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Distribution and biological characteristics of young short-finned squid (*Illex illecebrosus*) in the Northwest Atlantic, February 20-March 11, 1981

by

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Abstract

During a Feburary 20-March 11 research survey in the Slope Water and Gulf Stream 8,275 juvenile *Illex illecebrosus* were captured using midwater trawl. Catches in the upper 300 m occurred in Slope Water with greatest catches at 100 m being located near the northern boundary of the Gulf Stream. Catches were also high in North Atlantic Central Water, at depths of 500 m and 1000 m. Catches occurred during all periods of the 24 hr cycle, but more frequently during dusk and darkness.

Sexes were found to be equal and there was no difference in size due to sex. There was no apparent difference in length in the north-south direction. However, at 100 m there was an obvious increase in length in the west-east direction. This suggests that in the warm Slope Water juveniles are transported by eastward flow of the water mass.

Introduction

The short-finned squid (*Illex illecebrosus*) is distributed between Newfoundland and Labrador in the north to central Florida in the south. Between July and November it supports a fishery in Canadian waters (NAFO Subarea 3 and 4), which has resulted in catches as high as 153,000 t in 1979 (NAFO 1980).

The life cycle of this species is incompletely known since they are found on the continental shelf or inshore only between May and November. Late autumn offshore migration is believed to be related to spawning, as females are immature at this time but males are in more advanced stages of maturity (Squires, 1957; Mercer, MS 1973). Since squid captured in May-June are much smaller and males are immature it is belived that this species lives only one year and dies after spawning (Hurley and Beck, 1979). Thus, the period between December and May encompasses spawning as well as larval and early juvenile development.

The location of the spawning site remains a mystery since concentrations of spawning adults have not been encountered. Mature females have occassionally been captured over most of the range of the species and females which had mated have been captured during August-September, mostly near the southern extreme of their range (Dawe and Drew, this meeting). However, these are probably oddities rather than part of the normal breeding population (Durward et al., 1980), and so provide little insight as to the timing and location of spawning.

Larval and young juvenile Illex illecebrosus were first found in the vicinity of the continental slope, between New York Bight and Georges Bank (Roper and Lu, MS 1978). They suggested that spawning may occur during much of the year on the edge of the continental shelf over a broad area which may extend to the north and south of the mid-Atlantic States. Larvae would ascend to near-surface shelf waters and be transported seaward to Slope and Gulf Stream waters. Vecchione (MS 1978) collected larval Illex at the outer edge of the shelf between Virginia and New Jersey during February-March 1977. However he noted that their distribution may extend beyond the shelf and to the north. Smallest larvae captured were belived to be approximately two days old (Vecchione, MS 1978), which supports the suggestion of Squires (1967) that spawning may occur in January or February. He also noted that further sampling is required to identify spawning and hatching areas.

In 1979 larval and juvenile Illex illecebrosus were captured during a joint Canadian/USSR research survey in more northern waters off the continental shelf of Nova Scotia and the Grand Bank (Amaratunga et al., MS 1980, Fedulov and Froerman, MS 1980). Largest catches occurred during the night at 100 m in the Slope Water near the northern boundary of the Gulf Stream (Fedulov and Froerman, MS 1980). Based largely on areal variation in length frequency distributions they postulated that spawning occurs in the vicinity of the continental slope and larvae are transported to the northern boundary of the Gulf Stream.

Slope Water is described as a region of mixing between Shelf Water and Gulf Stream Water and it may vary between 20-120 miles wide. The transition between Shelf Water, to the north and west, and Slope Water is defined by a sudden increase in minimum temperature and salinity above 10°C and 34.5°/oo (McLellan et al. 1953). Steepening of isotherms and an increase in temperature and salinity mark the transition between Slope Water and Gulf Stream Water (Gatien, 1976).

Gatien (1976) has shown the existance of two distinct zones in the Slope Water. Labrador Slope Water is a mixture of Labrador Current Water and North Atlantic Central Water (NACW). This region, which lies against the continental shelf is low in oxygen content and salinity and flows westward. Stommel (1958) noted that since temperature-salinity curves are so similar on both sides of the Gulf Stream upwelling of North Atlantic Central Water against the continental shelf probably occurs.

The warm Slope Water extends 300-400 m deep and lies adjacent to the Gulf Stream. It is a well mixed, oxygen-rich zone formed by horizontal mixing between Gulf Stream and Shelf Water (Gatien, 1976). In this zone temperature and salinity increase to the east due to increased mixing across the northern boundary of the Gulf Stream. Below the warm Slope Water lies an incomplete mixture of Labrador Slope Water and North Atlantic Central Water.

This paper presents data collected during a research survey directed for larval and juvenile Illex illecebrosus in the vicinity of the Slope Water mass and Gulf Stream during Feburary 20-March 11, 1981. Distribution of catches are described in relation to physical properties of the water masses. Biological characteristics of juveniles are also described toward determining mechanisms of transport.

Materials and Methods

The survey was conducted during February 20-March 11, 1981 aboard the Canadian research vessel GADUS ATLANTICA, a 260 ft. stern trawler. The survey area extended north-south between 41°43'90"N and 37°16'00"N and west-east between 56°00'00"W and 47°00'00"W (Fig. 1). Midwater trawling was attempted initially using an Engel 400 mesh midwater trawl. However, due to unknown problems this trawl did not operate properly and so the first five stations were considered unsuccessful. Thereafter midwater trawling was conducted using the vessel's commercial trawl, an Engle midwater trawl 80 (EMT 80).

This trawl has a 1.2 cm mesh nylon codend liner. Plankton was sampled using 505 um. mesh bongo nets. The survey was conducted along four transects (A-D, Fig. 1), which extended true south along lines of longitude. Transects were spaced at 120 mile intervals.

