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ABSTRACT :

Observations and data gathered on the fishery and biology of the white hake are presented. Characters distinguishing the white hake present in the study area from the red hake, often confused with the former, are listed. Hake landings are largest in this area (ICNAF division 4T). The offshore vessels landed larger hake (50-70 cm) than the inshore fishermen (40-55 cm).

After trying various skeletal structures, otoliths were finally used for age determination studies. A yearly length increase of 7-9 cm was estimated for hake from both Cape Bear, P.E.I. and Cheticamp, N.S. Males and females from Cape Bear were 50% mature at 4 years of age (52 cm) and 5 years of age (59 cm) respectively. Peak spawning occurred during the second half of June. Fecundities were found to increase exponentially with length. The fecundity of a 62 cm hake was 540,000 while that of a larger one of 109 cm was 29 million ova.

Biology of Hake (Urophycis tenuis Mitchill) in Gulf of St. Lawrence

On the Biology of the Hake (Urophycis tenuis Mitchill)

in the Southern Gulf of St. Lawrence

by

Stephen J. Nepszy

A thesis presented to the Faculty of Graduate Studies and Research of McGill University in partial fulfilment of the requirements for the degree of Master of Science.

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1. INTRODUCTION

The common white hake (Urophycis tenuis Mitchill) of the Canadian Atlantic coast has been fished consistently in the North-west Atlantic ocean and especially in the Gulf of St. Lawrence with little being known of its biology or habits. It is often caught with cod and haddock but full investigation of the species was not carried out because of its low commercial value. The white hake is exclusively an Atlantic water species, ranging in distribution from Newfoundland to Cape Hatteras (Bigelow and Schroeder, 1953). It is fished by both inshore and offshore vessels in the southern Gulf of St. Lawrence, on the Grand Banks of Newfoundland and in the Bay of Fundy. In the Gulf of Maine and off southwestern Nova Scotia, it is often caught with the closely allied but smaller red hake (Urophycis chuss Walbaum).

Since hardly any knowledge of the contribution of the white hake to the Northwest Atlantic fishery or the general biology of the species is known, an investigation into these aspects was launched by the Biological Station of the Fisheries Research Board of Canada, St. Andrew's, New Brunswick.

The only information available on the white hake was found in the length and weight observations of Cornish (1907), Craigie (1927) and Cox (1921), the studies made by Battle (1951) and the growth estimations of Rojo (1955). The first three authors could not distinguish between red and white hake and presumed that most of the hake examined were *Urophycis chuss*. Other observations and data were also obtained from past records kept at the Biological Station.

The area chosen in which to study this species was the southern Gulf of St. Lawrence primarily because the landing statistics showed it to be one centre of abundance of hake. Since the fishery here is a summer one, the field work reported was carried out during the summer months of 1965 and 1966 from the fishing port of Souris, Prince Edward Island (Fig. 1). The two fish plants in this town process the catches brought in by 16 otter trawlers and a strong force of inshore fishermen. Consequently, a great deal of fish were available for sampling and close examination.

2. MATERIALS AND METHODS

Sampling of fish was done on research vessel surveys, commercial otter trawlers, and at the fish plants and wharves of Souris. During the summer of 1965, length measurements (tip of snout to end of tail), otoliths and sex differences were obtained for the fish sampled. However, in the following summer, state of maturity, weight, and some stomach contents were also recorded for most of the hake examined.

Cruises on the research vessel, M.V. Harengus, of the Biological Station were undertaken during both summers. The hake were caught by otter trawl. The cod end of the net had a 1 $^{1}/_{8}$ inch liner to capture the small and consequently young hake. All the fish caught on these cruises were examined for the features mentioned previously.

Because of the desire of the fishermen to eviscerate and store the hake in the hold as quickly as possible, only a portion of the total catch of the commercial trawler could be sampled. As the catch was landed on the deck, 6 quart baskets of fish were taken randomly and sampled. The baskets usually contained approximately 25-35 hake. Trips and samples were taken, during both summers, on the commercial trawler, M.V. Paula Marie of Souris.

The hake caught by otter trawlers were landed with viscera removed and heads on. At the fish plants, they were unloaded into crates with 400 pounds of fish weighed out to each crate. Hake larger than 80 centimeters (cm.) in length were culled and placed in separate crates. However, culling was not often necessary because of the scarcity of very large hake. When sampling at the plant, two or three crates were chosen at random from the total catch of one vessel and the fish contained therein were measured and sometimes weighed individually. Otoliths were usually removed from a stratified sample; that is, two pairs of otoliths were taken from fish of each centimeter length group.

The inshore fishermen landed their catches in the whole or round condition and then proceeded to eviscerate them on the wharves. Since the catch landed from individual boats usually averaged 1000 pounds or less, the entire catch could be measured without difficulty. Generally, the eviscerated hake were measured and otoliths removed but, occasionally samples of round fish were put aside and examined for sex differences and state of maturity.

3. THE FISHERY

Identification

Prior to giving an account of white hake in the Gulf of St. Lawrence, reliable identification of the species studied as Urophycis tenuis Mitchill had to be established. At the beginning of the century, Craigie (1927) and Cox (1921) referred to the hake they examined in the Gulf of St. Lawrence as red hake (Urophycis chuss Walb.). Cornish (1907) was uncertain whether those which he examined were red or white hake. Other observers (Vladykov and McKenzie, 1935) considered only one species, the red hake, present in the Gulf. Leim and Scott (1966) mention that both species are in the Gulf of St. Lawrence but that it is extremely difficult to distinguish between them. Musick (personal communication) of the United States Bureau of Commercial Fisheries, who was studying the red hake along the Atlantic coast and especially in the Gulf of Maine, examined some hake from the Gulf of St. Lawrence sent to him in 1965. At first examination, he found them unusual and thought that they possessed characteristics of both red and white hake. However, upon subsequent and more thorough observations of hake landed at Souris, he was firmly convinced they were indeed Urophycis tenuis Mitch.

Listed below are the characteristics he gives distinguishing the two species of hake.

Table 1. Characters for identification of red (*Urophycis chuss*) and white (*Urophycis tenuis*) hake.

Character	*Urophycis chuss*	*Urophycis tenuis*
1. Color	reddish brown	purplish grey (with bronze overtones.)
2. Gillraker count	3 on upper bar	2 on upper bar.
3. Scales on lateral line	94-118	120-145.
4. Dorsal fin filament	2X or > the length of 1st dorsal	< 2X the length of 1st dorsal.
5. Length at maturity	28 to 32 cm. and >	> 55 cm.
6. Maximum total length	52 cm.	125 cm.

In this study, the hake examined conformed to characteristics 1, 3, 4, 5, and 6 for the white hake. Since Musick discovered character 2 during the latter part of the 1966 summer when most of the sampling for this study was completed, it was not looked for. Consequently, no information on this character was obtained. Since the hake he examined at Souris were figuratively the same as sampled during both summers for this particular study, the latter were then also considered *Urophycis tenuis*.

Distribution

According to the observations of Bigelow and Schroeder (1953), the white hake has a general distribution from Newfoundland to Cape Hatteras. They are at the northern part of their range in the Newfoundland area, occurring on the south coast at St. Pierre Bank and the southern part of the Grand Bank (Templeman, 1966). Large numbers of hake are seldom reported and they are seldom found far north of the southern Grand Bank (Frost, 1938; Templeman, 1966). In the latter areas they are caught incidentally with redfish or haddock. In the Bay of Fundy and off southwestern Nova Scotia, the white hake are often caught and landed with the smaller red hake and rarely distinguished from them.

From the landing statistics of the Dominion Bureau of Statistics and the International Commission of the Northwest Atlantic Fisheries (ICNAF), the greatest abundance of hake was located in ICNAF division 4T (Fig. 2). Both inshore and offshore fishing for hake is carried on in this region.

Evidence for two main fishing grounds for hake was obtained from questioning the offshore fishermen. One area is off Cheticamp, Nova Scotia (Fig. 1) in a gully of 92-110 meters depth. This area was considered at one time a very popular fishing ground for haddock and hake, but in recent years the catches have diminished. The other location is in the Northumberland Strait off Cape Bear, Prince Edward Island, where depths are in the 37 meter range (Fig. 1). A great quantity of hake is caught here during the late summer and early autumn

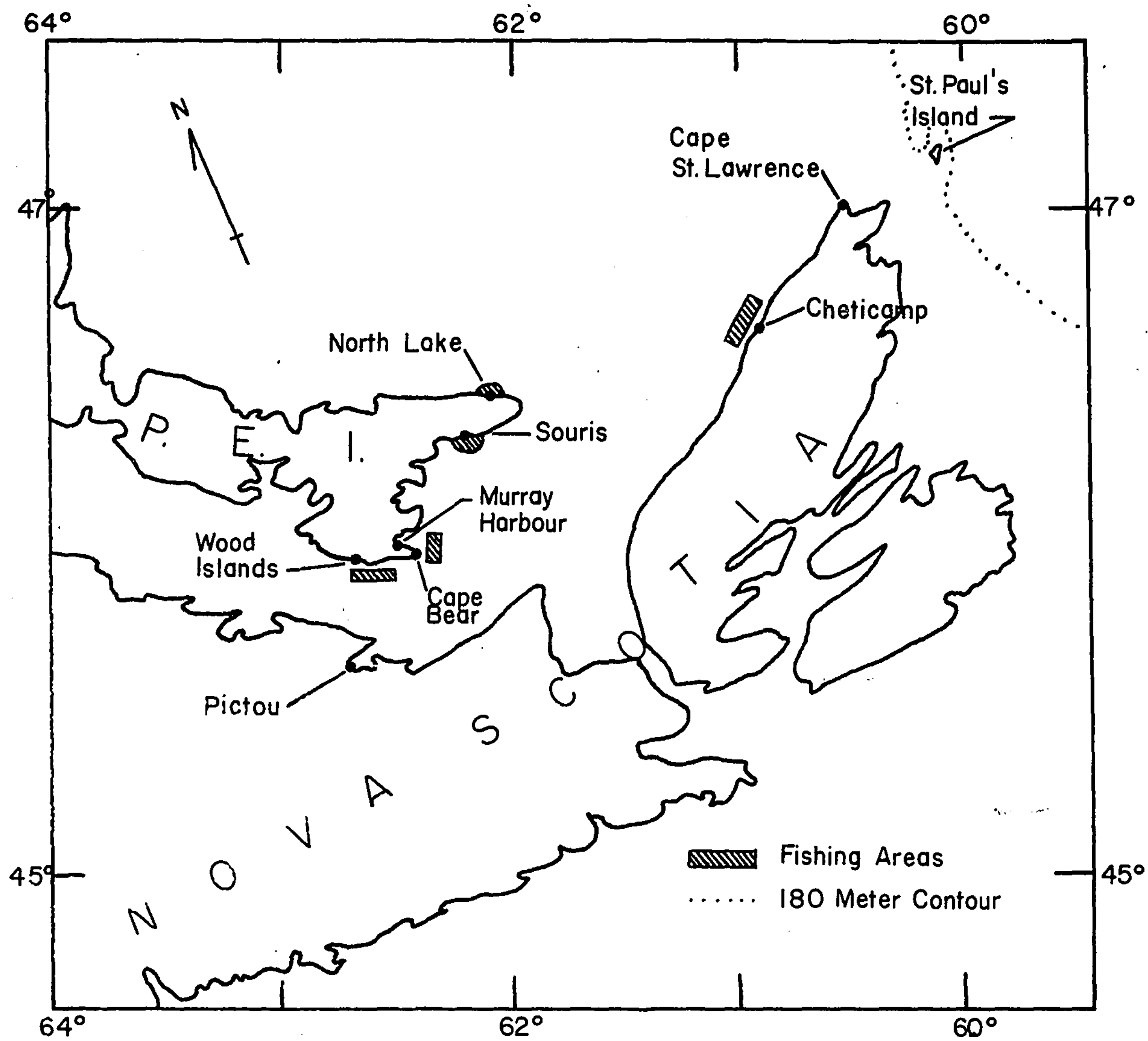

Fig. 1. Map showing the main fishing areas in the study region where Urophycis tenuis Mitch. was caught. The localities of this region mentioned in tne text are also included.

