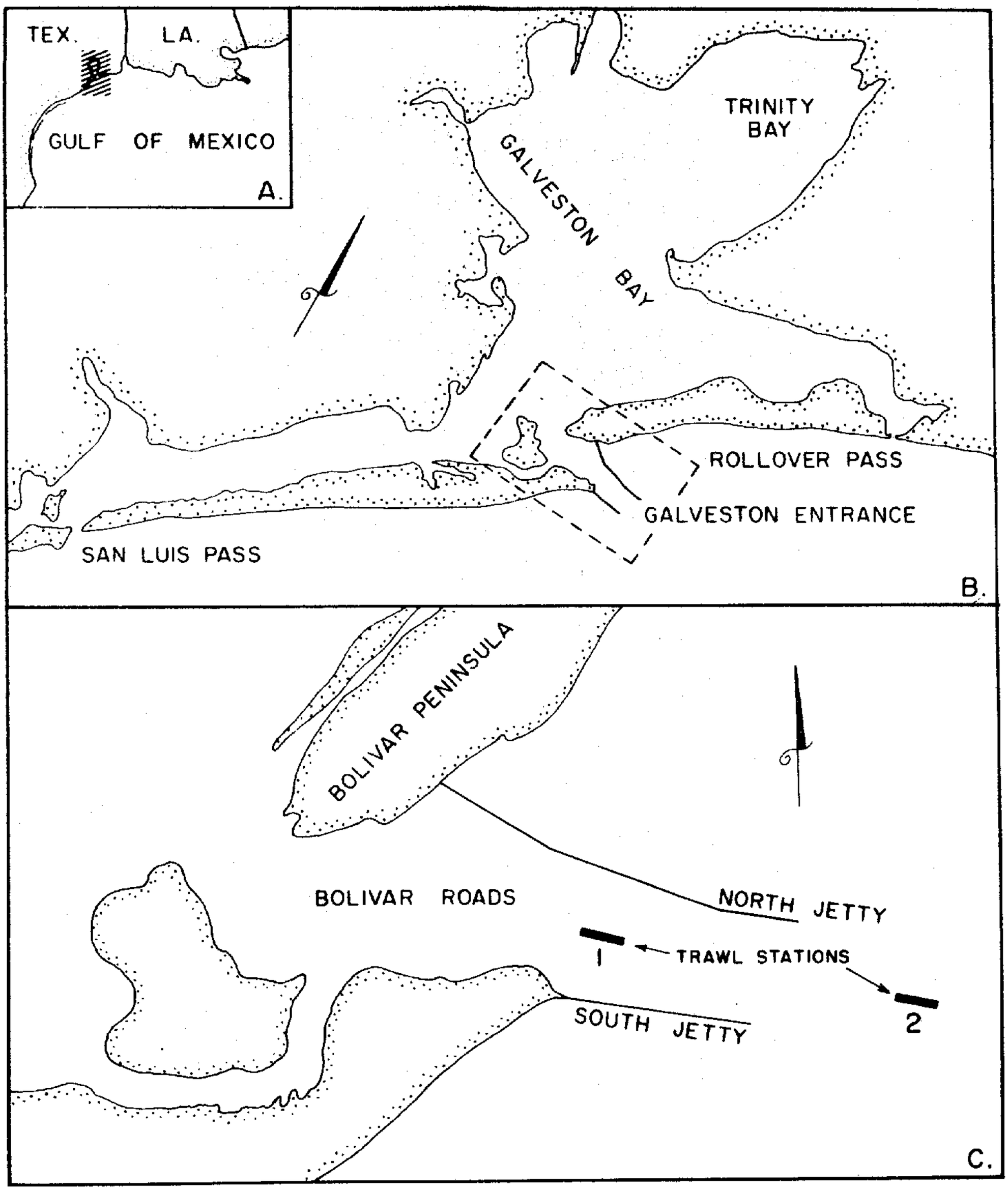

Fig. 1 Galveston Bay and Bolivar Roads tidal pass showing locations of stations at which trawl samples were taken.