The survey was functionally divided into two phases. Phase 1 was directed toward investigating distribution of larval and juvenile Illex in relation to physical properties of the water masses. Transect A represents this aspect of the survey. On this transect stations were selected on the basis of frequent XBT casts to 750 m. At each station EMT 80 sets of 30 min duration were performed at depths of 100 m, 300 m, 500 m and 1000 m. Standard oblique bongo tows (15 min) were also executed, to 50 m and 200 m. Temperature and salinity were sampled at 0, 50, 100, 200, 300, and 500 m using Kneutson reversing bottles. Also, due to observed fine-scale temporal and areal variations in temperature, the vertical temperature profile was described following each set using an XBT cast to 750 m. Standard meteorological data were also recorded. In the early stages a 24 hr station was attempted. However due to poor weather conditions the complete series of EMT 80 and bongo sets were replicated only once (Stations 8 and 9 for convenience). Since this problem persisted there was no further opportunity to properly investigate diel variability in catch rate.

Phase II of the survey (transects B-D) was aimed at studying broader geographic aspects of distribution and size of Illex as well as collecting additional data pertaining to phase 1. Stations were located at 60 mile intervals along transects. Operations at each station included 30 min EMT 80 sets at 100 m and 300 m as well as a standard oblique bongo set to 200 m. Temperature and salinity were sampled at 0, 100, 200 and 300 m using Kneutson reversing bottles and an XBT cast to 750 m was performed after each set. Standard meteorological data were also recorded. Poor weather conditions precluded occupation of more than one station on transect D. Because of this problem and initial operational problems effective fishing time was restricted to 13 days (Feburary 23-March 7).

Sampling on board involved initially weighing the total EMT 80 catch and removing all cephalopods. A subsample was sorted for fish and crustaceans, which were preserved in 5% formalin. Illex specimens were counted and either frozen or fixed in 5% formalin and preserved in 70% alcohol. Other cephalopods were preserved in 70% alcohol. Positive identification of all cephalopods was later performed in the laboratory. Preliminary identification of cephalopods other than Illex was achieved to various taxonomic levels.

Plankton samples from bongo nets were estimated volumetrically and preserved in 5% buffered formalin after being macroscopically examined for cephalopods. These samples have not yet been processed and so will not be dealt with here.

All measurements of Illex were performed on animals preserved in 70% alcohol. For each of the two largest catches (Stations 12 and 15 at 100 m) samples of 100 animals were dissected and sex determined. Dorsal mantle length and total weight were also measured. For all other sets a maximum of 50 specimens were sampled for length and weight only. Length was measured to the nearest mm using Helios dial calipers. Total weight was measured to the nearest 0.01 gm using a didigital readout balance, Sartorius model 1213 MP.

Stations were plotted in relation to water masses using charts of sea surface temperature provided by Maritime Command Headquarters (unpubl. material). Statistical analysis included chi-square to test for significance of observed sex ratios and regression analysis to describe length-weight relationships by sex. The Student's t-test was used to test for differences in mean length due to sex. All other comparisons of length frequency distributions were performed using one-way analysis of variance (ANOVA). Statistical significance was accepted at the 0.05 probability level.

Results

Distribution

The location of stations in the survey area is shown in Fig. 1. The total catch of juvenile Illex from midwater trawling was 8,275 with a mean overall catch rate of 183.9 animals per set (Table 1). Catches occurred at all depths and during daylight as well as darkness. Catches occurred to the northern limit of transects A-C where catch rates were low (Stations 6, 17 and 18), whereas no catches were experienced at the most southern stations (Stations 13, 14, 19, 20, 21) (Table 1). Two exceptionally large catches occurred at 100 m at station 12 during darkness (3,462) and station 15 during daylight (2,546).

Location of stations in relation to water masses is indicated approximately by the distribution of sea surface isotherms (Fig. 2). Although isotherms plotted represent averages for weekly intervals and currents are subject to considerable areal and temporal variability, surface temperatures generally corresponded to those recorded from XBT. It appears that transect A extended along the axis of a meander of Slope Water formed by northward extension of the northern boundary of the Gulf Stream (Fig. 2). This is consistent with the observation of irratic fluctuations in surface temperature along transect A and Illex catches as far north as station 6. Station 12, the site of highest catch, appears to have been located near the northern boundary of the Gulf Stream, whereas station 13 (zero catch) was probably within the Gulf Stream. Although Fig. 2 for the latter period indicates that station 15 was located in the Gulf Stream it is noted that a southward meander of slope water, probably formed by an incursion of cold Labrador water, was transported eastward across transect B during the survey period (Fig. 2). Thus, at time of sampling, station 15 may have been within Slope Water or near the northern boundary of the Gulf Stream. Although eastern transport and northern displacement of the northern edge of the Gulf Stream occurred during the survey period, it appears likely that zero catches at later stations (19-21) were related to sampling in Gulf Stream Water.

Vertical temperature profiles (Fig. 3) for stations at which maximum catches occurred (Stations 12 and 15) suggest that station 15 was located in Slope Water. At station 12 the temperature at 100 m was 19°C, indicating that this station may have been within the Gulf Stream. However, for this station temperature decreased by more than 11°C to 750 m indicating that it may have been located near the northern boundary of the Gulf Stream. Lower temperature in the upper layer at station 15 indicates that this station was located within Slope Water. Temperature decreased by 8°C from surface to 750 m.

Temperature-salinity (T-S) diagrams with catches overlain are shown for depths of 100, 300 and 500 m (Fig. 4). Most zero catches were associated with maximum values of temperature and salinity for each depth. This relationship is most obvious for the lower depths. Zero catches were generally associated with temperature and salinity values exceeding 18°C and 36.5‰ at 100 m, 16.8°C and 36.4‰ at 300 m, and 12.5°C and 35.4‰ at 500 m. It is clear, especially for the lower depths, that zero catches were associated with higher salinities and temperatures characteristic of Gulf Stream Water. The distinction is most pronounced at 300 m where catches usually occurred at temperatures of less than 15.5°C and salinities less than 36.0‰, conditions characteristic of Slope Water. The relationship at 100 m may be obscured by near surface mixing of the water masses as well as fine scale areal variation in physical properties, and vessel drift. Thus physical properties recorded at station 12 may not be representative of the exact position of Illex capture for that station.

The general relationship between catch rate and time of day and depth is shown in Table 2. Although data are confounded by position of stations, it is clear that Illex were most abundant at 100 m. Since two large catches bias these data, the effect of time of day must be considered for depths separately. In this way it appears that catches were generally largest during dusk and darkness periods but especially during the night. Below 100 m, catch rates increased to maximum depth, suggesting that Illex may be transported at greater depth.