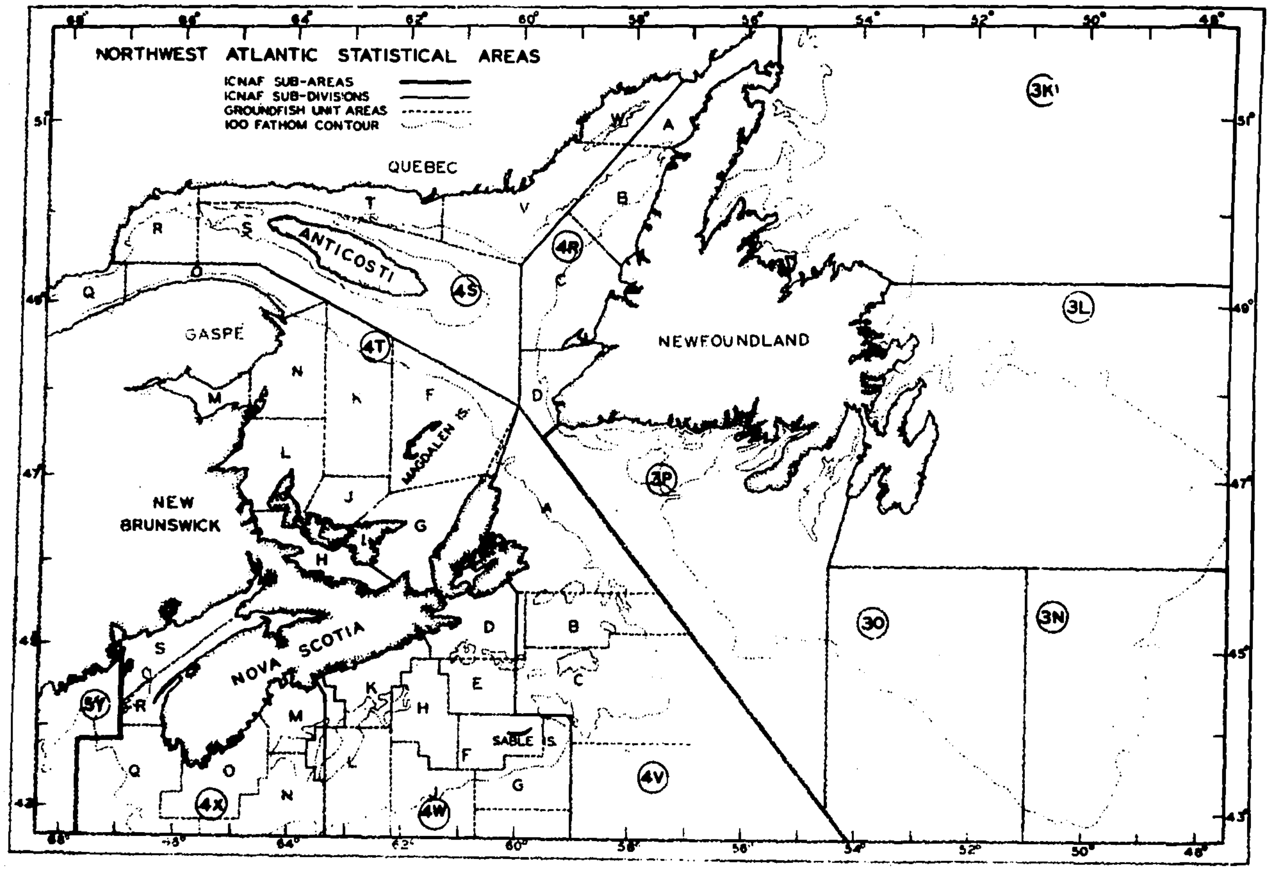

Fig. 2. Map showing the ICNAF statistical subareas and divisions for the Maritimes, Quebec and Newfoundland.

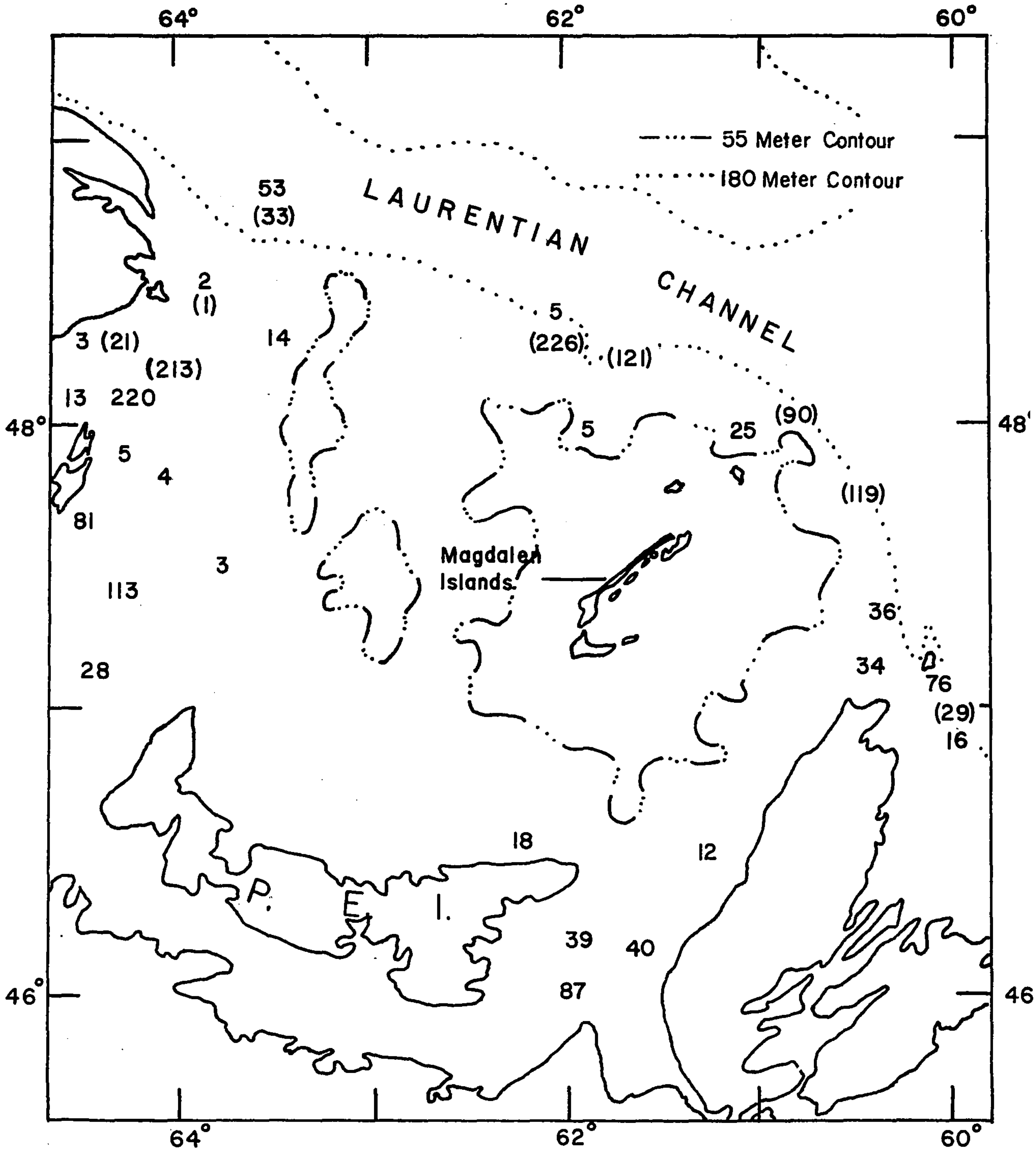

Fig. 3. Numbers of hake caught at different locations by the research vessels: (1) M.V. Harengus from May 1959 to November 1965 and (2) C.G.S. Cameron (numbers of fish in parenthesis) from January 1960 to April 1962.

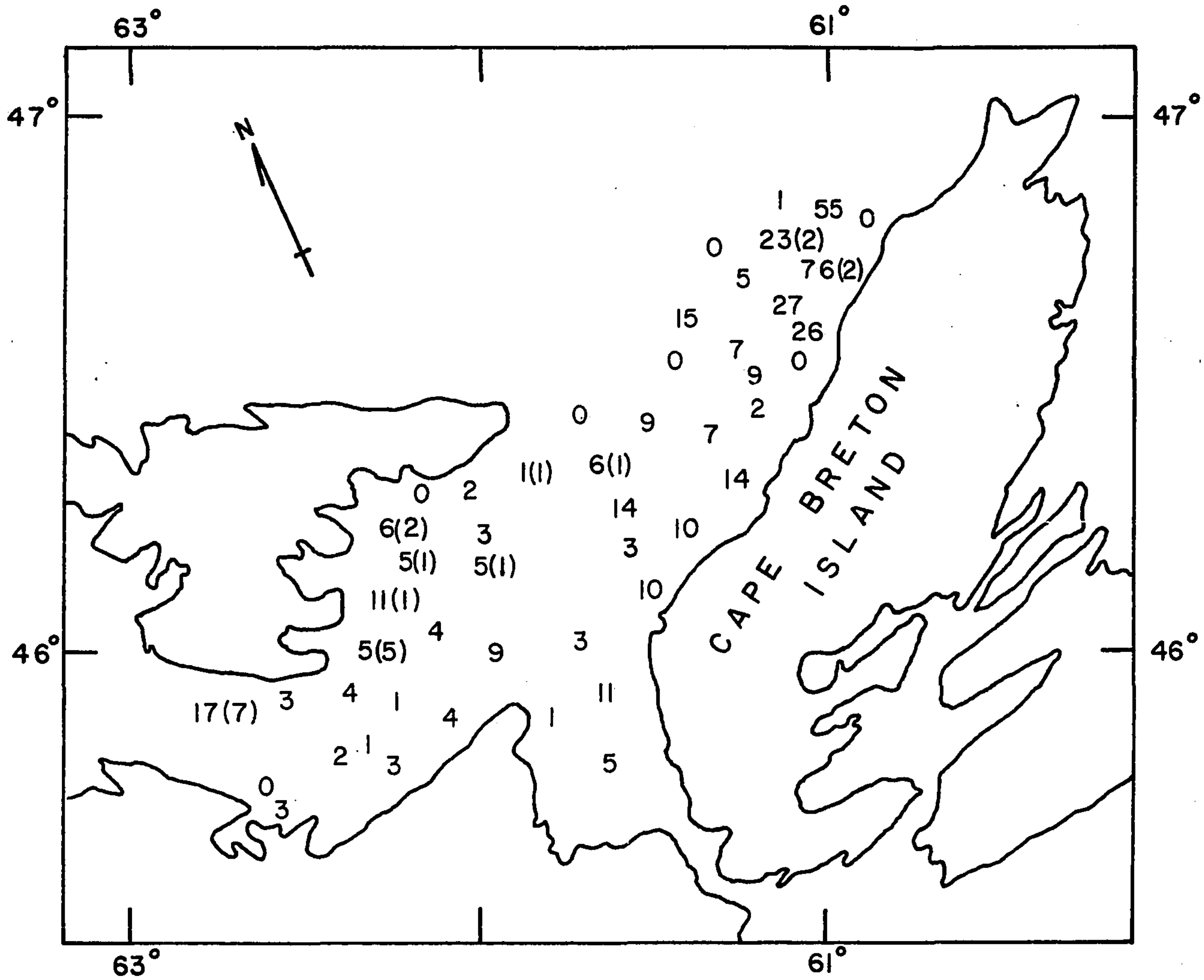

Fig. 4. The stations and respective numbers of white hake caught per $^1/_2$ hour tow at each station during the M.V. Harengus cruise, June 6-18, 1966. Numbers in parenthesis refer to the numbers of ripening female hake caught per station and from which the ovaries were preserved.

months.

