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A close relationship is found between long-finned squid distribution and bottom water temperatures.

Aspects of the Distribution and Abundance of the Long-Finned Squid, *Loligo pealei*, Between Cape Hatteras and Georges Bank

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ABSTRACT

Variations in distribution and abundance of the long-finned squid, Loligo pealei, *found between Cape Hatteras and Georges Bank were analyzed for the years 1967-1971. Spring catches of long-finned squid were greatest at depths from 111 to 183 m; in the fall the squid were most abundant at depths of from 27 to 110 m. A close relationship was found between the distribution of long-finned squid and bottom water temperatures. Best catches of squid were consistently made at locations where the temperature was above 10°C. Variations existed between day and night trawl catches, with daytime catches about nine times nighttime catches. Squid were larger in size during the spring than in the fall. The relative apparent abundance during the spring averaged 5.2 thousand tons compared to 22.7 thousand tons in the fall. It is probable that recruitment accounts for most of this increase. When the fall estimate is adjusted for inshore populations and the differences in diel catch rates, the fall apparent abundance is calculated to average 60,000 tons. Total standing stock cannot be determined without additional information.*

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INTRODUCTION

Loligo pealei Lesueur, known variously as the long-finned squid, common squid, bone squid, and the winter squid, is abundant in waters off the eastern United States. *L. pealei* is a neritic species inhabiting the waters over the continental shelf, and is one of five Atlantic members of the genus *Loligo*. The species has recently received much attention in Northwest Atlantic fisheries.

Intensive fishing operations by Japan, Italy, Spain, Federal Republic of Germany, Cuba, the Soviet Union and others, have resulted in record harvests of long-finned squid in the waters between Georges Bank and Cape Hatteras. A National Marine Fisheries Service (NMFS) Market News Report (B-8, Jan. 11, 1973) indicated that in 1971 the Japanese catch of squid "off New York" amounted to 15,000 metric tons with an additional 5,000 tons harvested by the Spanish. Yet, despite this surge of commercial activity, knowledge of the ecology and life history of this squid remains limited.

Literature pertinent to the biology of *L. pealei* stocks between Cape Hatteras and Georges Bank has been reviewed by Mercer (1970a); Summers (1969), in collaboration with NMFS, determined the relative abundance and winter distribution of *L. pealei* in Atlantic coastal waters during 1967 and 1968; Vovk (1969) reported on a large number of trawl collections taken between 1958 and 1968 by AtlantNIRO. Mercer (1969a, 1969b, 1970c) analyzed the long-finned squid catches taken by the *A. T. Cameron* in otter trawl surveys on the continental slope of the western Atlantic and provided observations on the temperature-depth distribution of the species.

Using NMFS groundfish survey data, Edwards (1968) estimated the standing crop of long-finned squid to be approximately 318 thousand tons for the area between western Nova Scotia and Cape Hatteras. Summers (1969) provided estimates of the overall abundance of long-finned squid in the Middle Atlantic Bight at 3.4 (1967) and 2.1 (1968) thousand tons. He emphasized that these were minimum estimates and indicated that the largest biomass of squid was in the 110 to 183 m depth zone.