Biological Characteristics

Sex composition was examined for equal samples of 100 specimens each from 100 m sets at stations 12 and 15. Sexes were found to be equal ($\chi^2 = 0.02$, $P > 0.05$). Lengths ranged from 1.0 to 3.0 cm. Comparison of lengths between sexes for stations 12 and 15 at 100 m combined (Fig. 5) showed that there was no difference due to sex ($t = -0.47$, $P > 0.05$). Apparent bimodality was due to combination of samples.

Length-weight relationships for both sexes were best described by a power curve ($r = 0.97$, Fig. 6). There was obviously no difference in condition of Illex between sexes. Due to similarity in size and equality of sexes, sex was not considered in other analyses.

Comparison of lengths in the north-south direction (Fig. 7) was performed using samples collected at 100 m from station 9 (Set 37), 10 (Set 44), 11 (Set 51) and 12 (Set 52). Mean length was significantly greater for Set 51 ($F = 77.25$, $P < 0.001$). However since these stations were likely located along a Slope Water meander, this difference may actually be associated with transport mechanisms which normally operate in a west-east direction. Since mean lengths at all other stations were so similar (16.5-16.7 mm) it is felt that there was actually no difference in length in the north-south direction.

A comparison of mean length in the west-east direction was performed by comparing samples from 100 m sets at stations 12 (Set 52) and 15 (Set 67) (Fig. 8). Length frequency distributions differed significantly ($F = 490.69$, $P < 0.001$), with mean lengths of 16.5 mm at Station 12 and 24.0 mm at Station 15.

A provisional list of cephalopods other than Illex collected during the survey, is presented in Table 3. Enoploteuthids and Onychoteuthids represented greatest catches, besides Illex.

Discussion

Temperature-salinity diagrams indicate that catches in the upper 300 m occurred in Slope Water (greater than 10°C and 35°/oo) (Fedulov and Froerman, MS 1980). Location of stations in relation to surface isotherms showed that greatest catches at 100 m occurred near the northern boundary of the Gulf Stream as was found by Fedulov and Froerman (MS 1980). Catches at greater depths (500-100 m) occurred in North Atlantic Central Water and were largest toward the northern extreme of the survey area. Catches generally did not occur in Gulf Stream Water as indicated by unusually high temperatures and salinity at all depths (greater than 16.5°C and salinity of approximately 36.5°/oo).

It appears that the largest catch occurred in Gulf Stream Water as indicated by temperature and salinity. However since this is not consistent with the overall trend, hydrographic data for this station may not be representative of the exact position at which the catch occurred. The temperature-salinity relationship at 100 m is not as clear as for greater depths. This confusion is due to a variety of factors which include fine-scale areal and temporal variations in movement of water masses. Increased horizontal mixing in the upper layers toward the east (McLellan et al., 1953) is a further difficulty in relating catches to physical properties of the water masses.

Below 100 m catch was greatest at maximum depth (1000 m) indicating that juveniles may be distributed to great depths in North Atlantic Central Water. However further interpretation is confused by the possibility that catches during deeper sets may have occurred during retrieval of the gear. More large catches occurred during dusk and darkness, although one of the largest catches occurred during daylight.

Areal differences in length frequency distributions are not consistent with the hypothesis of Fedulov and Froerman (MS 1980) that larvae and juveniles are transported from the continental slope to the northern boundary of the Gulf Stream. There was no noticeable difference in mean length of samples between northern and southern extremes of the survey area. However there was a pronounced increase in mean length in the west-east direction. Thus it appears that transport of juveniles at least in the warm Slope Water may occur in the north-easterly direction. This agrees with the finding of larval and small juvenile Illex illecebrosus near the southern extreme of their range (Roper and Lu, MS 1978, Vecchione, MS 1978). However it has been noted that spawning probably occurs to the north as well (Vecchione, MS 1978).

The importance of Slope Water in the transport of young short-finned squid is reflected in the fact that this water mass originates at Cape Hatteras (McLellan et al. 1953), near the southern limit of the range of the species. Surface temperatures in the vicinity of the Slope Water and Gulf Stream, between the Nova Scotian Shelf and the Grand Bank, during January appear to be related to later season levels of inshore squid abundance at Newfoundland (Dawe and Hurley, this meeting). Further, it has been shown that the timing of first occurrence of squid on the southwest slope of the Grand Bank in May-June is related to incursion of Slope Water on this area of the continental shelf (Hurley, MS 1980, Dawe and Hurley, this meeting).

Although data presented here are insufficient to serve as a basis for drawing conclusions concerning location of the spawning site, several observations are presented which may be useful in formulating a working hypothesis for future research surveys. Greatest catches from this survey at 100 m occurred near the northern boundary of the Gulf Stream. Catches in the water mass dominated by North Atlantic Central Water (500 and 1000 m) were relatively large throughout the north-south extent of this transect. Temperature and salinity characteristics are similar on both sides of the Gulf Stream (Stommel, 1958) and smallest juveniles and larvae yet described have been captured near the continental slope (Roper and Lu, MS 1978; Vecchine, MS 1978), a region where upwelling of deeper North Atlantic Central Water occurs (McLellan et al., 1953). Catches during this survey did not generally occur in Gulf Stream Water, even at depths of 1000 m. These observations, considered with the fact that spawning concentrations have not yet been located suggest that spawning may occur in North Atlantic Central Water on the oceanic side of the Gulf Stream. Larvae and young juveniles could be transported to the northern side of the Gulf Stream by upwelling of deep North Atlantic Central Water. Transport of larvae and young juveniles, at least in the upper warm Slope Water appears to occur by north-eastward flow of this water mass.

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Table 1. Summary of catches of Illex illecebrosus broken down by transect, station, depth, and period of time (day or night).