2.4 Hydrology

Salinity to the nearest 0.1°/oo (determined by titration) and temperature to the nearest 0.5°C were measured from a surface-water sample taken at the tidal pass station on each sampling date. Air temperatures were obtained from "Local Climatological Data" for Galveston, Texas, U.S. Weather Bureau.

3 VERTICAL DISTRIBUTION

Catch of emigrating white shrimp by depth and sampling date are given in Table I. The mean numbers of shrimp caught at each depth were compared by analysis of variance. Before analysis, however, catch values were transformed to Log 10 (number caught + 1). Data from sampling dates on which no shrimp were caught, and samples taken at night were not included in the analysis. The analysis of variance indicated a significant difference in catch per unit of effort between depths (Table II).

Duncan's Multiple Range Test indicated that catch per unit of effort increased significantly from surface to bottom (Table III). The values of transformed mean catch per tow tested were: surface, 0.1288; midwater, 0.4974; and bottom, 0.7408. Shrimp were caught in large numbers in surface tows on 19 October and 2 November, but were absent in the surface tows on all other sampling dates (Table I). High tidal velocity and extremely turbid water on these two dates possibly accounted for the occurrence of shrimp in the surface waters.

4 PEAKS OF EMIGRATION

Air and water temperatures, salinity, and the mean number of shrimp caught per tow (depths combined) are presented in Fig. 2. In general, temperatures decreased during the season, whereas salinity showed no definite seasonal trend. Extreme drops in temperature did, however, usually correspond with extreme drops in salinity. This relation is explained by the occurrence of cold north winds, reflected in air temperature, causing a decrease in water temperatures in the bay and forcing cold, low-salinity bay water through the passes.

Peaks of white shrimp emigration were correlated closely with rapidly decreasing temperatures and salinities (Fig. 2). The relation between temperature and emigration agrees with the findings of Lindner and Anderson (1956) who stated that large juvenile and subadult white shrimp move to warmer water (the Gulf of Mexico in our study) as a result of falling temperatures in estuaries. Our first peak of emigration occurred 19 October, when daily mean water temperature dropped from 24° to 19°C. The next three peaks of emigration coincided also with drops in temperature. For the rest of the season, however, the relation is not clear, probably because temperature changes were not as great and because emigration was more nearly constant. White shrimp emigration occurred at tidal pass temperatures between 19° and 8°C.

5 SIZE AT EMIGRATION

The number and mean total length of all white shrimp taken in the tidal pass by date, water depth, and sex are shown in Table IV. The numbers of shrimp shown in Table I disagree with the numbers shown in Table IV because additional trawl samples, not included in Table I, were taken on 19 October, 2 November, 11 December and 4 January.

The mean lengths of shrimp caught in surface, midwater, and bottom tows on 19 October and 2 November (the only dates on which shrimp were taken at the surface) were compared by analysis of variance (Table V), and mean lengths of shrimp caught in midwater and bottom tows were compared by using a paired comparison t-test ($t = 1.99$; $t_{.05} = 2.31$ for 8 d.f.). The t-test was also used to compare mean lengths of males and females ($t = 1.27$; $t_{.05} = 2.20$ for 11 d.f.). Samples in which less than 10 shrimp were caught for each depth or for each sex were not used. No significant differences were found.

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TABLE I

Number of white shrimp caught per 8-min tow on ebbing tides in Bolivar Roads tidal pass (August 1966 - January 1967)