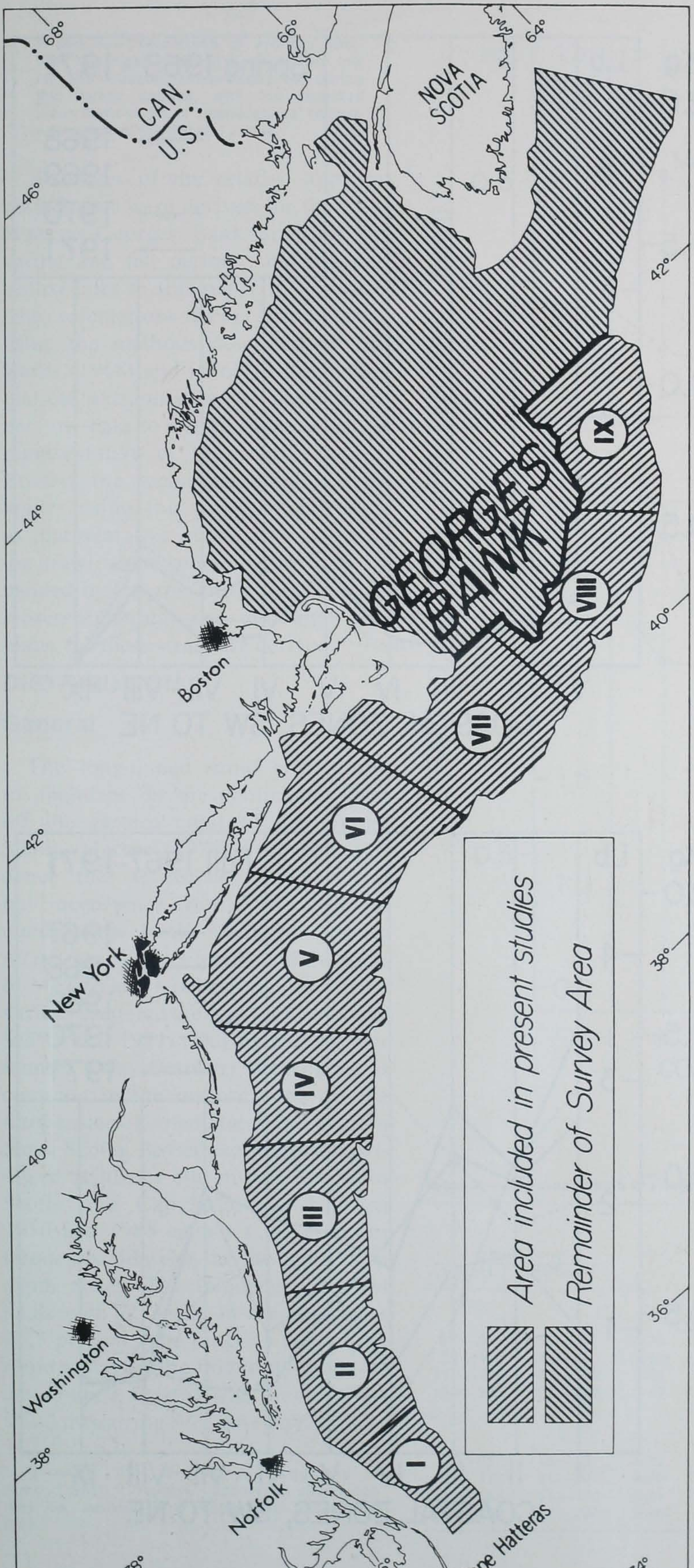


Figure 1.—Atlantic region sampled by semi-annual *Albatross IV* surveys showing coastal zones included in this study and the entire groundfish survey area.

DATA AND TECHNIQUES

The NMFS's Northeast Fisheries Center has conducted a semi-annual trawl survey of the fishing grounds between the 27 m and 366 m isobaths from Nova Scotia to Cape Hatteras since the fall of 1967. Operations have been performed using the fishery research vessels *Albatross IV* and *Delaware II*. Each cruise covered an approximate surface area of 75,000 square miles. A general description of the gear and methodology employed in the trawl survey program is provided by Grosslein (1969).

In brief, standard 30-minute otter trawl hauls (3.5 knots towing speed) were accomplished at randomly preselected stations within each of 58 strata (Figure 1). Sampling was organized according to a stratified random design which permitted a minimum of two stations per stratum. The total number of stations sampled differed for each cruise (Table 1), but the sampling scheme provided unbiased availability estimates for individual strata and sets of strata. Catch data for *L. pealei* from nine of these cruises and the relation of catch to geographical area, depth, and bottom water temperature are presented in this paper. Comparisons between spring and fall catch patterns are also documented.

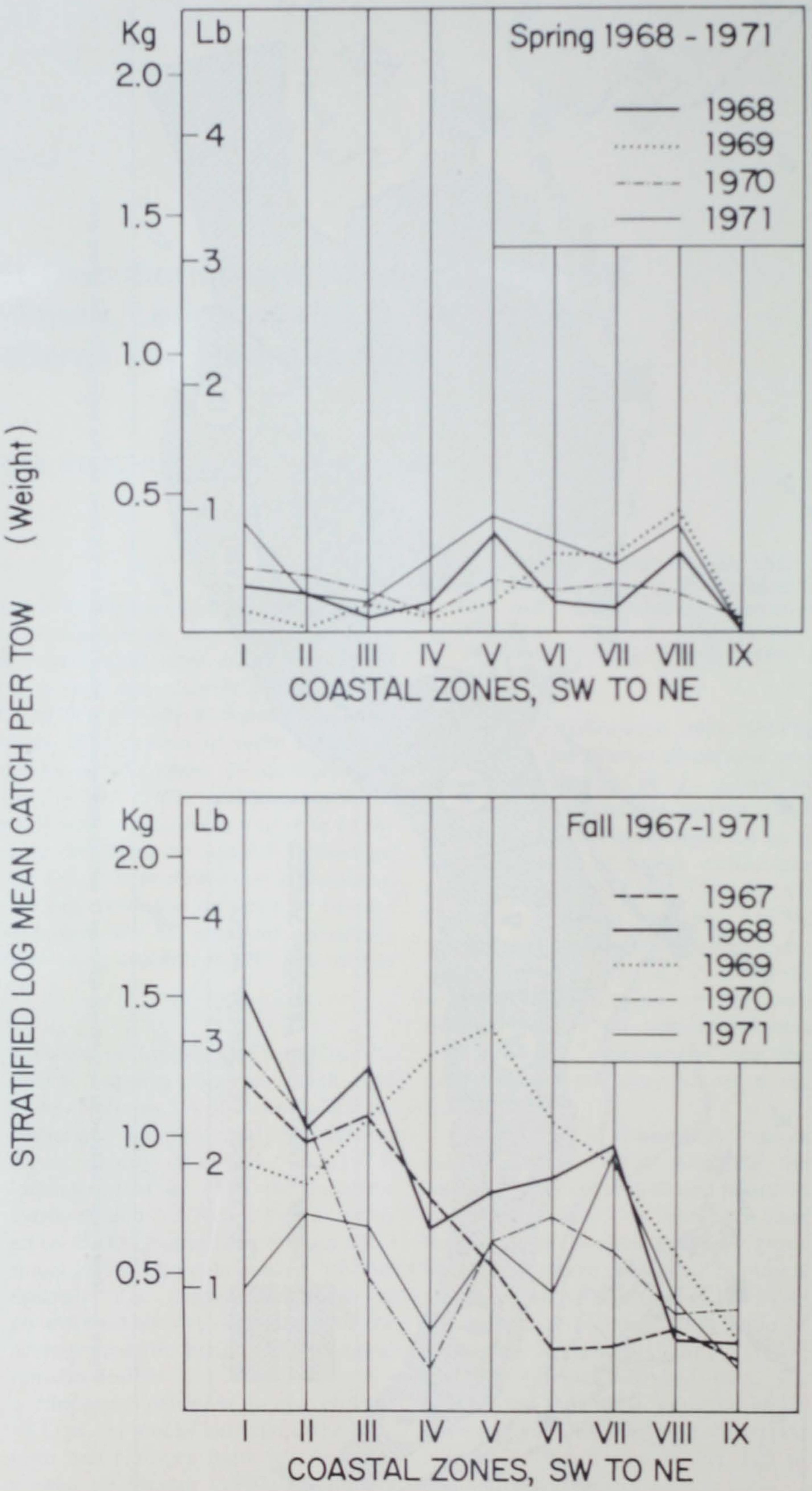
Table 1.—Inclusive dates for spring and fall *Albatross IV* survey cruises, 1967-1971.