In addition to the offshore areas, there are also a few inshore fishing areas in the region studied. At Souris, hake fishing is done 3 to 4 miles east of the town in waters of 24 to 37 meters depth. Further south, at Murray Harbour, the inshore boats generally go out 10 to 20 miles to set their lines. North of Souris at North Lake (Fig. 1), the fishermen set their gill nets 4 to 5 miles from the shore.

Records of white hake catches in the Gulf of St. Lawrence by the research vessels, M.V. Harengus and C.G.S. Cameron were obtained and plotted in Fig. 3. The records revealed that hake were caught as far north as the Gaspé tip and along the western edge of the Laurentian Channel.

In an effort to obtain more knowledge of the distribution of this species in this region, a survey cruise was undertaken on the M.V. Harengus from June 6-18, 1966. The forty-nine sampling stations and the quantity of hake caught per stations are shown in Fig. 4. The 1 $^{1}/_{8}$ inch liner was placed in the cod end of the net and half-hour tows were taken at each station. Only 428 hake were caught and examined during the entire survey. The figure shows a concentration of hake caught in the Cheticamp area in the gullies fished by commercial otter trawlers.

Hake are ground dwellers and more sluggish in movement than other groundfish. This is not conclusive proof that they do not migrate over great distances but it probably is a contributing factor. However, enough information was not amassed to state whether there is any seasonal migration of this species.

Landing Statistics

Landings of hake for the Maritimes and Quebec are recorded solely as hake (Urophycis spp.) in the Fisheries Statistics of Canada from 1942-1965. White and red hake landings are not differentiated. The statistics for hake landed in the Maritimes and Quebec from 1942 to 1965 are shown in Fig. 5. The greatest contributors to this fishery are the provinces of Prince Edward Island and Nova Scotia. In the years prior to 1963, P.E.I. generally contributed one third of the total hake landed while Nova Scotia contributed approximately one half of the total landings. However, in the years from 1963 to 1965, each of these two provinces has contributed one half of the total hake landed in Eastern Canada.

In an effort to obtain the total landings for *Urophycis tenuis*, the ICNAF landing statistics for subarea 4 were studied since this was the region where most of the white hake were caught (see Fig. 2). From 1954 to 1959, the landings of white and red hake are recorded separately. The white hake landings are recorded for the Maritimes, Quebec and Newfoundland, while red hake figures are recorded for the United States only. The ICNAF landings from 1955 to 1958 for the Maritimes and Quebec correspond to those figures recorded by the Canadian Fisheries Statistics. However, beginning in 1959, the ICNAF statistics recorded unspecified hake (both red and white) for all of Eastern Canada and white hake alone for the United States. From 1961 to 1964, the two hake species are separated for United

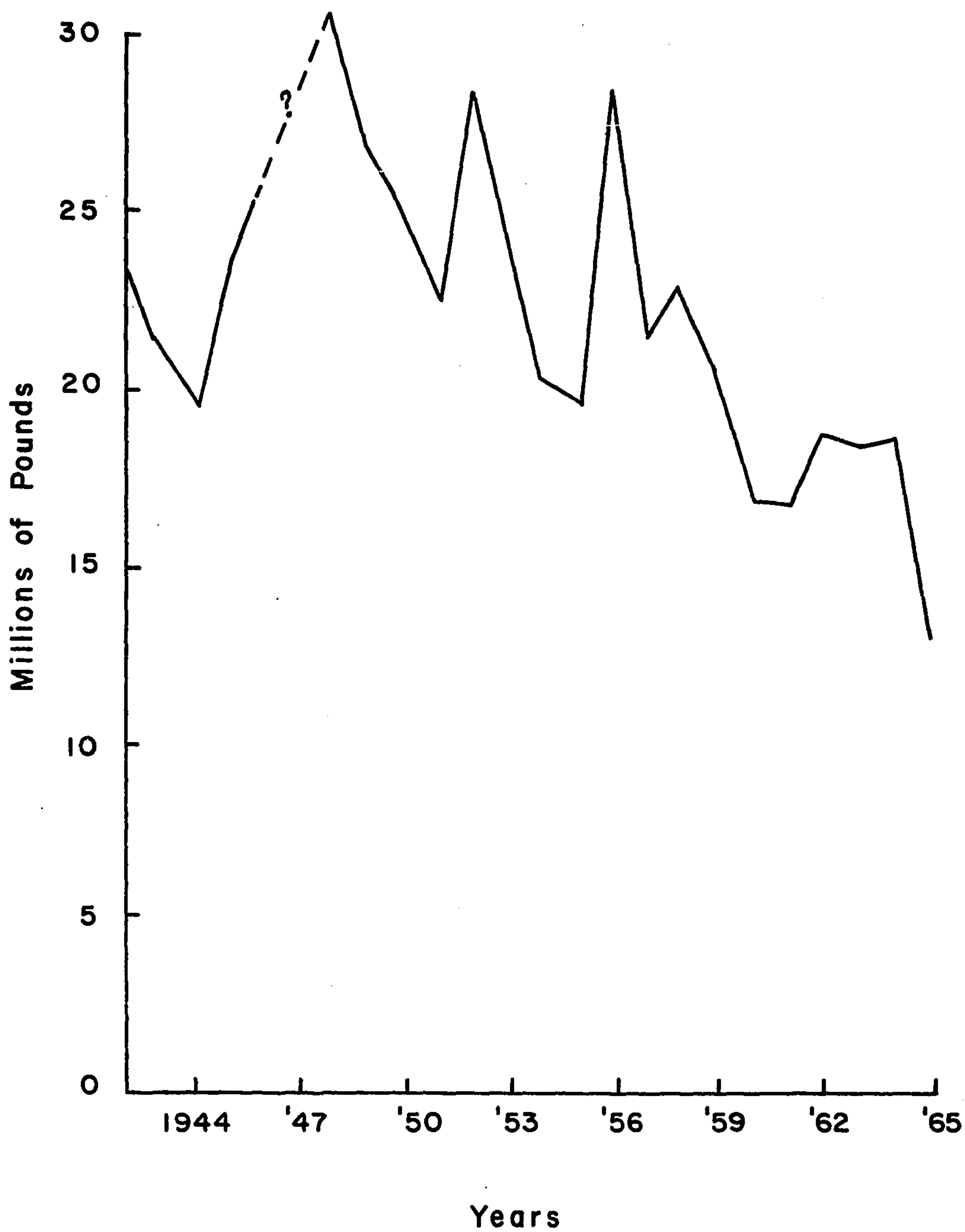

Fig. 5. Total landings of hake, both red and white, in millions of pounds (gutted-heads on weight) in the Maritimes and Quebec from 1942 to 1965.

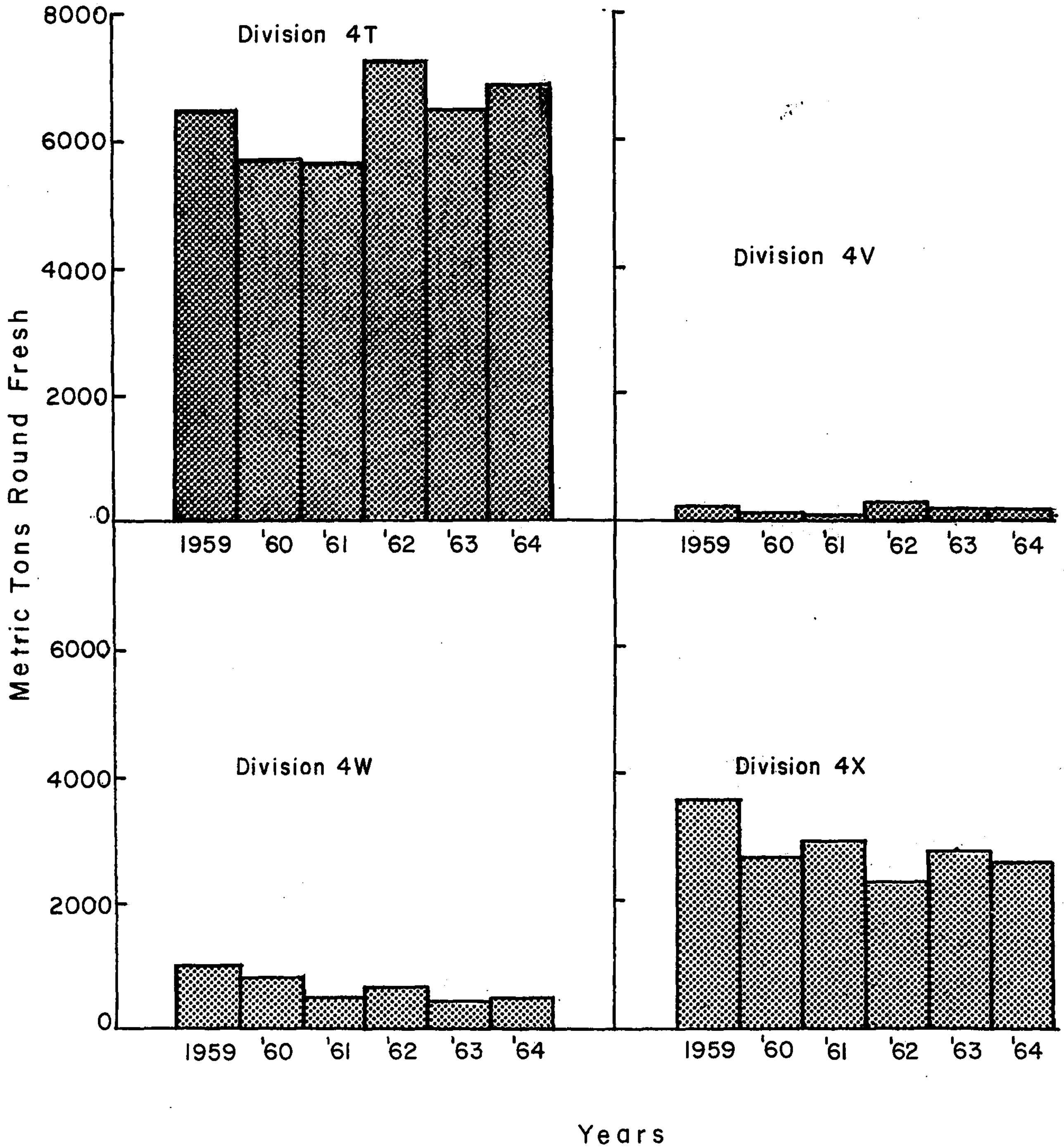

Fig. 6. Hake landings by ICNAF divisions in the Maritimes and Quebec from 1959-1964.

Fig. 7. Relative contribution of the hake landed in ICNAF division 4T to the total hake landed in the Maritimes and Quebec.

States landings but remained listed as unspecified for Eastern Canada with the exception that in 1963 and 1964 only white hake are recorded in Newfoundland. However, in 1965, white hake are recorded separately for each country and red hake are recorded for the United States.

The ICNAF subareas were separated into divisions in 1959 and the landings from these divisions were subsequently recorded. Hake landings for the divisions of subarea 4 were obtained from the Canadian Fisheries Statistics for the years 1959 to 1964 (Fig. 6). The largest landings are in division 4T and they remained quite constant for the years recorded. Although the hake are simply listed as hake with no species denotation, it is believed from this present study that the majority of hake landed in this ICNAF division 4T are indeed *Urophycis tenuis*. Division 4X also shows a relatively large catch of hake but since the area in this division is off southwestern Nova Scotia (Fig. 2), the hake caught here include both red and white species with the former predominating.

To illustrate that ICNAF division 4T contributes a large amount to the hake fishery, the relative contribution of hake landed there compared to the total hake landed in the Maritimes and Quebec is presented in Fig. 7. Although the relative contribution from this division has gradually increased over the years, the hake fishery, at least in the Maritimes and Quebec, has generally been decreasing. The landing statistics of Fig. 5 show an increase from 1944 to 1948 but since then a decline has been recorded except for large catches in 1952 and 1956.