Transect	Station	Depth (m)	Time D/N	Catch (Nos.)	Catch/set
A	6			135	34
		100	N	38	
		300	N	79	
		500	N	17	
		1000	N	1	
	7	300	D	0	0
	8			367	92
		100	N	0	
		300	D	40	
		500	N	183	
		1000	D	144	
	9			1003	251
		100	D	288	
		300	N	311	
		500	N	103	
		1000	N	301	
	10			274	69
		100	D	67	
		300	N	64	
		500	D	74	
		1000	D	69	
	11			156	39
		100	N	148	
		300	D	5	
		500	D	2	
		1000	D	1	
	12			3615	904
		100	N	3462	
		300	D	113	
		500	N	0	
		1000	N	40	
	13			0	0
		100	D	0	
		300	D	0	
		500	D	0	
		1000	D	0	
Transect A Total and Catch/set ($\bar{x}$)				5550	191
B	14			0	0
		100	N	0	
		300	N	0	
	15			2623	1311.5
		100	D	2546	
		300	D	77	
	16			93	46.5
		100	D	26	
		300	N	67	

Table 1. (Continued)

Transect	Station	Depth (m)	Time D/N	Catch (Nos.)	Catch/set
	17			3	1.5
		100	D	0	
		300	D	3	
Transect B Total and Catch/set ($\bar{x}$)				2719	339.8
C	18			6	2
		100	D	1	
		100	D	2	
		300	D	3	
	19	300	D	0	0
	20			0	0
		100	D	0	
		300	D	0	
Transect C Total and Catch/set ($\bar{x}$)				6	1
D	21			0	0
		100	D	0	
		300	D	0	
Transect D Total and Catch/set ($\bar{x}$)				0	0
Grand Total and Mean Catch/set				8275	183.9

Table 2. Mean catches of *Illex illecebrosus* summarized by depth and time intervals within the 24-hour period (total catch in parenthesis).

Time period		Depth (m)				
Time of Day	Hours	100	300	500	1000	Depths Combined
Dawn	500-900	945 (2835)	3 (3)	0 (0)	0 (0)	283.8 (2838) (n = 10)
Day	901-1500	0 (0)	66 (198)	0 (0)	69 (69)	26.7 (267) (n = 10)
Dusk	1501-1900	31.67 (95)	40 (40)	38 (76)	72.50 (145)	39.56 (356) (n = 9)
Night	1901-2400 0001-500	1216 (3648)	130.25 (521)	101 (303)	114.0 (342)	283.18 (4814) (n = 17)
Periods combined		411.13 (6578) (n = 16)	47.63 (762) (n = 16)	54.14 (379) (n = 7)	79.43 (556) (n = 7)	

Table 3. Summary of total catch of cephalopods (*Illex* excluded) collected during the survey (identified at various taxonomic levels).

Cephalopods	Catch No.
Octopoteuthidae	19
Octopus sp.	16
subclass Coleoidea	36
Histioteuthidae	6
Cranchia scabra	35
Cranchiidae	65
Chiroteuthidae	15
Mastigoteuthidae	1
Family chiroteuthidae or Mastigoteuthidae	5
Enoploteuthidae	400
Ornithoteuthis	1
Onychoteuthidae	152
Spirula spirula	1
Lycoteuthidae	47
Stoloteuthis leucopetera	2
Pyrgopsis lemur	7
Pyroteuthis margaritifera	20
Ommastrephidae	31
Abraliopsis	9
Ommastrephes pteropus	2
Thysanoteuthidae	1
Thelidoteuthis alessandrini	1
Bathyteuthoidae	2
Thelidoteuthis sp.	2
Ommastrephes bartrami	1
Brachioteuthidae	1
Ctenopterygidae	1
Sepiolidae	1