Date	Depth of tow			Date	Depth of tow		
	Surface	Midwater	Bottom		Surface	Midwater	Bottom
Aug. 1*	0	0	0	22	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
3*	0	0	0	26*	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
8	0	0	0	29*	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
11*	0	0	0	Oct. 3	0	0	0
	0	0	0		0	0	1
	0	0	0		0	1	0
15*	0	0	0	7	0	1	0
	0	0	0		0	0	0
	0	0	1		0	0	0
18*	0	0	0	11*	0	1	1
	0	0	0		0	0	0
	0	0	0		0	0	0
22	0	0	0	13	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
26*	0	0	2	19	16	15	15
	0	1	2		20	35	12
	0	0	3		10	2	10
29*	0	0	0	20	0	0	3
	0	0	0		0	0	0
	0	1	0		0	0	1
Sept. 1*	0	0	0	24*	0	0	0
	0	0	0		0	1	0
	0	0	0		0	0	0
6	0	0	0	27	0	0	0
	0	0	0		0	0	1
	0	0	0		0	0	0
12*	0	0	0	31	0	0	0
	0	0	0		0	0	0
	0	0	0		0	0	0
15	0	0	0	Nov. 2	153	26	85
	0	1	0		269	113	65
	0	0	0		163	22	75

Contd

TABLE I (contd)

Date	Depth of tow			Date	Depth of tow		
	Surface	Midwater	Bottom		Surface	Midwater	Bottom
Nov.	0	36	1		0	23	25
3	0	6	13	12	0	54	41
	0	18	11		0	12	41
	0	1	5		0	0	7
7	0	0	2	15	0	0	1
	0	1	2		0	0	1
	0	1	3		0	0	22
10	0	5	1	17	0	0	27
	0	0	2		0	0	20
	0	0	1		0	0	0
14	0	0	1	22	0	0	3
	0	1	1		0	0	1
	0	0	0		0	5	24
18	0	0	1	23	0	3	48
	0	0	0		0	86	44
	0	0	0		0	15	8
21*	0	0	0	28	0	30	24
	0	0	1		0	10	23
	0	1	1		0	1	44
25	0	1	4	30	0	0	18
	0	5	6		0	0	51
	0	330	11	Jan.	0	2	5
28	0	13	12	3*	0	3	4
	0	24	7		0	6	4
	0	1	2		0	0	0
30	0	0	0	6	0	0	7
	0	1	1		0	0	1
Dec.	0	0	0		0	4	6
2	0	0	0	9	0	3	4
	0	0	0		0	13	5
	0	1	3		0	0	1
5	0	0	2	12	0	0	0
	0	1	2		0	1	0
	0	0	6		0	0	3
8	0	2	1	18	0	0	0
	0	1	2		0	0	0
	0	10	14		0	0	2
11	0	8	23	27	0	0	4
	0	14	64		0	1	2
				Total	631	974	1,004

* Night samples

TABLE II

Analysis of variance of the mean number of shrimp caught per tow (transformed values) between water depths

Source of variation	d.f.	Sum of squares	Mean square	F.
Between depths	2	15.38255	7.69127	24.49*
Within depths	240	75.37036	0.31400	
Total	242	90.75291		

* Significant at the 99-percent level

TABLE III

Duncan's multiple range comparison of the mean number (means of transformed values) of shrimp caught in surface, midwater, and bottom tows

Comparison between		$x_a - x_b$	Least significant range
a	b		
Bottom	Surface	0.612	0.237*
Bottom	Midwater	0.243	0.227*
Midwater	Surface	0.369	0.227*