From the apparent ambiguity associated with these two species of hake, the reliability of the aforementioned statistics for white hake must be questioned. The hake landings for ICNAF division 4T (Fig. 6) are strongly believed to be those of the white hake species. This is substantiated by evidence presented earlier in this paper. Prior to 1959, there were no divisions of the ICNAF subareas and hake were recorded in different fashions as previously mentioned. Therefore, one cannot state that landings from 1942 to 1959 in Fig. 5 are mostly white hake and yet they cannot be discounted since obviously white hake are included in the statistics.

Offshore Fishery

Offshore fishing for hake in the southern Gulf of St. Lawrence is mostly done in the regions of Cheticamp, N.S. and Cape Bear, P.E.I. Offshore vessels catching hake are all wooden side trawlers ranging in length from 60-80 feet. A Yankee No. 35 trawl net with a 2 $^{1}/_{4}$ inch single mesh cod end is generally used. Those boats leaving the port of Souris remain on the fishing grounds for 5 to 7 days and then return to unload their catch at the local fish plants.

During the summer of 1965, these trawlers caught hake off Cheticamp in May and June and then in the later months concentrated their efforts to the Cape Bear region. For many years this was the pattern followed by those fishermen in pursuit of hake. However, throughout the early summer of 1966 the numbers of hake were very scarce off Cheticamp. The fishermen did not expect the

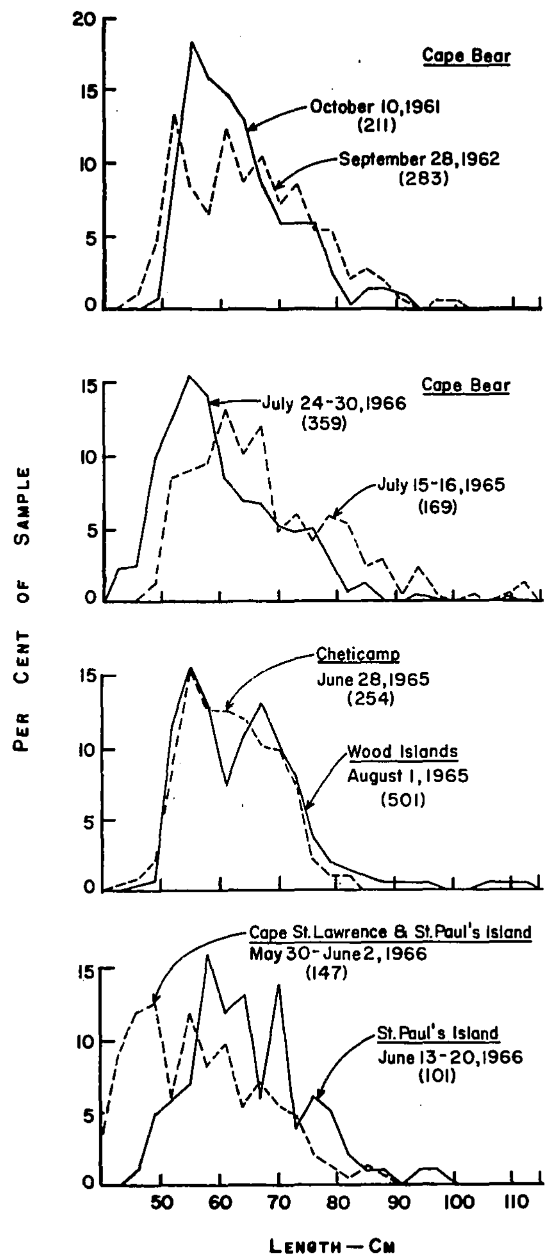

Fig. 8. Length-percent distributions of white hake caught in various localities by offshore vessels from 1961-1966. Numbers of fish sampled are in parenthesis.

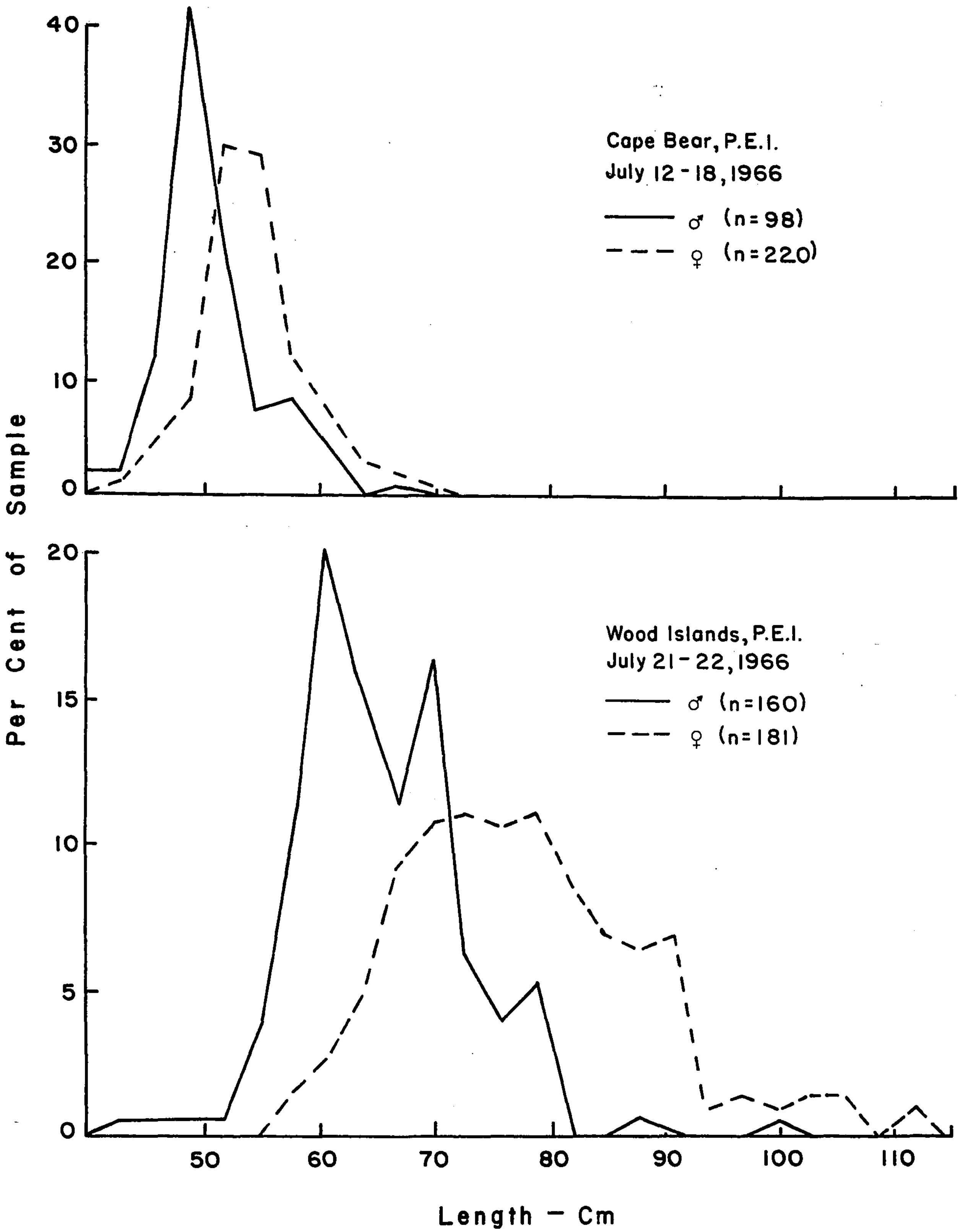

Fig. 9. Length-percent relationships of male and female white hake caught by offshore trawlers at Cape Bear and Wood Islands, P.E.I., July, 1966.

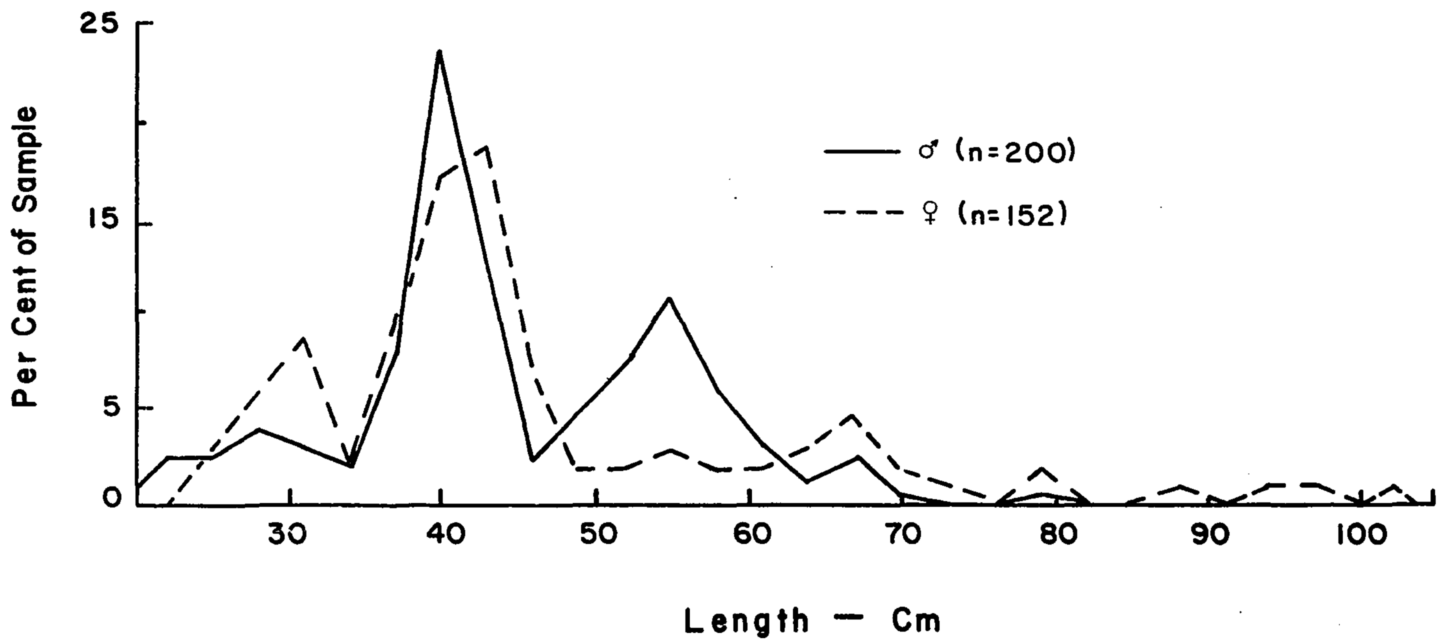

Fig. 10. The percentage ratio of 200 male and 152 female hake caught 10 miles northeast of Pictou, N.S., by the M.V. Harengus, July 10-12, 1965. The codend of the net was outfitted with a 1 $^1/_8$ inch mesh liner.

unproductiveness of this area and consequently concentrated their efforts on the Cape Bear area. The offshore vessels often went as far west as Wood Islands. In this area, soft, muddy bottoms alternate with hard, rocky ones and otter trawling here sometimes led to serious damage of the net.

Size distributions of hake caught by otter trawl in the Cape Bear area during the years 1961, 1962, 1965, and 1966 are shown in Fig. 8. There has been no significant change in the size caught over the years thus indicating the presence of a fairly stable and large hake population. The majority of fish landed were in the 50-70 cm. length range. However, in 1966, the larger fish were not as abundant as in previous years and a greater proportion of smaller fish were being caught. The proportion of male fish to female fish caught (Fig. 9) also reflects the greater proportion of hake in the smaller length groups. The hake caught off Wood Islands were slightly larger than those from adjacent Cape Bear. In both areas, however, the female fish were found in the larger length groups.

Length distributions from other areas such as St. Paul's Island and Cape St. Lawrence (Fig. 1) where depths are 174-192 meters and Cheticamp with a depth of 92-110 meters showed almost the same range and proportion of hake as those caught off Cape Bear where depths are 35-40 meters (Fig. 8).

Throughout the summer of 1965, some sets of the otter trawl of the M.V. Harengus were made in waters north of Pictou, N.S. (Fig. 1). The cod end of the net was outfitted with a 1 $^1/_8$ inch mesh liner which prevented the small fish and especially hake from escaping. The length distributions of the male and female hake from these sets are presented in Fig. 10 and are quite similar to those of Fig. 9. The distributions of Fig. 10 reflect the greater proportion of male fish in the smaller length range and the prevalence of females in the larger length groups.