Year	Season	Dates	No. of stations
1967	Fall	17 Oct—9 Dec	271
1968	Spring	4 Mar—16 May	262
1968	Fall	10 Oct—26 Nov	275
1969	Spring	5 Mar—10 Apr	266
1969	Fall	8 Oct—23 Nov	276
1970	Spring	12 Mar—29 Apr	289
1970	Fall	3 Sep—11 Sep 15 Oct—20 Nov[1]	294
1971	Spring	9 Mar—1 May	301
1971	Fall	30 Sep—19 Nov	303

[1] First leg of this survey operation was performed with research vessel *Delaware II* using same equipment and following same procedures as *Albatross IV*.

The survey data examined includes the results of 2,537 otter trawl stations between Cape Hatteras and Nova Scotia. The catch of long-finned squid amounted to a total of 7,483 kg. Of

Figure 2.—Index of log mean catches of *L. pealei* per tow by coastal zones.



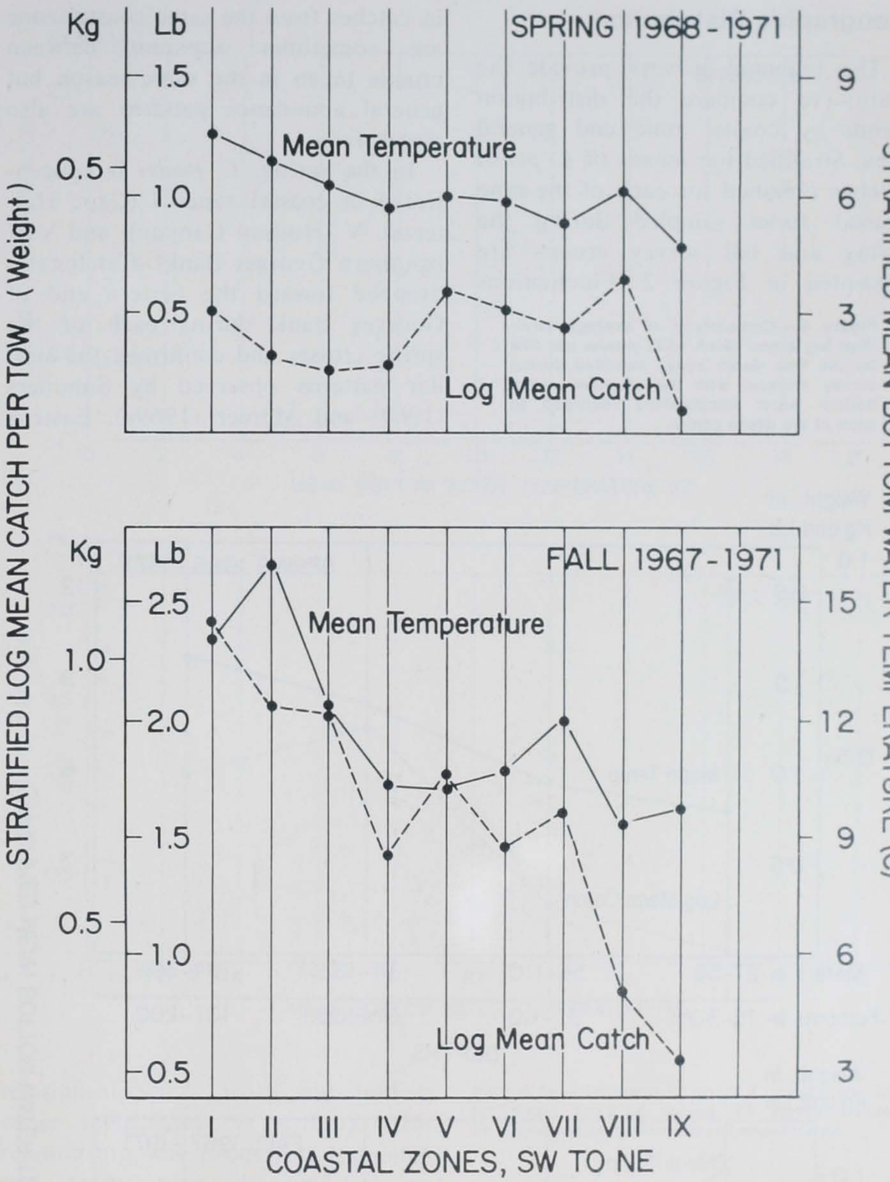
this total, 99.3 percent (7,429 kg) was taken in 784 trawl stations between the eastern portion of Georges Bank and to the south and west of Cape Hatteras; only these data are analyzed here.