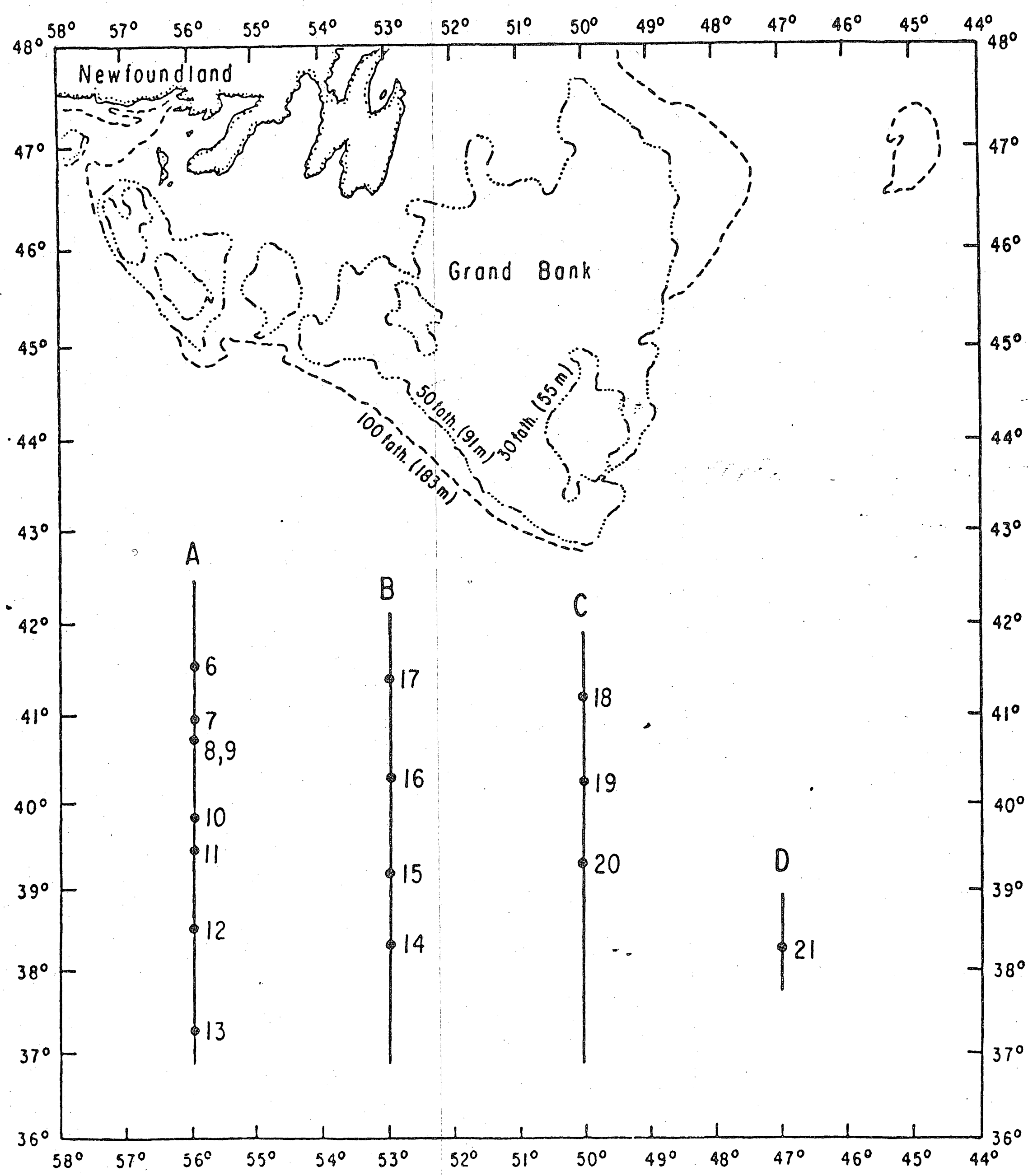

Fig. 1. Location of stations along transects in relation to latitude and longitude.

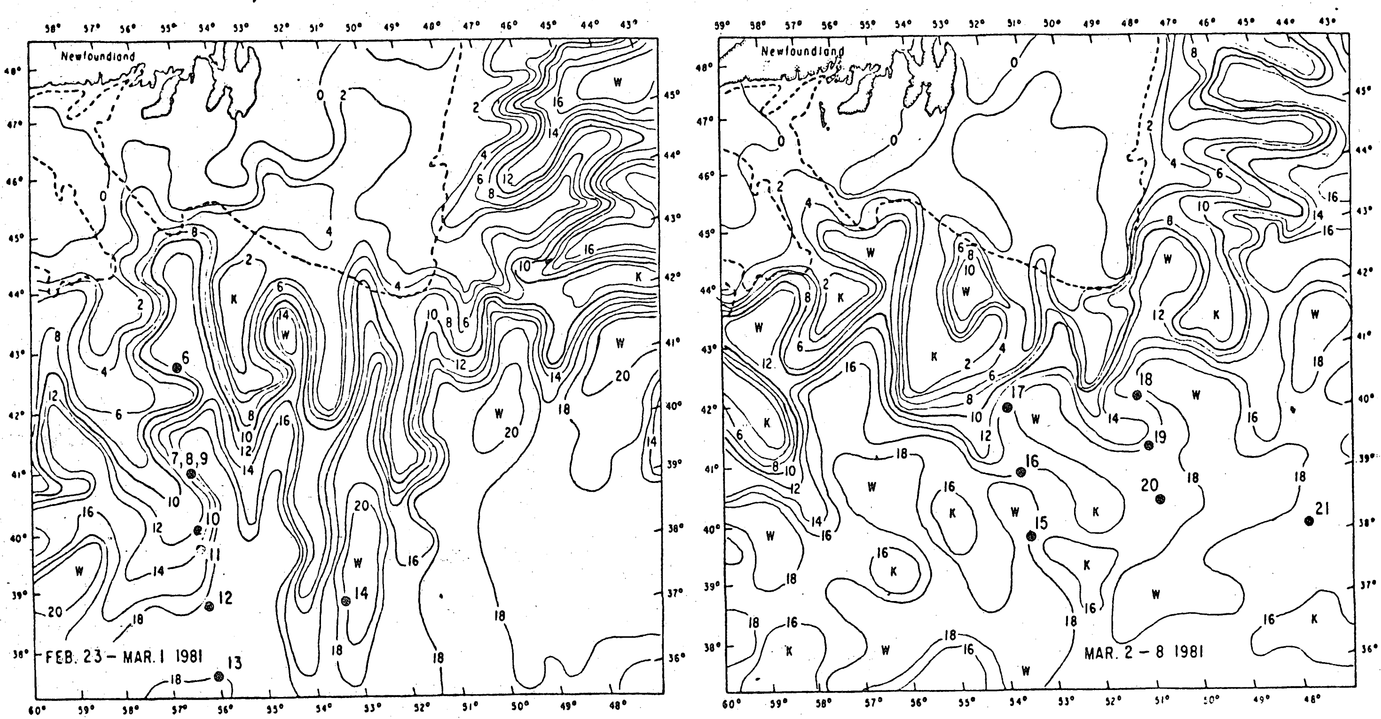

Fig. 2. Location of stations in relation to water masses as indicated by sea surface isotherms.