Inshore Fishery

The inshore fishing for hake at Souris does not begin until mid-July, after the lobster fishing season. At this time, the fishermen outfit their boats with the equipment used to catch groundfish. Most fishermen set out 18 or 20 fishing lines each, an individual line being 300 feet long with, generally, 6 feet spacing between gangings The length of the gangings varies from 30 to 36 inches and to the end of each is attached a number 15 or 16 long shank hook. Fishing is done 3 to 4 miles east of Souris at depths of 24-37 meters. The fishermen distinguish between an "in" zone of 24-29 meters and an "out" zone of 33-37 meters. Both of these fishing areas have a smooth but hard and muddy bottom and the majority of fishing lines are set to pass over both the zones.

The hake caught on these inshore grounds are generally smaller than those landed by the otter trawlers. In Fig. 11, the bias is evident toward the smaller lengths of 40-55 cm. and there was no significant change during the two summers when samples were taken. Proportions of male to female fish in the two years reflect the similar situation found for the otter trawled hake; greater proportions

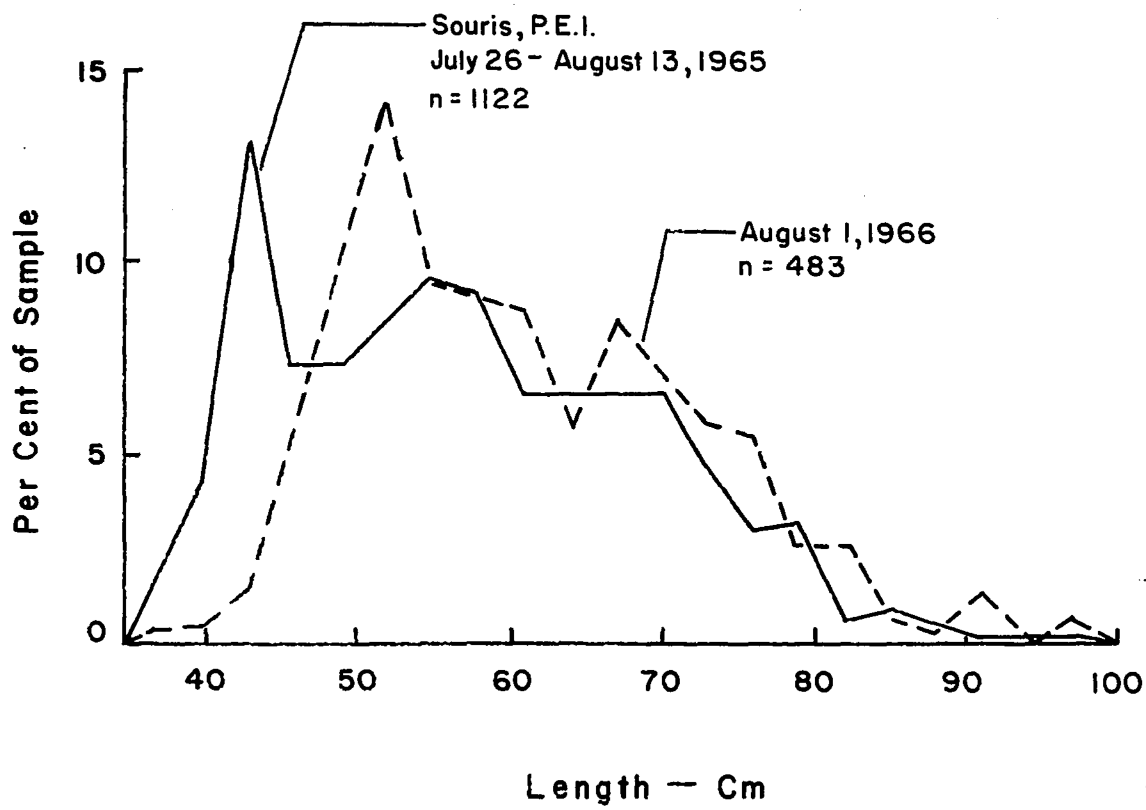

Fig. 11. Length-percent distributions of hake caught by the inshore vessels of Souris, P.E.I. in 1965 and 1966.

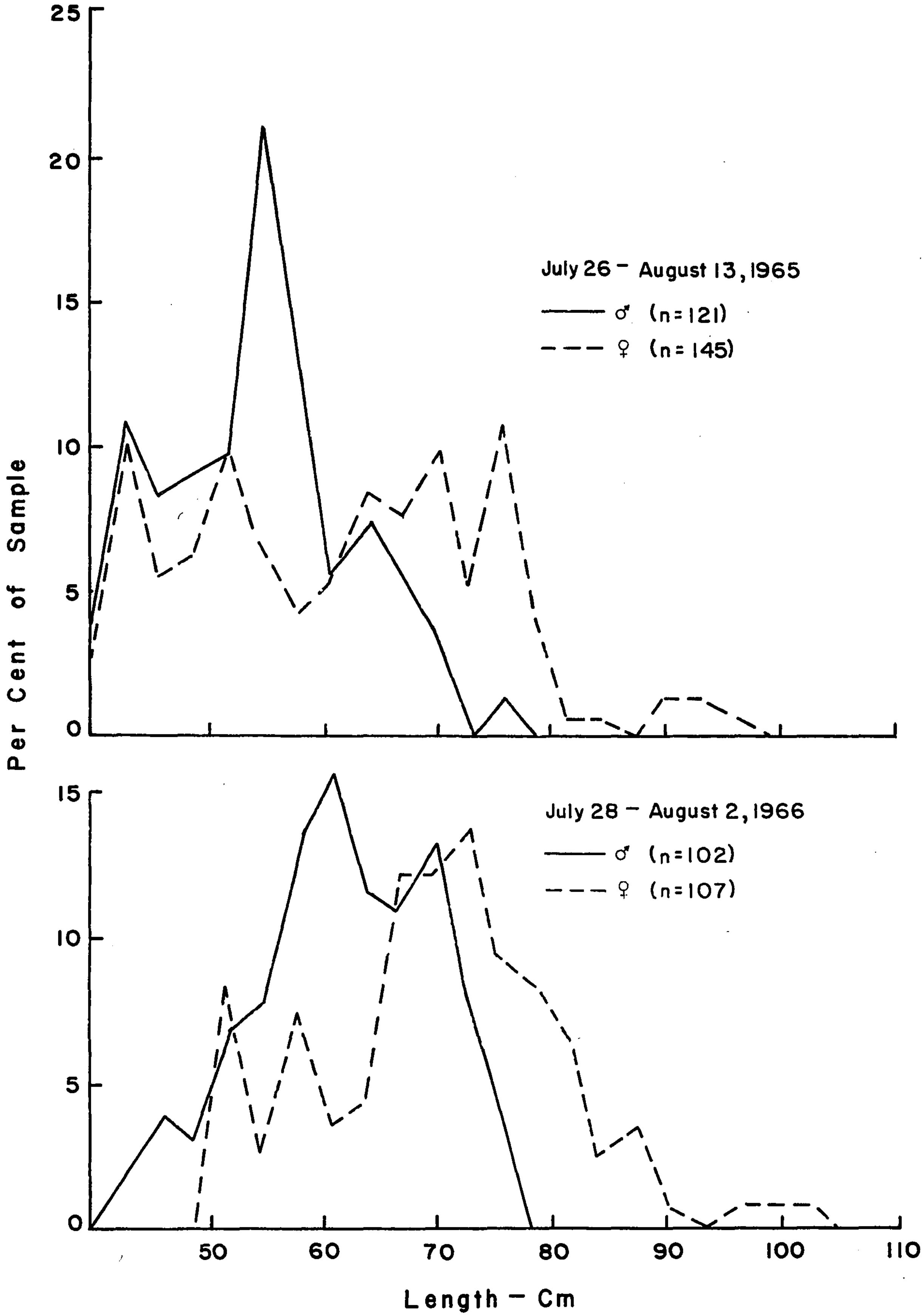

Fig. 12. The percentage ratios of male and female hake landed by the inshore vessels at Souris in 1965 and 1966.

of males in the smaller length groups and more females in the larger lengths (Fig. 12).

Farther south on the P.E.I. coast at Murray Harbour, the fishermen set lines and gill nets over rocky bottoms in areas 12 miles off Cape Bear. Glass floats are attached to the lines so that the latter rest just above the bottom and do not become entangled in the rocks. The gill nets have a mesh size of 5 or 6 inches. While the Souris fishermen leave their lines in the same position for long periods of time, those at Murray Harbour haul and set their lines daily in different locations. They set them in areas where fishing was reported good or where, because of experience, they feel the fish will be there on that particular day.

Another area where hake are caught in plentiful numbers is located north of Souris at North Lake (Fig. 1). Here also, lines and gill nets with a 5 or 6 inch mesh are used in the fishery. Fishing is done a few miles directly north of the village in water 29-40 meters deep.

4. GROWTH

Otolith Collection and Technique

The age determination of any fish species is a very important contribution to the general biology of that species. It was all the more important in this study of Urophycis tenuis Mitch. since no previous investigation had resolved the problem of a reliable age indicator for this species. Battle (1951) in her studies tried to age the hake by using its scales but found the annuli very unclear and indefinite. In this present study, preliminary investigation of the scales confirmed the conclusions of Battle. Since the structure very often employed in fish ageing is the otolith, it was decided to collect and examine them from this species. The structure removed in sampling was the large sagitta otolith described by Parker (1900) in the cod. Initial examination of some otoliths found them difficult to read but they were better than the scales and as described later were subsequently used as age indicators.

Because of the difficulty encountered with otoliths, it was thought that some other bony structures of the white hake skeleton might show a clearer yearly growth pattern. Therefore, several frozen hake were obtained, the flesh removed using very hot water and then the various bony structures detached and examined in the laboratory. The bones and techniques used in the age determination studies of other species were first examined (Menon, 1950; Hart, 1949; Tåning, 1938; Dannevig, 1956). These included the occipital and opercular bones of

Fig. 13. Photograph of an otolith from a 4 year old, 58 cm. long white hake. The solid line indicates the axis generally used for reading the otolith. The dotted line was an alternate axis.

Fig. [illegible] [illegible] from a 4 year old, 56 cm. [illegible] [illegible] solid line indicates the axis [illegible] [illegible]. The dotted line [illegible] [illegible].

the skull and then the vertebrae. The opercular bones, successfully used by Le Cren (1947) for perch studies, were very thin and transparent and annular rings could not be distinguished very well. Vertebrae, examined in a 50% glycerine solution and in a solution of 3 parts methyl salicylate to 1 part benzyl benzoate, often showed annular rings but the demarcation between the annuli was not as clear or reliable as found in the otoliths. The occipital, maxilla and mandible bones, and fin rays were also examined but they too lacked distinct annular rings.

During the summer of 1965, the otoliths of over 800 hake were collected and stored in vials in a 50% glycerine solution. For examination purposes, the otoliths were broken transversely and each piece implanted, with the broken surface up, in modelling clay. The otoliths were then examined in the 50% glycerine clearing solution through a stereomicroscope using a direct source of transmitted light with shading from a scalpel. These hake otoliths were very difficult to read and many were unreadable. The photograph of an otolith from a 58 cm. hake (Fig. 13) gives an indication of the problem that was faced. The annuli are not distinctly clear or separated. The solid line indicates the axis most often used to count the annular rings. When the reading along this axis was not clear, an alternate axis along the dotted line was used.

Several techniques were tried to improve the clarity of the annular rings in the otoliths. Some of the latter were air dried, while others were oven dried and then examined in the glycerine clearing solution. The burning technique of Christensen (1964) was not very helpful, often making the otoliths too brittle for examination. Glycerine, alcohol and xylol were tried as clearing agents but were not successful. However, a clearing solution of methyl salicylate and benzyl benzoate (3:1) seemed to clear the otoliths fairly well. Therefore, the procedure eventually adopted for age determination was as follows: otoliths were used as age indicators; they were collected, stored dry in envelopes and then examined in the salicylate-benzoate clearing solution.