The survey area between Georges Bank and Cape Hatteras was classified into nine coastal zones (designated by Roman numerals in Figure 1). Each zone possessed four sampling strata (except zones VIII and IX with only three strata) corresponding to the following depth range boundaries: 27-55 m (15-30 fm), 56-110 m (31-60 fm), 111-183 m (61-100 fm) and 184-366 m (101-200 fm). These area and depth classifications facilitated comparisons of data from similar regions from the nine cruises.

Catches of *L. pealei* were recorded aboard ship for each haul (sampling station). Routine data tabulated included total weight, length frequency, and total number of the individuals caught. Often, when large numbers of specimens were obtained, subsampling procedures were utilized. Concurrent with the biological sampling operations, hydrographic measurements were recorded for each station. These included bathythermograph casts which provided bottom temperature data. Upon completion of a survey, all catch information was transferred from trawl logs to magnetic tape permitting automatic data processing and computer summarization.

The stratified mean catch of *L. pealei*, calculated after a $\log_e$ transformation and expressed in terms of kilograms per tow, was used as an index of abundance. Log mean catch values have previously been employed in assessing *L. pealei* stocks (Summers, 1969), and are useful in evaluating species abundance trends when the frequency distribution of the catch is highly skewed (Grosslein, 1971). Such a positively skewed distribution was evident in squid catches in the present study and is frequently observed with other marine organisms.

Figure 3.—Comparison of average stratified log mean catch of *L. pealei* per tow for the coastal zones sampled during the survey cruises, with the stratified mean bottom water temperatures recorded in each of the coastal zones.



Estimates of the relative apparent abundance[1] were derived for the Cape Hatteras-Georges Bank area for the spring and fall periods, and are presented later in this paper in Figure 6. The calculations were accomplished using the methods described by Edwards (1968) and involved the mathematical extrapolation of mean catch per tow data to obtain biomass values representative of the areas sampled. Briefly, the technique employed involves using the trawl catch results as representative of the area swept by the trawl; these amounts are then expanded by the area these trawl catches represent (strata) and minimum estimates for these strata are derived.

DISTRIBUTION

General

The long-finned squid is common to abundant on the continental shelf off the eastern coast of the United States. Mercer (1970b) provides evidence that it reaches Nova Scotia but occurrence north of there is questionable. In the south, this species ranges at least to Florida and the Gulf of Mexico and has been reported from various scattered areas in the Caribbean Sea (Voss, 1971). During the warmer months (May-October) the species is common in the inshore zone off the northeastern United States and western Nova Scotia. Soviet exploratory trawling to depths of 800 m between Nova Scotia and Cape Hatteras between 1958 and 1968 caught *L. pealei* most frequently between the 40 and 225 m depth zones. The frequency of trawl hauls with *L. pealei* in the catch was 47.7 percent. The range in size of the squid taken during this study was 5-45 cm (mantle length) with most of the squid measuring 8-22 cm (Vovk, 1969).

[1] Following the terminology suggested by Marr (1951), "relative apparent abundance" may be derived from catch per unit-of-effort data.