* Significant at the 99-percent level

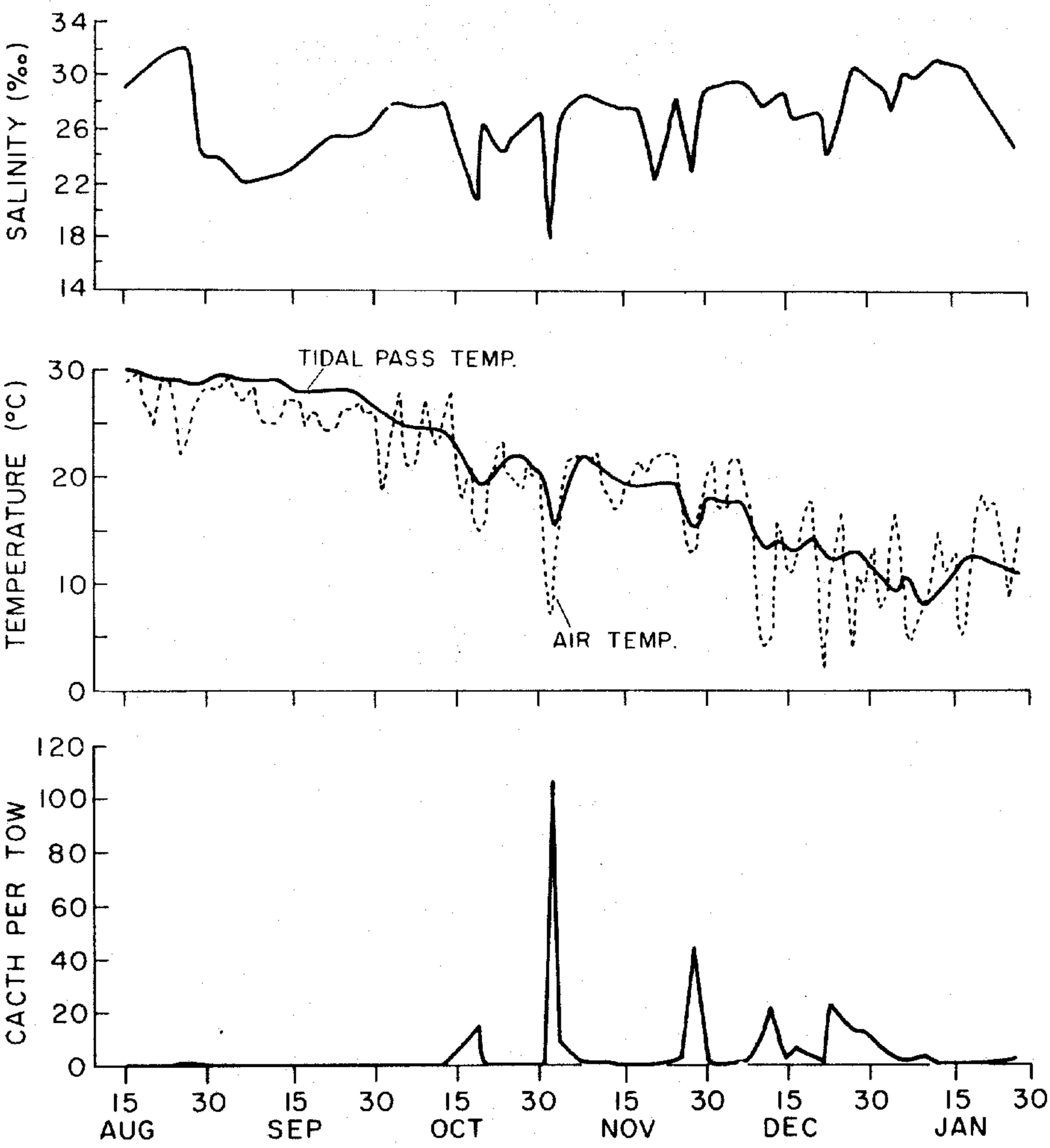

Fig. 2 Abundance of white shrimp caught in Bolivar Roads tidal pass as related to salinity and temperature.