Otoliths were removed from hake landed by the otter trawlers as well as those caught by the hook and line, inshore fishermen. Collections were generally made at Souris and on the few sea trips that were undertaken.

Validity of the Ageing Technique

The numerous bony structures employed in determining the age of any fish may not always provide the true age of the fish. The validity of the various age indicators must be established before they can be used with confidence in any particular study. Since the otoliths were used in ageing the white hake, their validity as age indicators had to be shown.

The reading of the otoliths was carried out as previously done on other gadoid species (Kohler, 1958, 1964; Fleming, 1960; May, 1966). It was assumed that the wide, opaque zones seen in the transverse section of the otolith were associated with periods of rapid spring and summer growth and the thin translucent zones with periods of slow, winter growth. One opaque zone plus one translucent zone were presumed to mark one year in the life history of the hake.

One method of determining the validity of the ageing technique is to examine the edge of the otoliths taken from fish throughout the year. Any changes in appearance of the edges which occurred on an annual basis would show that the otoliths were valid as indicators. Since the otoliths of hake were difficult to read and samples throughout the year were not obtained, the validity of using them as age indicators could not be shown. However, since the hake is a gadoid and related to the cod and haddock for which the method has been shown to be valid (Kohler, 1958, 1964; Fleming, 1960; May, 1966), it was assumed that this ageing technique might also be valid for the white hake. The following age-length relationships are presented on the basis of this assumption.

Age-Length Relationship

The otoliths from 368 hake from Cheticamp and Cape Bear were read by the author. From these, only 141 (38%) were found to be satisfactorily clear to warrant further examination. These were then examined repeatedly and the results used to plot the age-length relationships in Fig. 14. The mean length at age and its deviation for each group was calculated and plotted (Table 2; Fig. 14).

The hake from the above mentioned areas appear to have a similar growth rate between the ages of 5 to 9 years. However, in the earlier ages of 1 to 4 years, the Cheticamp fish seem to grow faster. Unfortunately, this evidence is inconclusive because of the lack of data for the Cape Bear fish in these age groups. The last three points

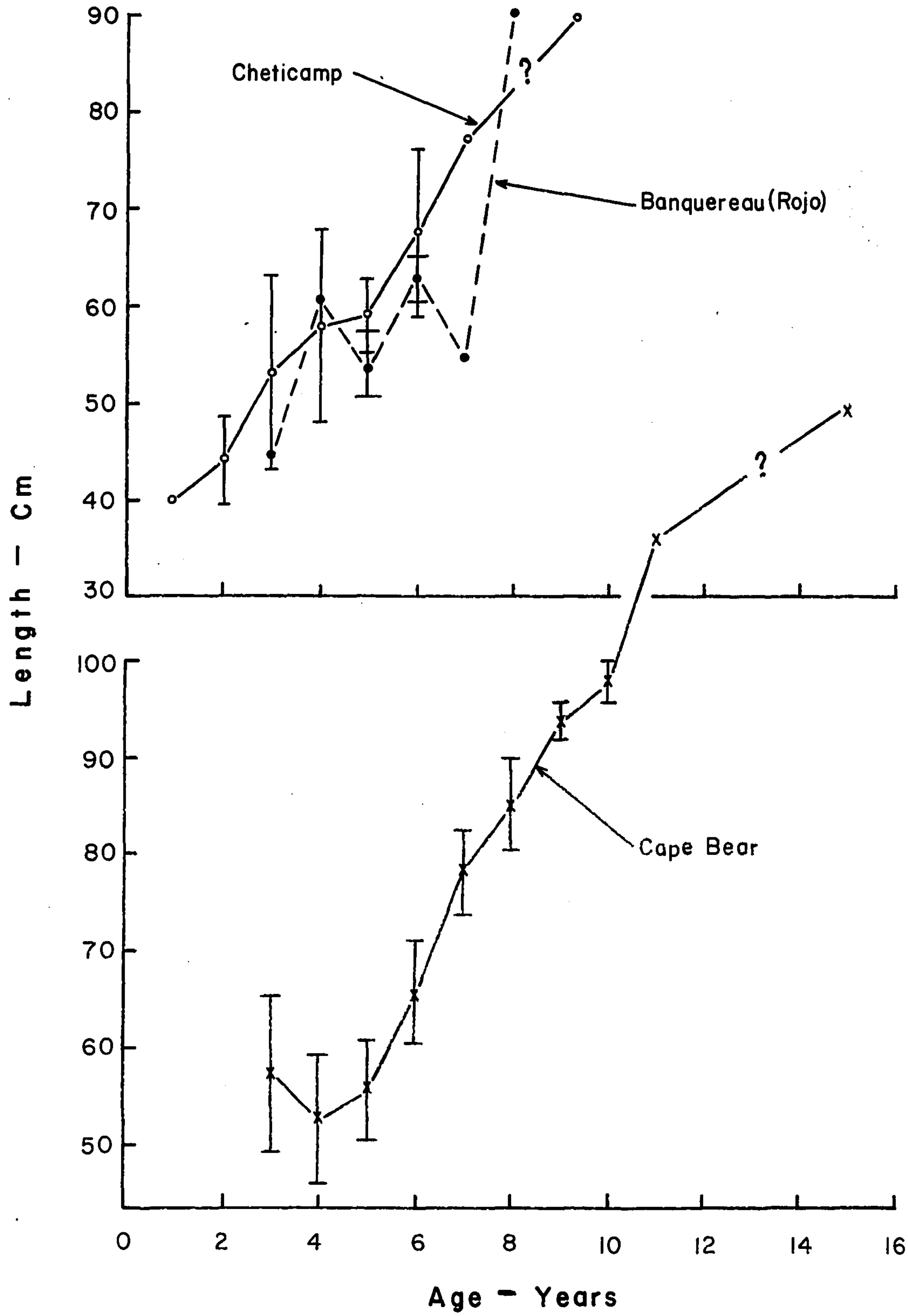

Fig. 14. Age-length relationships of white hake from Cheticamp, Cape Bear and Banquereau. The mean lengths at age with their standard deviations are shown.

Table 2. Mean length in centimeters of hake of different ages from areas shown. n is number of fish.

Age (years)	Mean length ± standard deviation (cm.)					
	Cheticamp	n	Cape Bear	n	Banquereau	n
2	43.9 ± 4.6	22				
3	53.4 ± 10.3	13	57.5 ± 8.8	2	45.0	1
4	57.4 ± 9.6	17	53.5 ± 5.6	6	61.0	1
5	58.8 ± 4.4	10	56.2 ± 5.6	9	54.5 ± 2.7	4
6	67.8 ± 8.4	6	66.0 ± 5.5	24	63.5 ± 2.5	2
7	77.0	1	78.4 ± 5.4	11	55.0	1
8			85.4 ± 4.7	10	92.0	1
9	90.0	1	94.0 ± 0.8	3		
10			97.5 ± 2.5	2		
11			109.5 ± 1.2	2		
15			111.0	1		

of the plot of Cape Bear fish have been joined but it is not certain whether the growth rate proceeds in this manner. There are no data for hake of ages 12, 13 and 14 years and only one fish each for the 11 and 15 year age groups. Similarly, a total of 5 pairs of otoliths were used to determine the age groups of 9 and 10 years. The latter points of the Cheticamp plot have also been joined but again the lack of a sufficient number of fish makes the growth rate line uncertain in these older age groups. Generally, though, for ages 5 to 9 years the growth rate is similar for the two groups of hake examined. A yearly length increase of 7-9 cm. is estimated from the figures.

The only other age-length data available for this species were those of Rojo (1955). He determined the ages from the otoliths of 10 white hake caught in the Banquereau region off Nova Scotia in waters of 203-220 meters deep. The mean length for these fish at that age were calculated (Table 2) and are plotted in Fig. 14. With some variation, his readings correspond for ages 4, 5 and 6 years with the Gulf of St. Lawrence white hake but his other readings are not at all similar. Since his readings for ages 4, 5 and 6 were taken from the otoliths of 1, 4 and 2 fish respectively, the tendency to say that these have a similar growth rate with the Gulf hake is not justified. There were more fish examined in the Gulf of St. Lawrence study. Nevertheless, more otoliths need to be read from both areas and more fish in each age group are required to obtain a satisfactory growth rate for this species.

Length-Weight Relationship

The weight of a fish usually varies as some function of its length. This relationship is expressed by the following equation:

$$W = aL^n \quad . . . . (1)$$

Where W is the weight of the fish, L its length, a is a constant while n is an exponent. If n equals 3, the fish is said to grow isometrically; that is, the form and specific gravity of the fish do not change throughout its life. However, very often n does not equal 3 since most species of fish tend to change their shape as they grow in length. In this instance, the growth of the fish is termed allometric and the general formula mentioned above is the "simple allometry formula" of Reeve and Huxley (1945).

Whole, round weights and weights with the viscera removed were obtained for 379 male and female hake landed at Souris, P.E.I. The fish were weighed on a spring balance and weights were recorded in pounds and fractions of pounds. Samples were taken mostly from the fish landed by the inshore boats because the catch was landed in the round condition and also it was much easier to obtain correct readings of the scale on land than at sea. During the cruises on the otter trawlers, the motion of the boat prohibited accurate recordings of fish weights.

Random samples of whole fish caught by the inshore boats were taken and each fish weighed, then eviscerated and weighed once more. The eviscerated weight reduces the variations in weight due to the stomach contents and the condition of the gonads (Kohler, 1959).

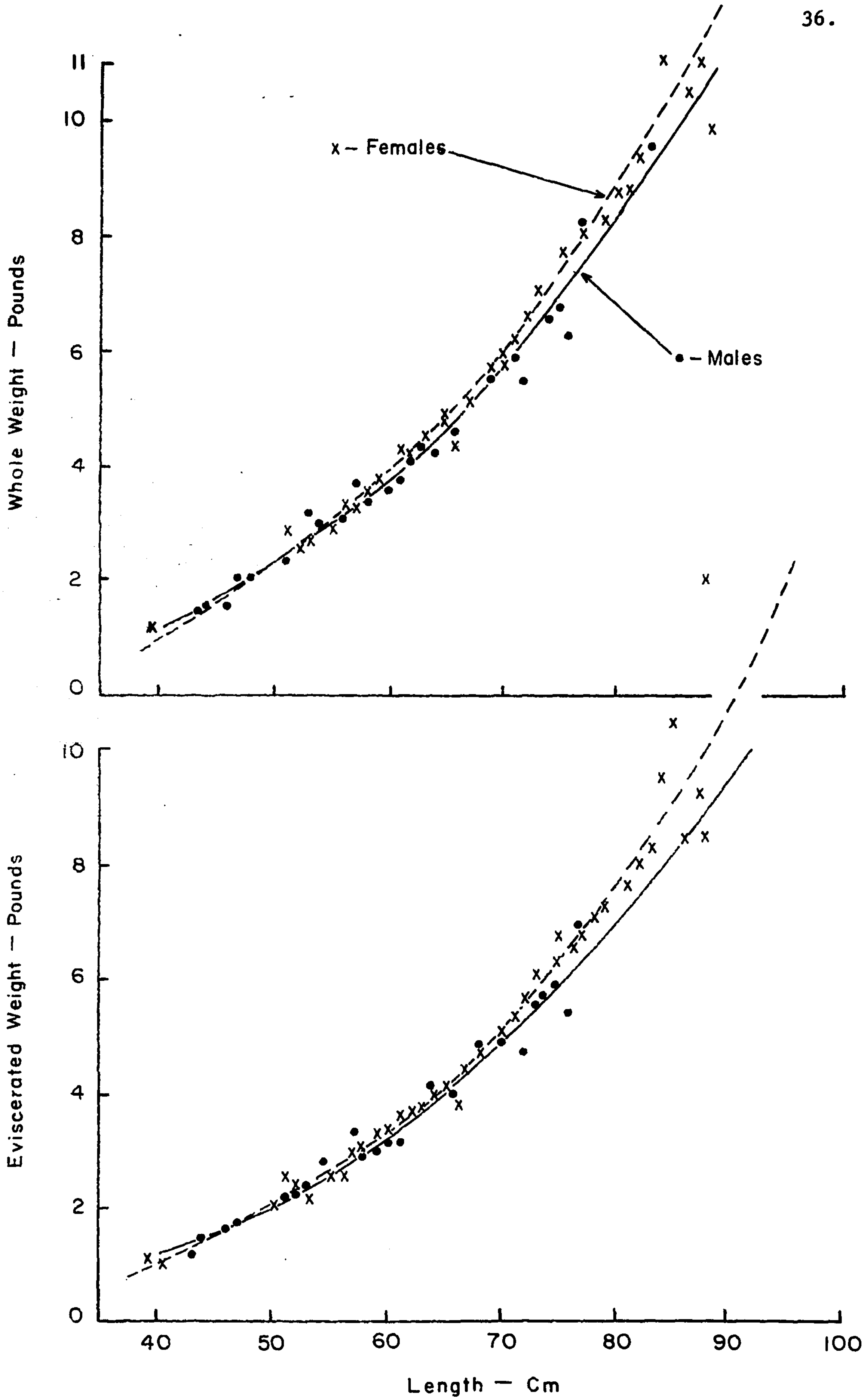

Fig. 15. The length-weight relationships of 103 male and 107 female, whole and eviscerated hake caught on the inshore grounds of Souris, P.E.I., July 28-August 2, 1966.