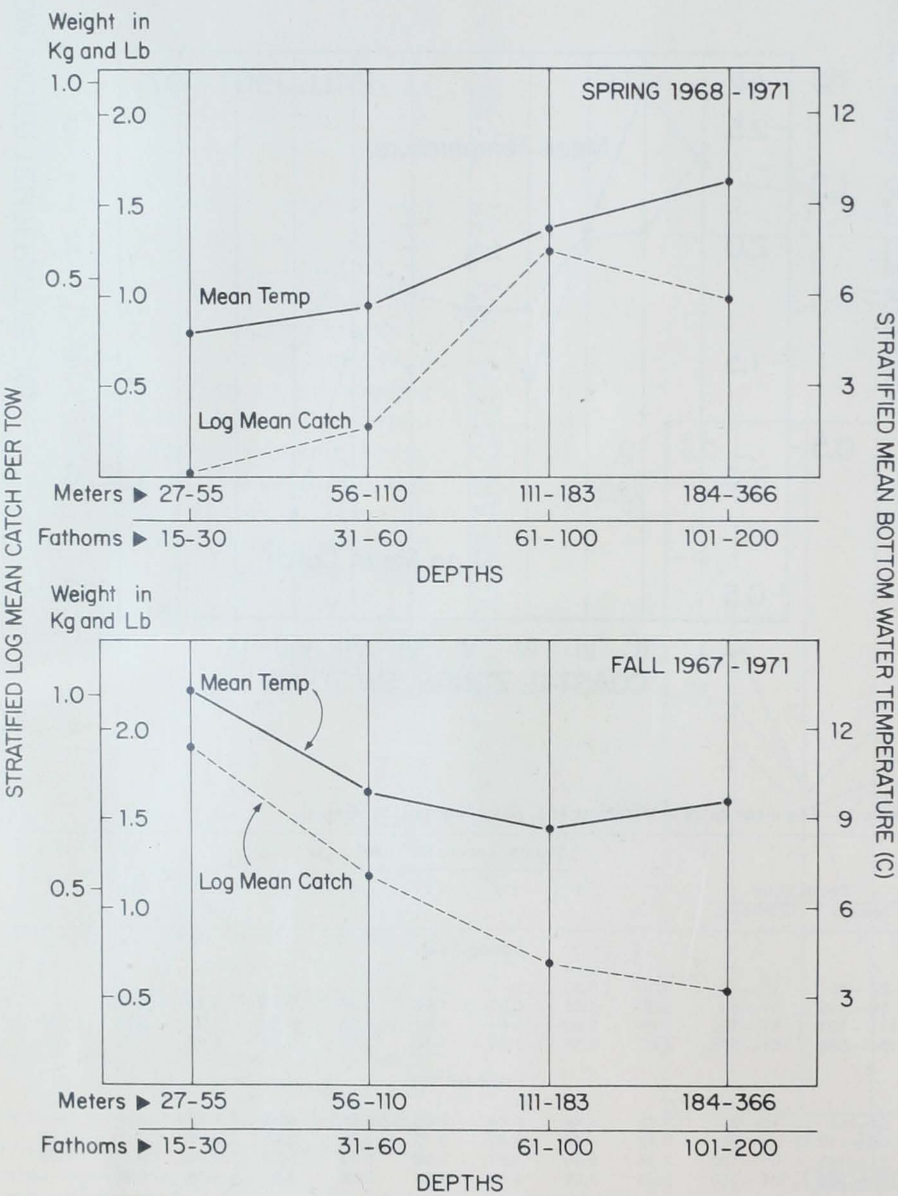
Table 2.—Log mean catch in kilograms of *L. pealei* per tow, by stratum.

Depth Zone		Coastal Zones, SW to NE								
Meters	Fathoms	I	II	III	IV	V	VI	VII	VIII	IX
					Spring 1968-71					
27—55	15—30	0.19	0.29	—	—	—	—	—		
56—110	31—60	3.30	1.65	0.22	1.06	1.76	0.77	0.22	0.33	—
111—183	61—100	7.04	5.83	5.83	4.84	5.83	4.62	4.62	5.46	1.39
184—366	101—200	4.07	2.31	2.53	1.10	0.95	2.00	2.60	1.72	1.07
					Fall 1967-71					
27—55	15—30	5.72	4.40	4.84	2.68	4.05	4.49	4.18		
56—110	31—60	4.49	4.66	4.00	3.70	3.39	2.03	3.56	2.20	1.36
111—183	61—100	2.14	6.16	3.34	3.56	5.19	5.50	2.38	0.79	0.26
184—366	101—200	2.46	1.89	1.85	2.29	2.68	1.85	0.79	0.62	

Geographic Distribution

The biannual surveys provide the ability to compare the distribution trends by coastal zone and general area. Stratified log means of *L. pealei* catches obtained for each of the nine coastal zones sampled during the spring and fall survey cruises are presented in Figure 2. Fluctuations in catches from the same coastal zone are sometimes apparent between cruises taken in the same season but general abundance patterns are also discernible.

Figure 4.—Comparison of average stratified log mean catch of *L. pealei* per tow for the four depth zones sampled during survey cruises, with the stratified mean bottom water temperature recorded in each of the depth zones.



In the spring, *L. pealei* is concentrated in coastal zones I (Cape Hatteras), V (Hudson Canyon), and VIII (southern Georges Bank). Catch rates dropped toward the eastern end of Georges Bank during each of the spring cruises and confirmed the similar patterns observed by Summers (1969) and Mercer (1969a). Eastern Georges Bank represents the approximate boreal limit of the long-finned squid during the March-May period of the surveys.