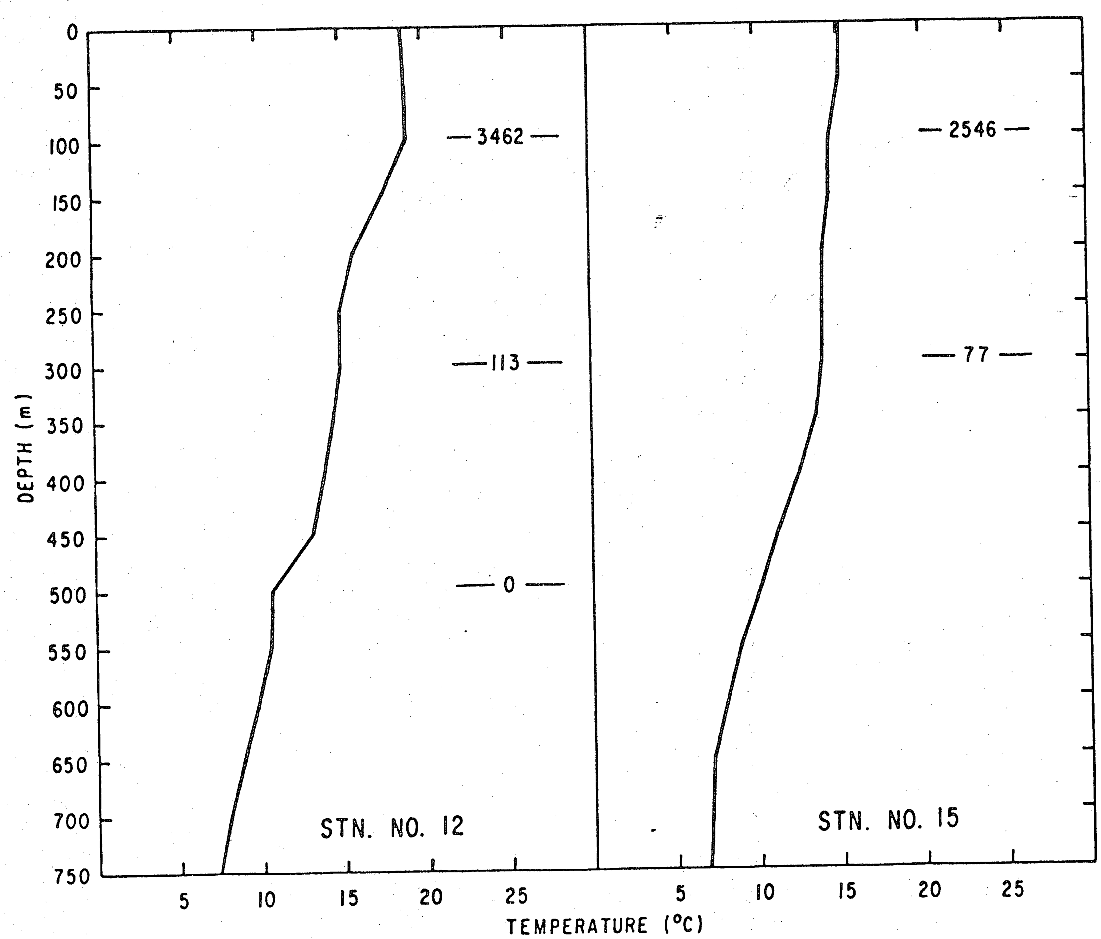

Fig. 3. Vertical temperature profiles to 750 m at Stations 12 and 15 (Stn. 12 catch at 1000 m was 40).

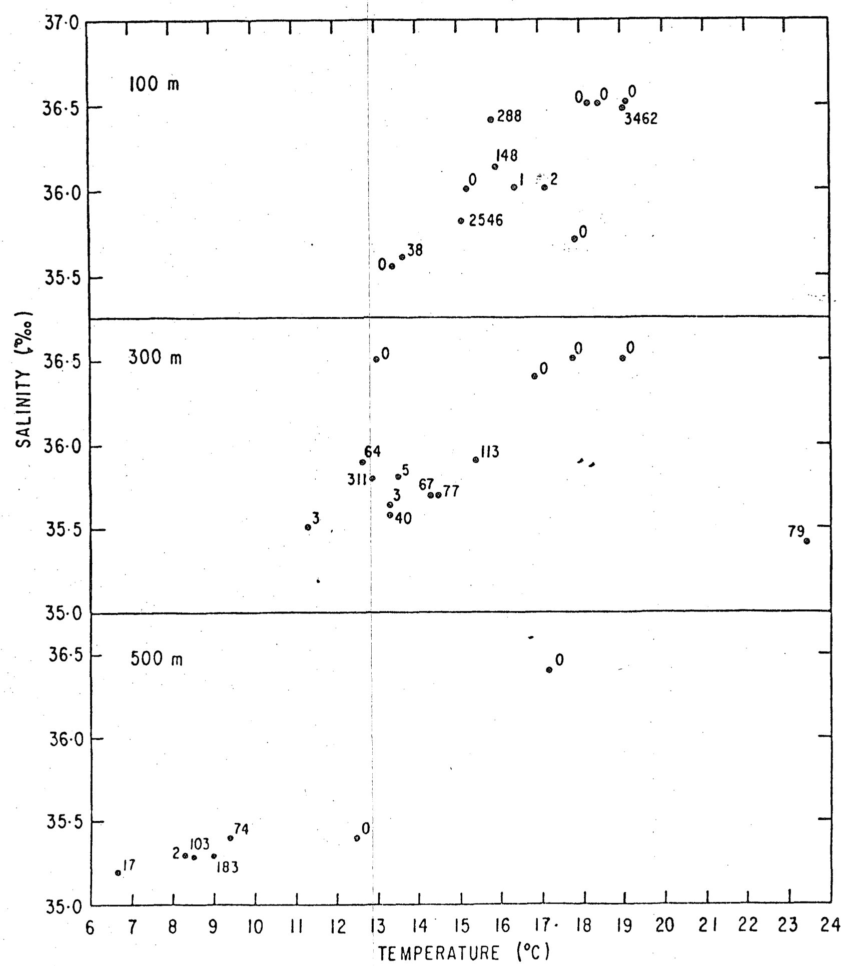

Fig. 4. Temperature-salinity diagram with catches overlain for all stations at 100, 300, and 500 m.

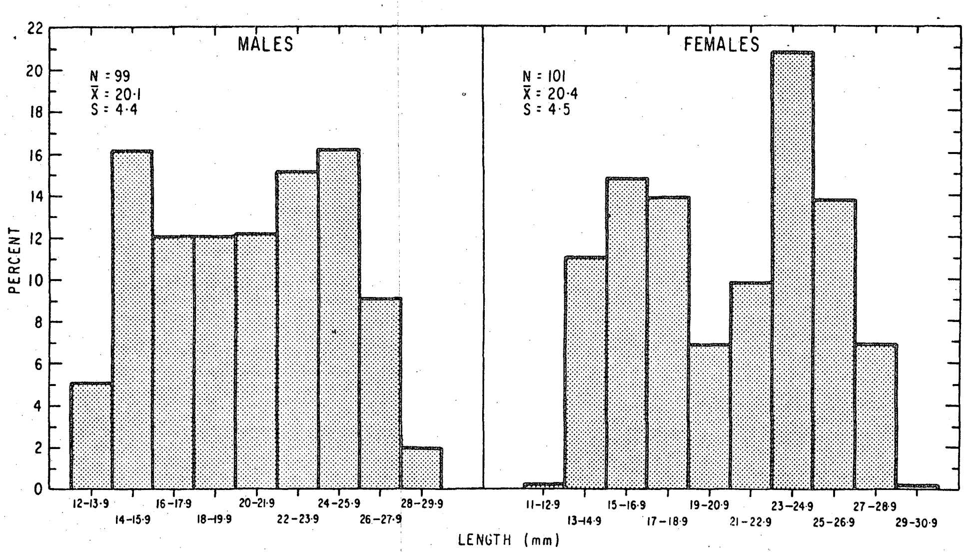

Fig. 5. Comparison of length-frequency distributions by sex, stations 12 and 15 at 100 m combined ($t = -0.47$, $P > 0.05$).