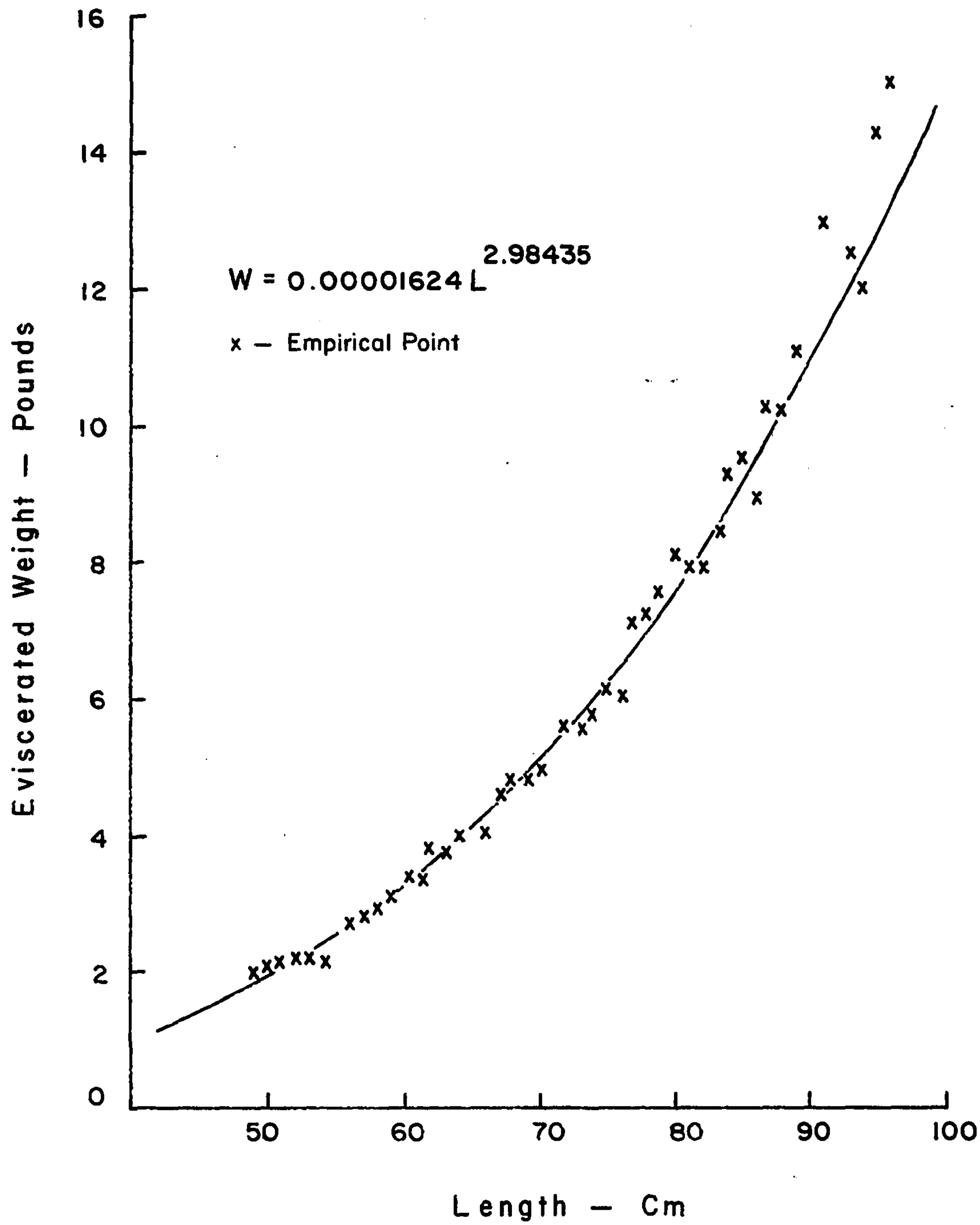

Fig. 16. The length-weight relationship of 169 eviscerated white hake otter-trawled off Cape Bear, P.E.I., July 16, 1965. The sexes were not differentiated.

Table 3. Values of n and a for equation (1) for all samples of hake examined.

Sample	n	a
Souris inshore whole weight ♂	2.79641	0.00003964
♀	2.90023	0.00002670
Eviscerated weight ♂	2.64627	0.00006430
♀	2.86891	0.00002624
Cape Bear - otter trawl eviscerated weight	2.98435	0.00001624

Since the hake landed by the otter trawlers were eviscerated, the weights recorded for fish plant samples were of eviscerated fish only. The recorded weights of the individual fish were transformed into pounds and ounces and with their respective lengths were programmed into a computer to obtain the allometric functions graphed in Figs. 15 and 16. The respective values for the equations of these functions are in Table 3.

The mean weights for each centimeter length group were calculated and plotted as the empirical points in both figures. From the values of n and a and from Fig. 15 it is evident that the female hake have a slightly greater rate of increase in weight with length than the male fish. The female hake in these samples are also found in the larger length groups.

5. MATURITY AND SPAWNING

Materials

Preliminary sampling of white hake for sexual maturity was carried out during the M.V. Harengus cruise from June 6-18, 1966. As seen from Fig. 4 the sampling stations were relatively far apart so that all the hake examined were not from a homogeneous population. These fish, as well as those sampled from Souris and Cape Bear were classified according to the maturity stages employed by Hickling (1935) and Battle (1951) for hake and Powles (1958) for cod. The developmental stages of Table 4 have been derived from these three sources. However, to obtain a better idea of the reproductive cycle and peak spawning time, the fish were later catagorized into one of the following phases: ripening, ripe and spawning, spent-recovering. The recorded lengths of the fish were placed into 3 cm. groupings to produce smooth curves for the length-maturity relationships.

Size at Maturity

The length-maturity relationships of hake from the different areas have been fitted by eye and in each it appears that the male fish mature earlier than the females (Fig. 17). The hake caught on the M.V. Harengus cruise had a 50% maturity point of 48.0 cm for

Table 4. Criteria of stages of maturity used in this study.

FEMALE	MALE
1. IMMATURE	
Ovaries small and pale, pink in colour. Membrane thin, smooth and transparent though eggs visible to naked eye.	Testes appear as minute pinkish coils.
2. RIPENING	
Ovary enlarged to more than twice former length and diameter. Small, opaque eggs visible to naked eye. Ovary orange in colour with surface highly vascularized.	Increase in volume and purplish to white in colour; coarsely coiled with slight pouch-like lobulations. No milt extruded when compressed.
3. RIPE	
Ovary well developed and distended; blood vessels inconspicuous. Some translucent eggs present among generally opaque egg mass. A few eggs may be extruded with external pressure.	Testes white and much distended into large, wavy lobules. Some milt extruded with application of pressure.

Table 4 continued.

FEMALE	MALE
4. SPAWNING	
Ovary purplish in colour. Eggs transparent and running freely.	Testes very white and convoluted. Milt runs freely at slightest pressure.
5. SPENT	
Ovary purple and flaccid. All eggs practically released. Membrane begins to shrink and become firm leaving the surface white with purple showing through.	Testes appear as shrivelled ribbons and reddish purple in colour. Vas deferens prominent against irregular surface of testes.
6. RECOVERING	
Ovary begins to take on a pinkish colour. Can be confused with immature condition in smaller fish but ovary is firm and membrane is thicker.	Testes larger than in immature condition and resumes pale pink colour.

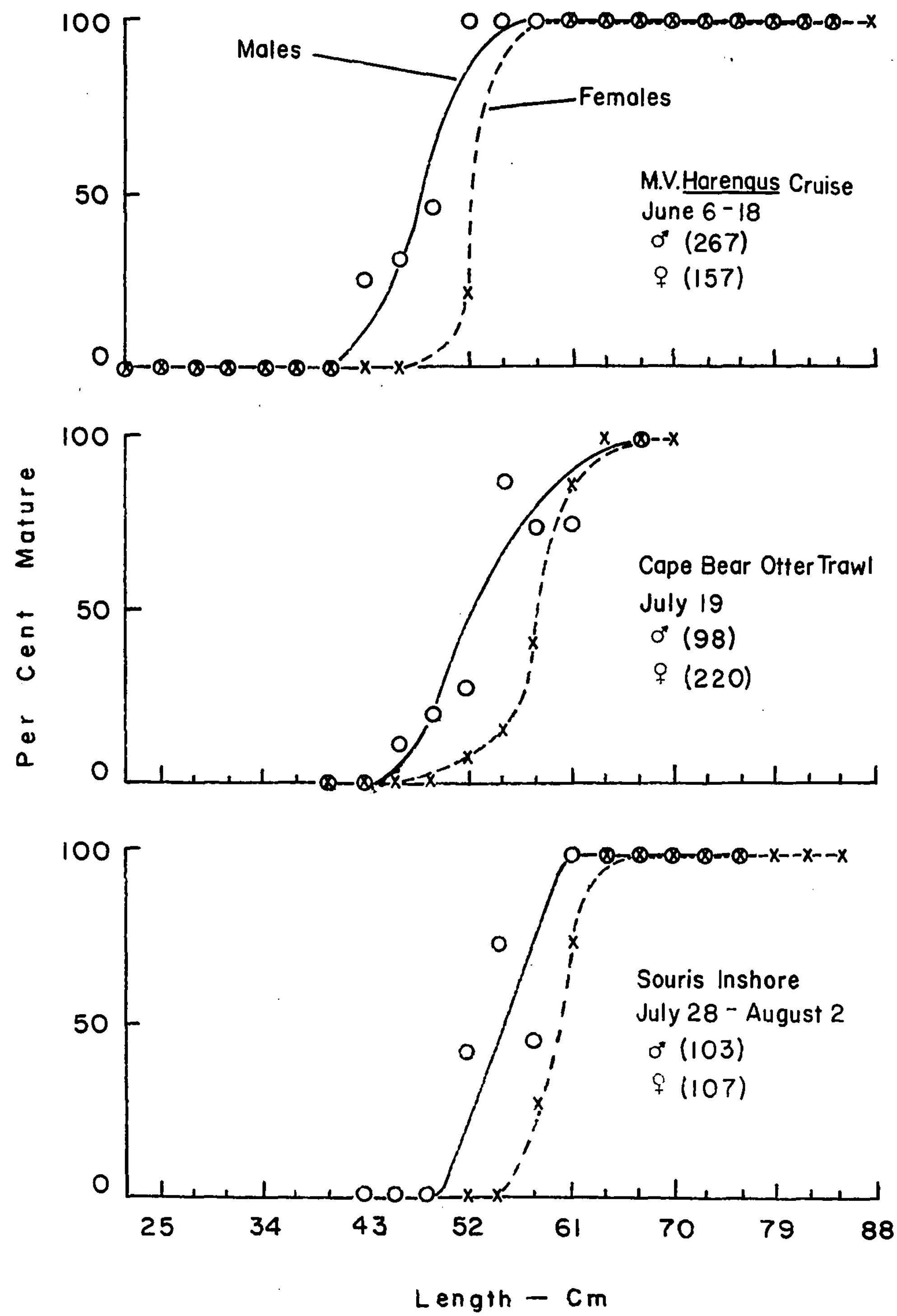

Fig. 17. Size at maturity of white hake from various areas in the southern Gulf of St. Lawrence, 1966.