In the fall, *L. pealei* stocks exhibited a maximum abundance in the southern areas and generally diminished in magnitude toward the northeast. Catches usually were larger at Hudson Canyon (zone V) and Cape Cod (zone VII) than those taken in adjoining areas and probably are indicative of local aggregations of squid in these waters. Concentrations of *L. pealei* were invariably greater during the fall than they were in the spring. Presumably this was a result of an increase in population size resulting from recruitment, although seasonal differences in availability and trawl efficiency are believed to account for part of the apparent differences.

Bathymetric Distribution

Other investigations (Vovk, 1969; and Summers, 1967) have established that long-finned squid concentrate along the outer edge of the continental shelf during the months when inshore water temperatures are low (December-April).

Variations in catches of *L. pealei* with depth contrasted sharply between spring and fall; these differences are indicated in Table 2. Catch indices are presented by stratum to illustrate similarities existing between regions of equal depth in different coastal zones.

Relatively large concentrations of squid occurred in spring in depths of 111-183 m (61-100 fm). Abundance indices for this depth zone were several times greater than those for other depths in each of the nine coastal zones. Individuals were seldom taken in less than 55 m and were never obtained in shallow waters north of Chesapeake Bay (coastal zone II). These observations parallel the findings of previous investigators (Mercer, 1969a; Summers, 1969; Vovk, 1969), and are further substantiated by the large mid-depth (111-183 m) catches of long-finned squid taken by the

Japanese fleet off of New York during winter and early spring, 1971-1972.[2]

Observations on bathymetric distribution of *L. pealei* in the fall indicated that the species was dispersed throughout the area in waters less than 110 m. Concentrations inshore were generally higher than during the spring. A similar phenomenon observed during the autumn in the area between Block Canyon and southern Georges Bank was noted by Vovk (1969).

A segregation of individuals of similar size with depth was common to both the spring and fall distribution of squid. Larger individuals usually were found at greater depths than were smaller specimens. This relationship is evident in the fewer squid per kilogram obtained in deeper waters during both seasons (Table 3). Comparable observations on the correlation of squid size with depth have been previously documented (Summers, 1967; Mercer, 1969a).

Table 3.—Stratified mean number of *L. pealei* per kilogram obtained from the four depth zones sampled.*

	Depth Zones			
Cruise	27—55 15—30	56—110 31—60	111—183 61—100	184—366(m) 101—200(fm)
Spring 1968	103.6	30.4	17.2	13.6
Spring 1969	—	20.2	12.1	9.9
Spring 1970	66.6	26.0	29.5	13.4
Spring 1971	334.6	29.9	12.1	9.9
Fall 1967	43.3	30.6	13.0	12.1
Fall 1968	30.4	20.0	15.4	15.0
Fall 1969	36.3	18.7	15.4	17.6
Fall 1970	27.1	29.9	20.24	32.8
Fall 1971	52.1	51.5	69.7	46.4

*According to Summers (1969) "The data may be converted to dorsal mantle lengths by a rough rule of thumb: Five centimeter *L. pealei* are approximately 44/kg, 10 cm *L. pealei* approximately 22/kg, 15 cm approximately 11/kg, 20 cm approximately 5.5/kg, and so on. This rule applies to fresh animals of mixed sexes, but not to squid less about 5 cm dorsal mantle length nor mature animals all of one sex."

Distribution Related to Water Temperature

The presence and abundance of long-finned squid was strongly influenced by water temperature. The relationship of *L. pealei* with bottom water temperature is striking. This relationship was prominent for catch and temperature changes between coastal areas (Figure 3), as well as for changes noted with depth (Figure 4). Squid was generally more abundant at higher bottom temperature both seasons. Summers (1969) reported that major catches of long-finned squid were restricted to a bottom temperature of 8°C or higher during winter. Observations of catch in relation to bottom temperature in the present study suggest that a similar situation exists during the spring and fall (Figure 5). During both seasons the catch of *L. pealei* was greatly diminished in strata with bottom temperatures below 8°C. The largest