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TABLE IV

Mean total length in millimeters of white shrimp,
by date, water depth, and sex

Date	Midwater		Bottom		Male		Female		All shrimp	
	No. of shrimp	Mean length	No. of shrimp	Mean length	No. of shrimp	Mean length	No. of shrimp	Mean length	No. of shrimp	Mean length
Aug. 25	0		1	135	1	135	0		1	135
26	1	140	7	147	5	144	3	150	8	146
29	1	160	0		0		1	160	1	160
Sept. 15	1	160	0		1	160	0		1	160
Oct. 3	1	160	1	70	1	160	1	70	2	115
7	1	155	0		0		1	155	1	155
11	1	150	1	135	0		2	142	2	142
19*	67	125	138	114	97*	120	178*	119	275*	119
20	0		4	112	3	98	1	155	4	112
24	1	110	0		0		1	110	1	110
27	0		1	110	1	110	0		1	110
Nov. 2**	194	98	258	94	485**	98	612**	95	1097**	96
3	60	123	25	123	46	123	39	124	85	123
7	2	97	9	105	5	102	6	106	11	104
10	6	98	6	107	5	96	7	107	12	102
14	1	100	3	102	3	100	1	105	4	101
18	0		1	120	1	120	0		1	120
21	0		1	120	1	120	0		1	120
25	7	113	11	116	12	116	6	112	18	115
28	367	100	30	98	214	100	183	99	397	100
30	2	102	3	98	3	100	2	100	5	100
Dec. 5	2	117	7	103	3	102	6	108	9	106
8	3	97	9	98	6	96	6	99	12	97
11	62	94	149	95	88	94	123	95	211	94
12	89	90	107	91	93	91	103	90	196	91
15	0		9	102	5	100	4	105	9	102
17	0		69	101	29	103	40	99	69	101
22	0		4	108	1	105	3	108	4	107
23	94	93	116	92	87	94	123	91	210	92
28	55	87	55	85	36	87	74	85	110	86
30	1	75	113	90	50	91	64	89	114	90
Jan. 3	13	94	11	87	12	87	12	94	24	91
4	2	95	9	95	6	93	5	97	11	95
6	0		8	91	5	90	3	93	8	91
9	20	92	15	88	16	93	19	88	35	90
12	1	65	1	85	1	65	1	85	2	75
18	0		3	93	3	93	0		3	93
27	1	100	8	98	6	97	3	100	9	98
Totals and weighted means	1056	100	1193	97	1331	99	1633	98	2964	99

* 70 shrimp having a mean length of 123 mm caught in surface tows.

** 645 shrimp having a mean length of 96 mm caught in surface tows.

TABLE V

Analysis of variance of the mean lengths of shrimp caught in surface, midwater, and bottom tows on 19 October and 2 November 1966

Source of variation	d.f.	Sum of squares	Mean square	F
Between depths	2	378.5433	189.2717	1.12
Within depths	21	3,547.2550	168.9169	
Total	23	3,925.7983		

Although lengths did not differ between either sexes or depths, mean lengths decreased during the study period. To illustrate this decrease, we plotted mean lengths against time and fitted a non-weighted linear regression to the data (Fig. 3). The null hypothesis that the mean sizes were similar at different times was rejected ($t = 9.50$; $t_{.01} = 2.90$ for 36 d.f.). Size at emigration decreased significantly during the study (Fig. 3) and closely followed decreasing water temperatures (Fig. 2).

Length-frequency distributions of white shrimp caught each week in the tidal pass and in the Gulf of Mexico are shown in Fig. 4. Only data from those weeks in which at least 30 shrimp were caught in each of the two areas (except for 8 - 14 January) are included. The mean length of shrimp caught in the Gulf was greater than the mean length of shrimp caught in the tidal pass for each week. Variation in length (both in the pass and Gulf) was greater 16 - 22 October and 30 October to 5 November than in the other weeks.

White shrimp, after emigrating from estuarine areas, tend to remain near shore or to migrate alongshore unless low temperatures force them offshore (Lindner and Anderson, 1956). If this situation existed during our study, possible components of the population that we sampled in the Gulf were (1) recent emigrants from Galveston Bay, (2) shrimp which emigrated from Galveston Bay over the entire emigration period, (3) shrimp which emigrated from other estuaries and moved alongshore to our Gulf station, and (4) shrimp which migrated to the sampling area from offshore. Consequently, we would expect that samples taken in the Gulf would be composed of larger shrimp than samples taken in the tidal pass if any of the last three components were included in the Gulf population sampled.

6 SEX RATIO

Of 2,964 white shrimp caught in the tidal pass (Table IV), 1,633 (55.1 percent) were females. A chi-square test indicated that the sex ratio did not deviate from a 1:1 ratio ($\chi^2 = 46.4$ with 37 d.f., $\chi^2_{.10} = 48.3$).