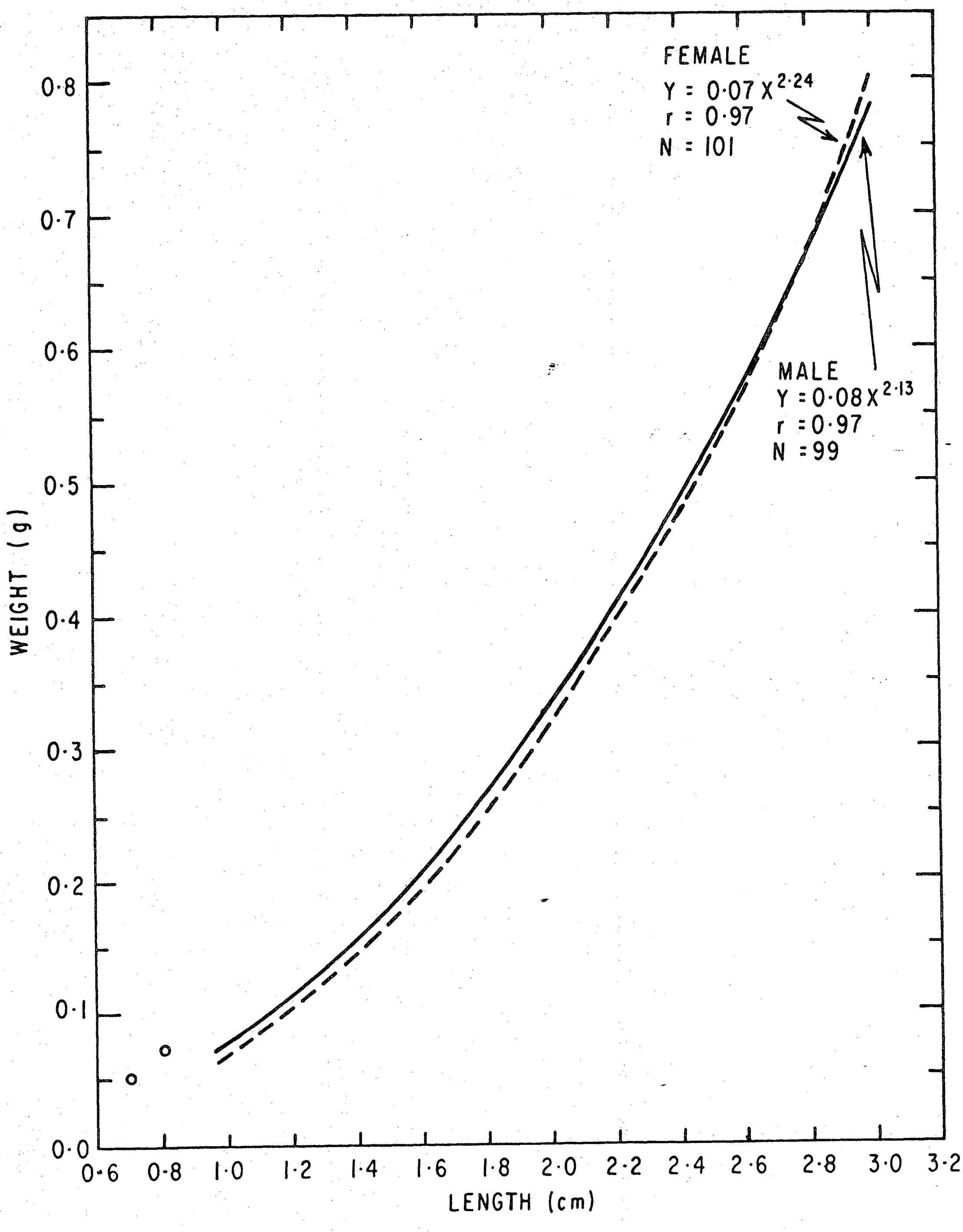

Fig. 6. Length-weight relationships for males and females, stations 12 and 15 at 100 m combined (open circles represent two specimens captured in bongo nets).