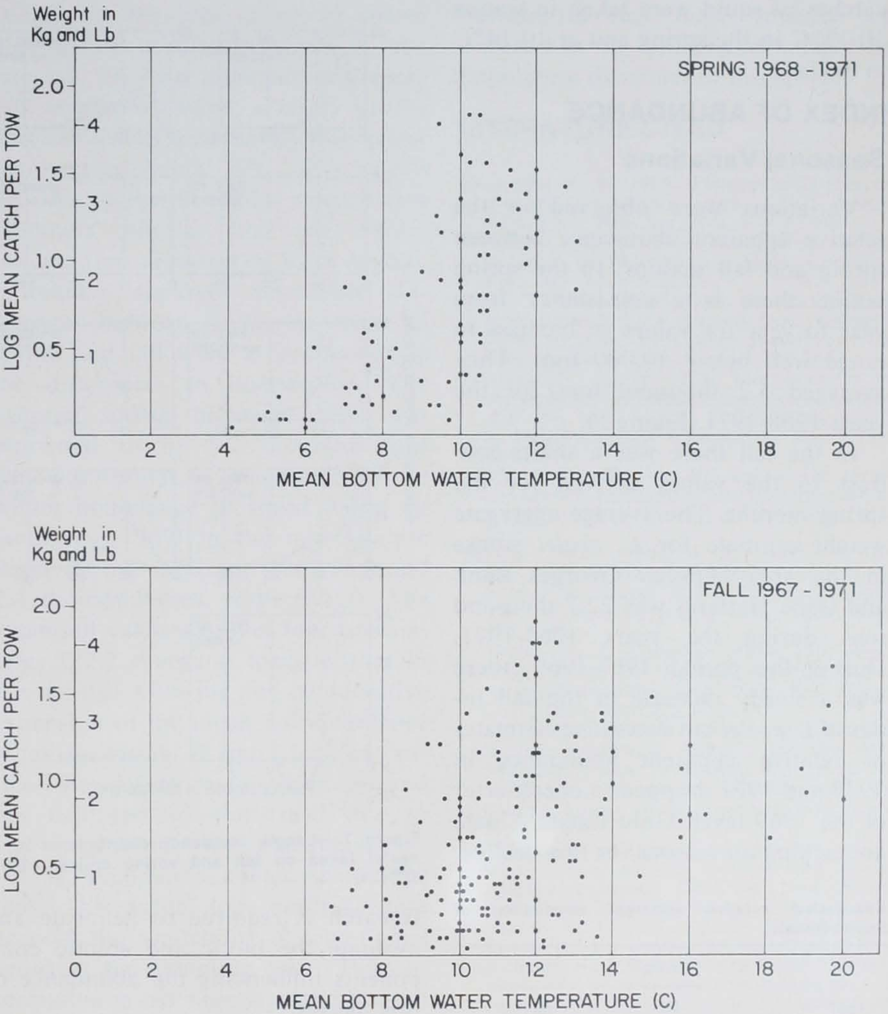
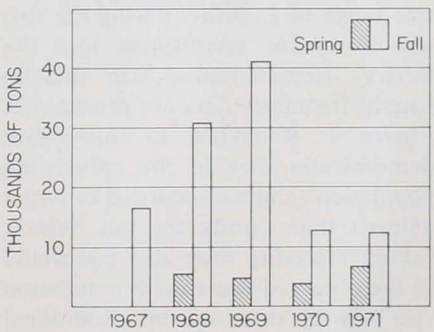


Figure 5.—Log mean catch of *L. pealei* per tow for strata sampled during the survey cruises, as a function of bottom water temperatures.

Figure 6.—Relative apparent abundance of *L. pealei* in the Northwest Atlantic (Georges Bank to Cape Hatteras) for spring and fall, 1967-1971.



[2] Personal communication with NMFS personnel and Boston Market News Report.

catches of squid were taken in waters 10-12°C in the spring and at 10-14°C in the fall.

INDEX OF ABUNDANCE

Seasonal Variations

Variations were observed in the relative apparent abundance between spring and fall seasons. In the spring season there is a consistency from year to year for values of biomass to range well below 10,000 tons. They averaged 5.2 thousand tons for the years 1968-1971 (Figure 6).

In the fall there was a sharp contrast to the values derived for the spring months. The average aggregate weight estimate for *L. pealei* stocks in the area between Georges Bank and Cape Hatteras was 22.7 thousand tons during the years 1967-1971. During the period 1967-1969, there was a steady increase in the fall index of *L. pealei* but successive estimates of relative apparent abundance in 1970 and 1971 dropped to one-quarter of the 1969 level. Unfortunately, data are lacking on reasons for this decline.

Unadjusted relative apparent abundance of *Loligo* (tons).

	Spring	Fall
1967	—	16,790
1968	5,719	30,821
1969	4,878	40,998
1970	3,690	12,710
1971	6,599	12,058
Total	20,886	113,377
Average	5,221	22,675

For any given year, the fall index was several times greater than in the spring. Possible explanations of this phenomenon may be related to the size range of *L. pealei* during the two seasons and/or recruitment into the fishery. Representative size (mantle length) frequency data are provided in Figure 7. Reference to this figure demonstrates that in the spring the population sampled consisted of larger animals than during the fall. Winter fishing mortality may also contribute to the observed decrease in population size between these seasons. Additional

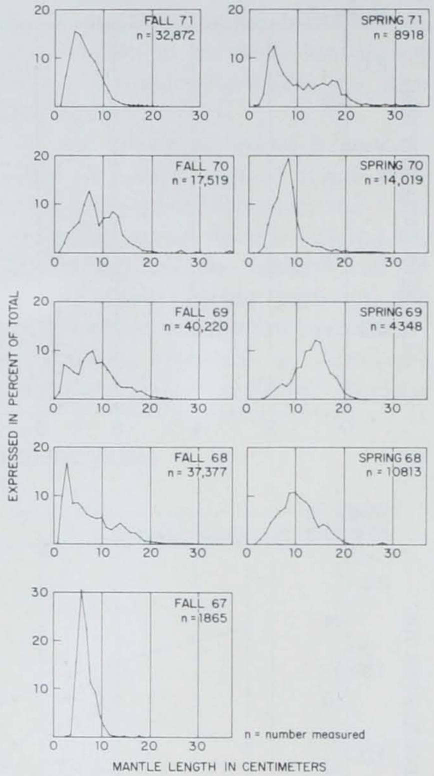


Figure 7.—Length frequency distributions of *L. pealei* taken on fall and spring cruises, 1967-1971.

research is required to delineate and evaluate the biotic and abiotic components influencing the abundance of this species.