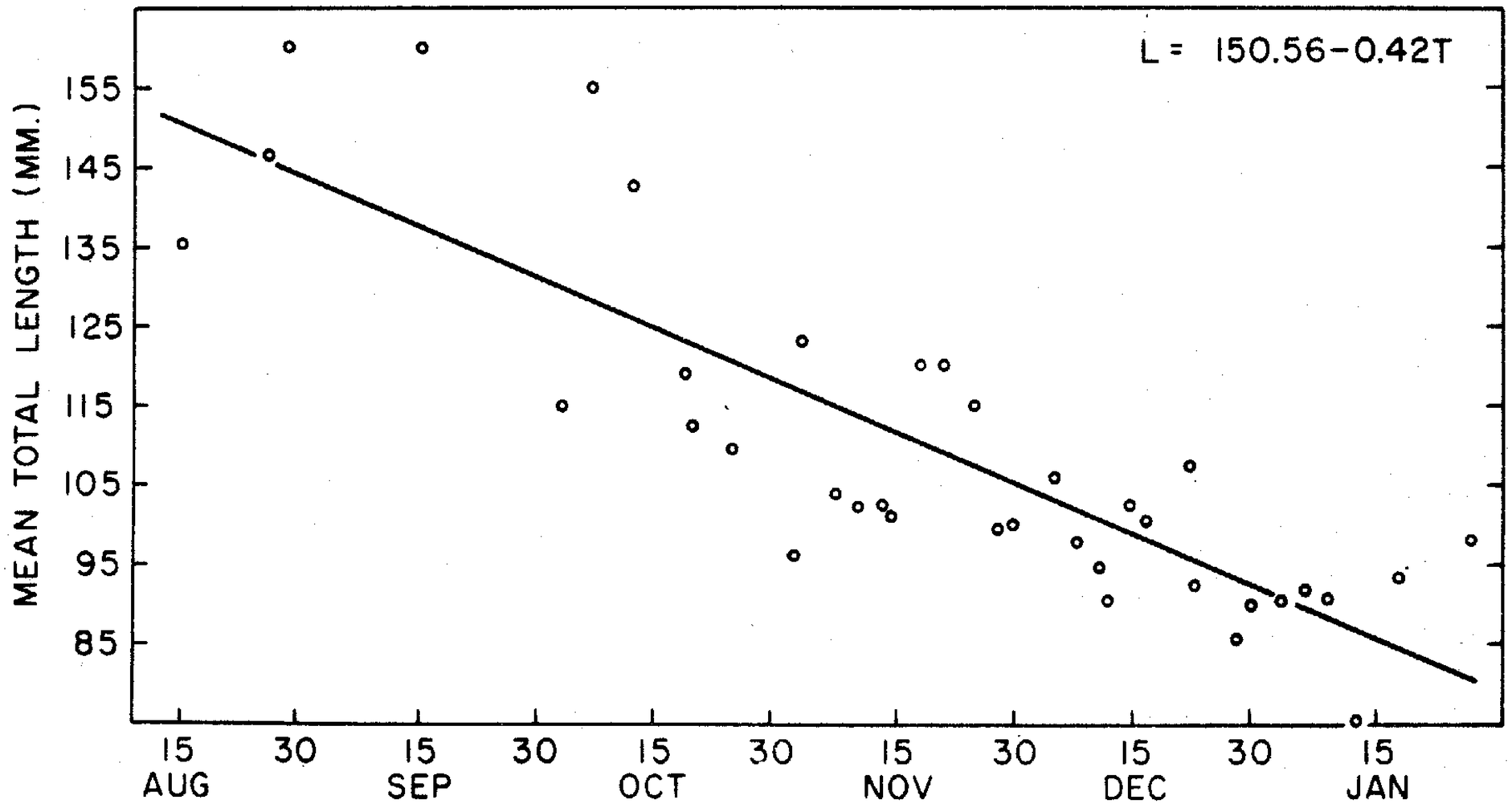

Fig. 3 Decrease in mean length of white shrimp caught in the Bolivar Roads tidal pass, 15 August 1966 to 27 January 1967.