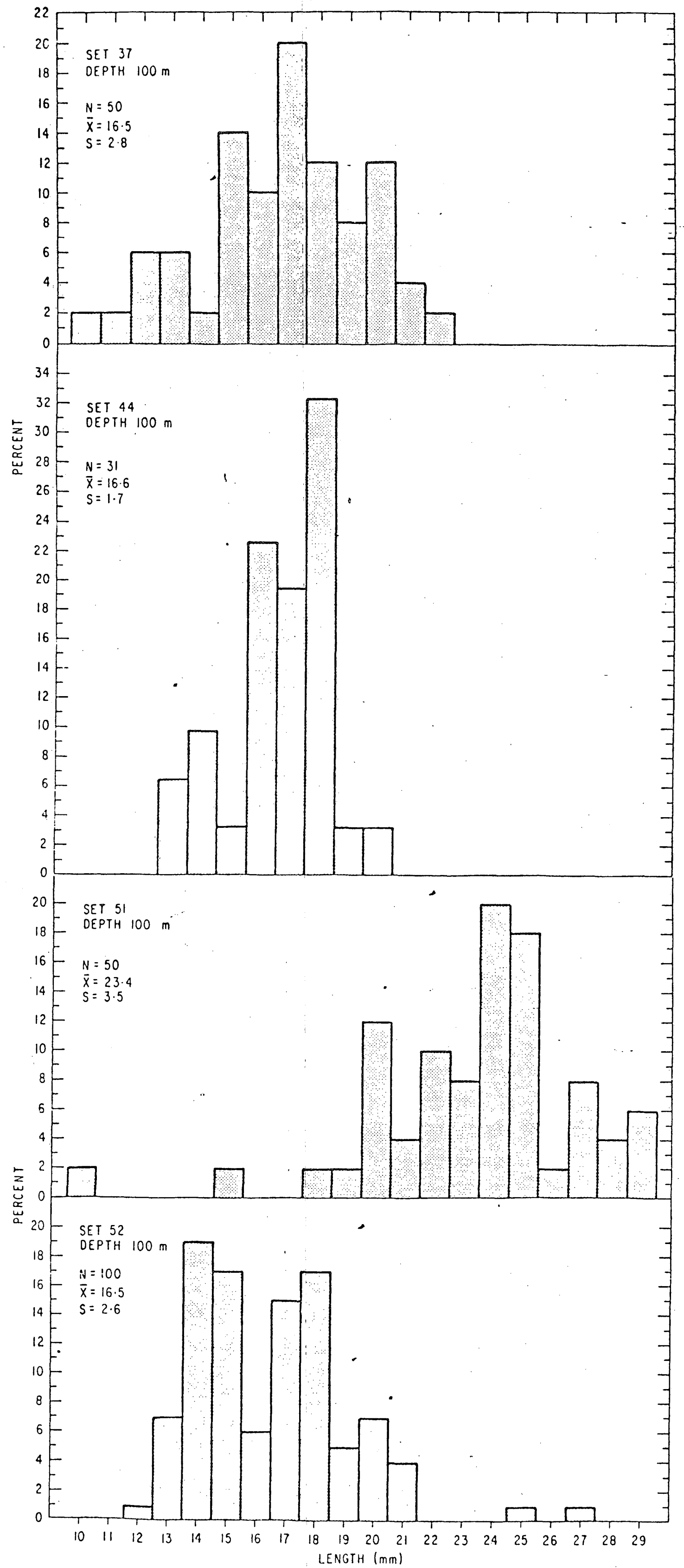

Fig. 7. Comparison of length-frequency distributions by latitude, stations 9 (Set 37), 10 (Set 44), 11 (Set 51), and 12 (Set 52) ($F = 77.25$, $P < 0.001$).

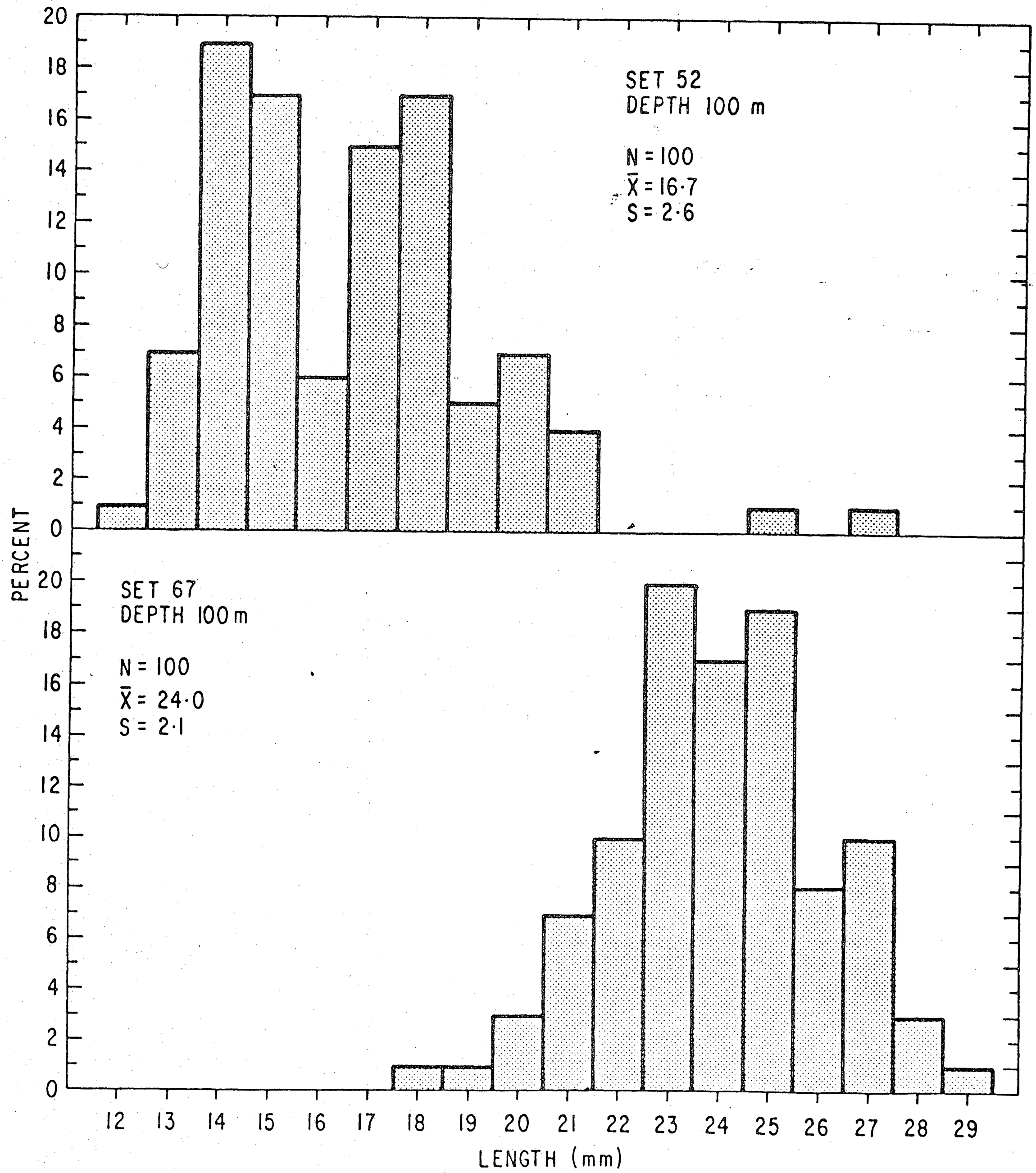

Fig. 8. Comparison of length-frequency distribution by longitude, stations 12 (Set 52) and 15 (Set 67) ($F = 490.69$, $P < 0.001$).