It is interesting to note that preliminary evaluation of fall survey data for 1972 shows a strong upward trend from the 1970 and 1971 index values (mean log weight/tow).[3] This information suggests that the four years of moderate to heavy fishing on long-finned squid stocks has not, in itself, been responsible for the decline from 1969 values shown in Figure 6.

The regularity with which fall abundance indices exceed spring values appears to indicate that surveys during the fall season are more valuable in determining changes in abundance. It should also be mentioned that at least a portion of the long-finned squid stocks are distributed at depths shallower than 27 m (15 fathoms) which mark the inshore boundary of the survey area. There is no specific information available which allows estimates of the inshore component to be derived. One study, however, (Summers, 1968) indicates substantial numbers of long-finned squid present in Vineyard Sound in early November 1967, at depths of 20 m. Haefner (1964) records the presence of *L. pealei* in Delaware and Chincoteague Bays during the summer season. As the shallowest depth zone (27-55 m) sampled during the fall surveys accounts for about half the total, an equal or greater density in waters of less than 27 m could add up to 50 percent to the abundance index. This could bring the total apparent abundance to about 34 thousand tons.

Values for both the spring and fall squid populations must be considered as minimum estimates. There is very little information on the vulnerability of *L. pealei* to the trawl gear used in sampling the population, but presumably the effectiveness of the trawl is quite low. Low efficiency is not unusual when sampling pelagic and quasi-pelagic species (Edwards, 1968).

Diel Variation in Catch

Analysis of catch rates by time of day indicates a relationship between day and night catches (Figure 8). This feature of behavior has previously been pointed out by Summers (1969). The phenomenon of daily vertical migration by marine animals is well established in the literature. In the case of the long-finned squid it affects the catches by trawl gear which only samples a narrow band of 3-4 m over the bottom. It follows that estimates of abundance for species which rise off the bottom daily must be cautiously evaluated. We do not have positive information on the reason for long-finned squid leaving the bottom but it may be associated with pursuit of food (such as euphausiids) which are known to migrate in a similar fashion.

In the present study about 90 percent of the survey catch of long-finned

[3] Personal communication, M. D. Grosslein.

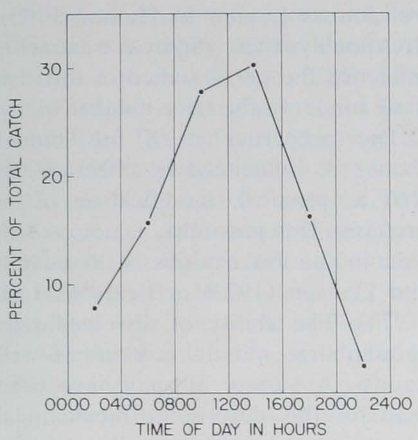


Figure 8.—Diel variation of catches of *L. pealei* survey cruises, 1968-1971.

squid was accomplished during daylight hours. If nighttime catches are increased by 90 percent to allow for squid which were unavailable at night and include our allowance for the population component that inhabited depths of less than 27 m, we will arrive at total calculated apparent abundance of about 60,000 tons for the fall season.

SUMMARY

The distribution and relative apparent abundance of *L. pealei* in the Georges Bank-Cape Hatteras area differed markedly during spring and fall. In the spring, the squid were located in modest numbers offshore in depths of 111-183 m, while in fall individuals were most abundant inshore at depths less than 110 m. This striking change in population can be accounted for by migration. Summers (1969) found that *L. pealei* migrate inshore in the late spring to spawn and return to deeper waters in the late fall. He also indicated that these fall migrations were a result of the species' intolerance to bottom water temperature below 8°C. The results of the present study corroborate Summers' findings and the similar observations reported by Vovk (1969).

Relative apparent abundance differences between *L. pealei* stocks in spring and fall were as prominent as the differences in distribution. The average spring biomass value was estimated to be 5.2 thousand tons and was similar in magnitude to the winter abundance of squid found by Summers (1969) in the mid-Atlantic Bight during 1967 and 1968 (3.4 and 2.1 thousand tons, respectively). The mean fall value was over four times as large (22.7 thousand tons) as that in the spring. Allowing for conservative expansion of the mean fall abundance index by virtue of squid located outside the survey area (inshore) and not captured by the trawl due to diel migrations, the calculated apparent abundance comes to 60,000 tons. This value does not take into account the availability of long-finned squid to the sampling gear. This information is not known at the present time. Until coefficients of availability and vulnerability are ascertained for *L. pealei*, all estimates must be considered tentative.

Data made available from the 1972 fall groundfish survey suggest that the downward stock fluctuations of 1970 and 1971 observed in this study are not necessarily fishery-related. The increase of commercial interest in sustaining a fishery for *L. pealei* necessitates that more research be undertaken to better understand the population dynamics of this species.

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