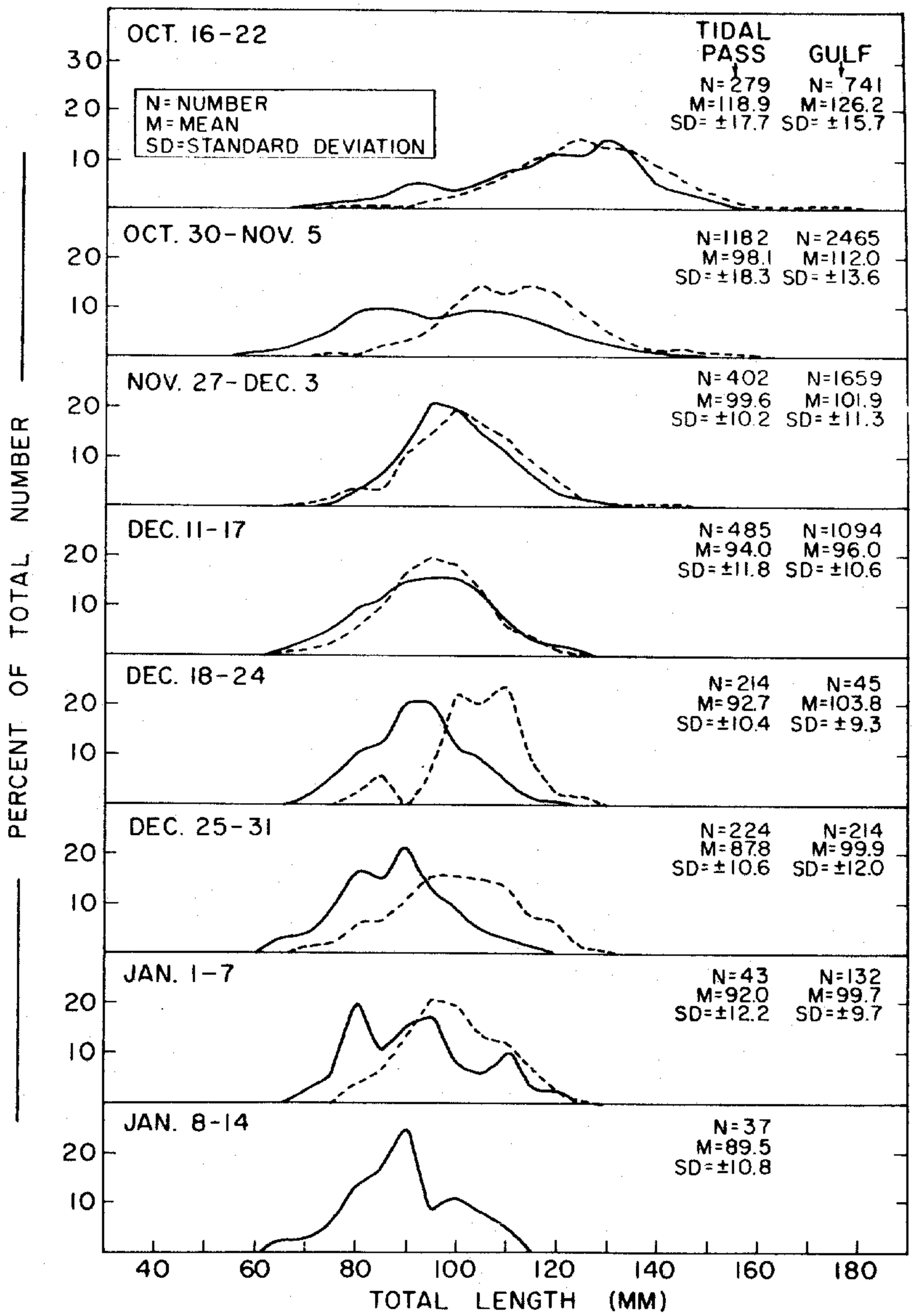

Fig. 4 Length-frequency distributions by week of white shrimp caught in the Bolivar Roads tidal pass (solid line) and in the Gulf of Mexico (broken line).

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