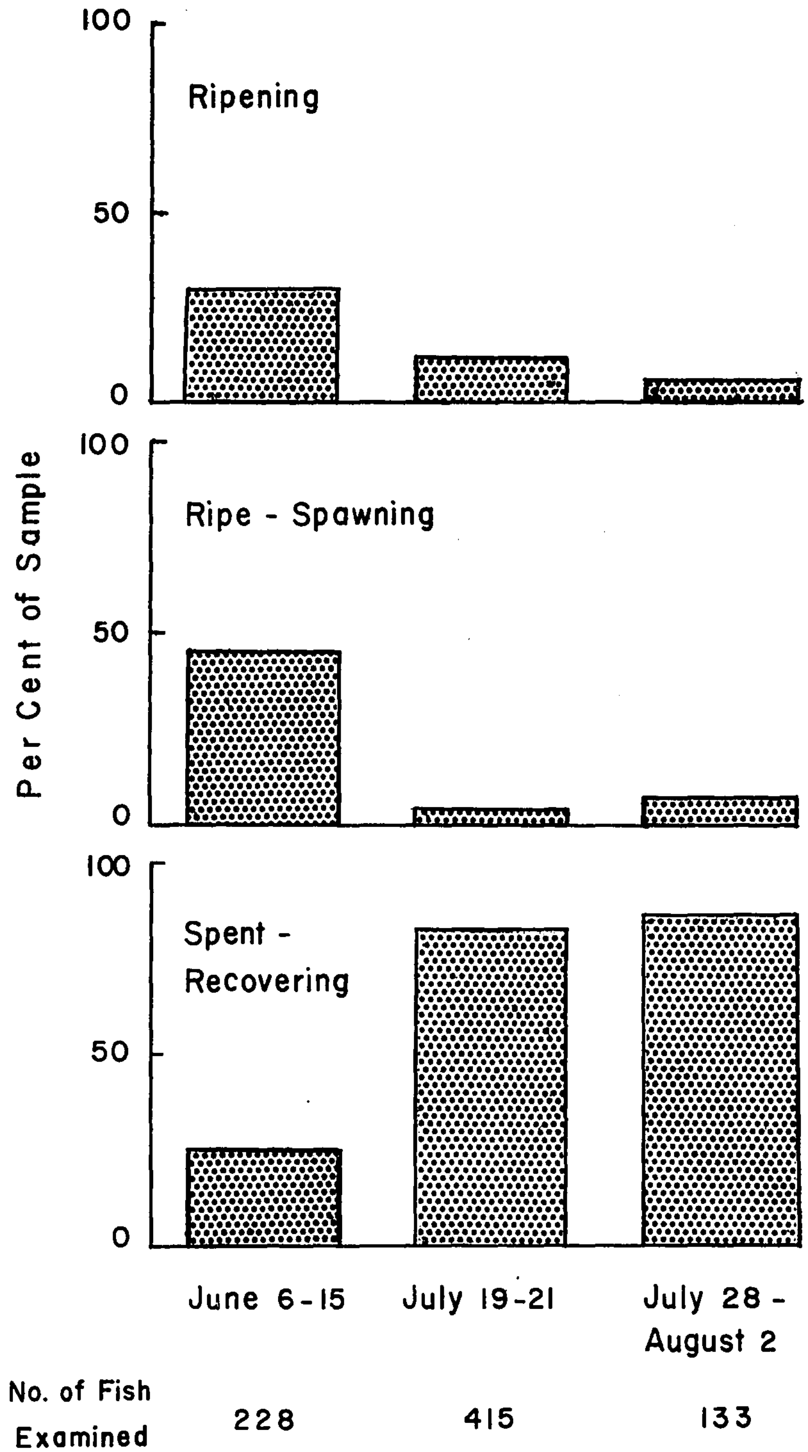

Fig. 18. Percentage of hake from the study region in the 3 main phases of the reproductive cycle from June 6 to August 2, 1966.

males and 52.4 cm. for females. However, for the otter-trawled hake from Cape Bear, the lengths at which 50% of the male and females were mature were 52.5 cm. and 59.0 cm. respectively. A similar relationship was found for the hake caught at Souris. The 50% maturity points there were 55.0 cm. and 60.2 cm. for males and females respectively.

Using the above data and referring to the age-length relationship (Fig. 14), it is evident that the male hake from Cape Bear become mature at 4 years of age while the female does so when approximately 5 years old. However, since there is no information on the growth rate of the two sexes, the difference in growth cannot be ascertained. The males may grow slower and thus be mature at or near the same age as the female hake.

Spawning Season

Observations during the summer of 1955 revealed that the hake had a peak spawning time towards the end of June. From the samples and observations taken during the succeeding summer, a peak spawning time was found to occur in the middle of June (Fig. 18). Although continuous samples were not obtained, those that were showed that prior to June 15 the majority of hake were ripening and ripe and that after a period of two or three weeks, the majority of hake were in a spent condition. Despite the lack of information from June 15 to July 19, previous observations and that presented here place the peak spawning time of white hake in the southern Gulf of St. Lawrence during the second half of June. Bigelow and Schroeder (1953) reported that spawning continues throughout late winter and spring. Battle (1951) found that the hake off Prince Edward Island spawned in midsummer while they were only maturing off Halifax, preparing to spawn in the autumn. Some sampling observations made in late July and August revealed some female hake which were still ripening and ripe. Therefore, spawning may continue throughout the winter but the peak time appears to be in June.

6. FECUNDITY

Materials and Methods

During the cruise of M.V. Harengus in 1966, 22 ripening females were caught (see Fig. 4) and then later on a trip on a commercial trawler in the Wood Islands region, 19 more samples were obtained. For fecundity studies, it is necessary to collect the ovaries in the ripening stage when all the eggs are opaque (Simpson, 1951). Once the ovary is ripe and the fish is spawning, the eggs are transparent and collecting the ovaries in this stage would not provide a valid estimation of the fecundity of the fish.

The ripening ovaries were removed from the fish and preserved in a jar containing a modified Gilson's fluid where the amount of acetic acid was doubled. To permit a better penetration of Gilson's fluid, the ovaries were slit once longitudinally and twice transversely before placing them into the preserving jars. When very large ovaries were encountered they were divided and the sections placed into several jars. Initially, the jars were shaken very frequently and later less often to free the eggs from the ovarian tissue and to prevent any adherence to the sides of the jars.

Various methods of estimating the fecundity were investigated. The wet method used by Simpson (1951) for plaice eggs and the volumetric technique were considered but rejected because of the small size of the hake eggs. The dry weight method had been found reliable (Powles, 1958) and seemed to be feasible for these eggs. The ripening eggs of hake have a diameter of 0.45-0.50 mm. but when they are ripe and ready to be shed by the female, their diameter increases to 0.65-0.80 mm. (Fig. 19).

No rigorous microscope investigation was carried out to distinguish between the different sizes of eggs found in the hake ovary. However, from observations of unprocessed eggs, the three sizes of eggs mentioned in other studies on hake and cod (Battle, 1951; May, 1966) were recognized. The three sizes were: (1) large, translucent eggs almost ready to be shed; (2) intermediate sized yolky eggs which would presumably be released within a few weeks; and (3) very small, whitish eggs which are oocytes and will be released next season. The latter oocytes must not be included in the fecundity estimate and the method used should dispense with them before counting.

To minimize the errors due to sampling techniques, it seemed that careful dry weights of the ripening eggs was the best method to follow. The procedure for each ovary was as follows:

1. The contents of the preserving jar were emptied into a tray and large pieces of ovarian tissue were removed, being careful to detach any adhering eggs. Then the eggs and solution were transferred to clean jars and the contents shaken to free all small pieces of ovarian tissue.
2. After shaking, when the eggs had settled to the bottom of the jar, the supernatant solution, containing pieces of tissue and the tiny white oocytes was carefully decanted.

3. Water was then added to the eggs and this mixture shaken again and the supernatant fluid decanted once more. This washing with water and then decanting was done several times.

4. After repeated washings, the eggs were left to settle overnight in the water. Next morning, there was a layer of tissue on top of the eggs. This was removed by a pipette and successive washings were carried out if there appeared to be any tissue present.

5. At this stage, when the eggs were considered free of ovarian tissue and very small whitish eggs, they were shaken in the jar with water and a sample removed with a pipette. From this sample, 3 subsamples of 1000 eggs each were counted out, dried and then weighed. The remaining eggs were returned to the original mass.

6. The total egg mass was then poured onto some bolting cloth which lined a funnel interior. The eggs were left on this cloth for a few minutes to allow the excess water to drain off. They were then removed from the cloth and spread out as thinly as possible with a spatula onto a sheet of absorbent utility paper. Another sheet of this paper was placed over the eggs and they were left to dry overnight. While drying, the eggs turned from light cream to a very dark brown colour and also became very hard.

7. After drying, the eggs were carefully scraped from the paper and placed into storage jars for future weighing and use in calculating fecundities.

The 1000 egg subsamples were counted under a stereomicroscope and placed into watch glasses. The latter were then placed into a dessicator to dry. The three subsamples were weighed to 0.0001 gm. and the mean weight calculated. To test the reliability of counting 1000 egg subsamples, 30 such subsamples were counted out, dried and weighed from one ovary (Table 5). No marked difference was found in the weights of the samples. Some of the 30 samples were oven dried at a temperature of 150^{o}C. The results in Table 5 show no significant difference between their mean weight and that obtained from the dessicator dried samples.

At least 3 subsamples were counted out from each ovary but occasionally 6 were taken to see if there were any variations in weight. Therefore, for each sample the mean dry weight of 1000 eggs as well as the weight of the total egg mass were obtained. These figures were then used in the following formula to estimate the fecundity of the respective female hake. A sample calculation is found in Table 5.

$$\text{Total number of eggs} = \frac{\text{Total dry weight of eggs (gms.)}}{\text{Mean weight of 1000 eggs (gms.)}} \text{ X } 1000$$

Length-Fecundity Relationship

Estimates of the fecundity of the hake caught during the M.V. *Harengus* cruise and those from Wood Islands were obtained using the above formula and then plotted against the respective fish length (Fig. 20). Initially, the two sets of data were to be pooled and one relationship obtained. However, as is shown in Fig. 20, it was

Table 5. Weights (gms.) of 30 samples of 1000 eggs to show the reliability of the counting method used in this study.

Sample weights (gms.)	
0.0188	
0.0187	Dessicator dried.
0.0188	Mean weight = 0.0187 gms.
0.0183	Standard deviation = ± 0.000195
0.0187	
0.0188	
0.0188	
0.0188	
0.0189	
0.0192	
0.0186	
0.0188	
0.0185	
0.0187	
0.0184	
0.0186	
0.0188	
0.0185	
0.0183	

Table 5 continued

0.0186	
0.0187	
0.0188	
0.0189	
0.0187	
0.0186	Oven dried for 2 hours at 150^{o}C.
0.0183	Mean weight = 0.0184 gms.
0.0182	Standard deviation = $\pm$ 0.00024.
0.0183	
0.0187	
0.0184	

Sample Calculation:

Length of fish = 81 cms.

Number of samples = 30

Mean weight of all samples = 0.0186 gms.

Standard deviation = 0.00022

Total dry weight of ovary = 101.3592 gms.

Total number of eggs = $\frac{101.3592}{0.0186}$ X 1000 = 5,449,419.

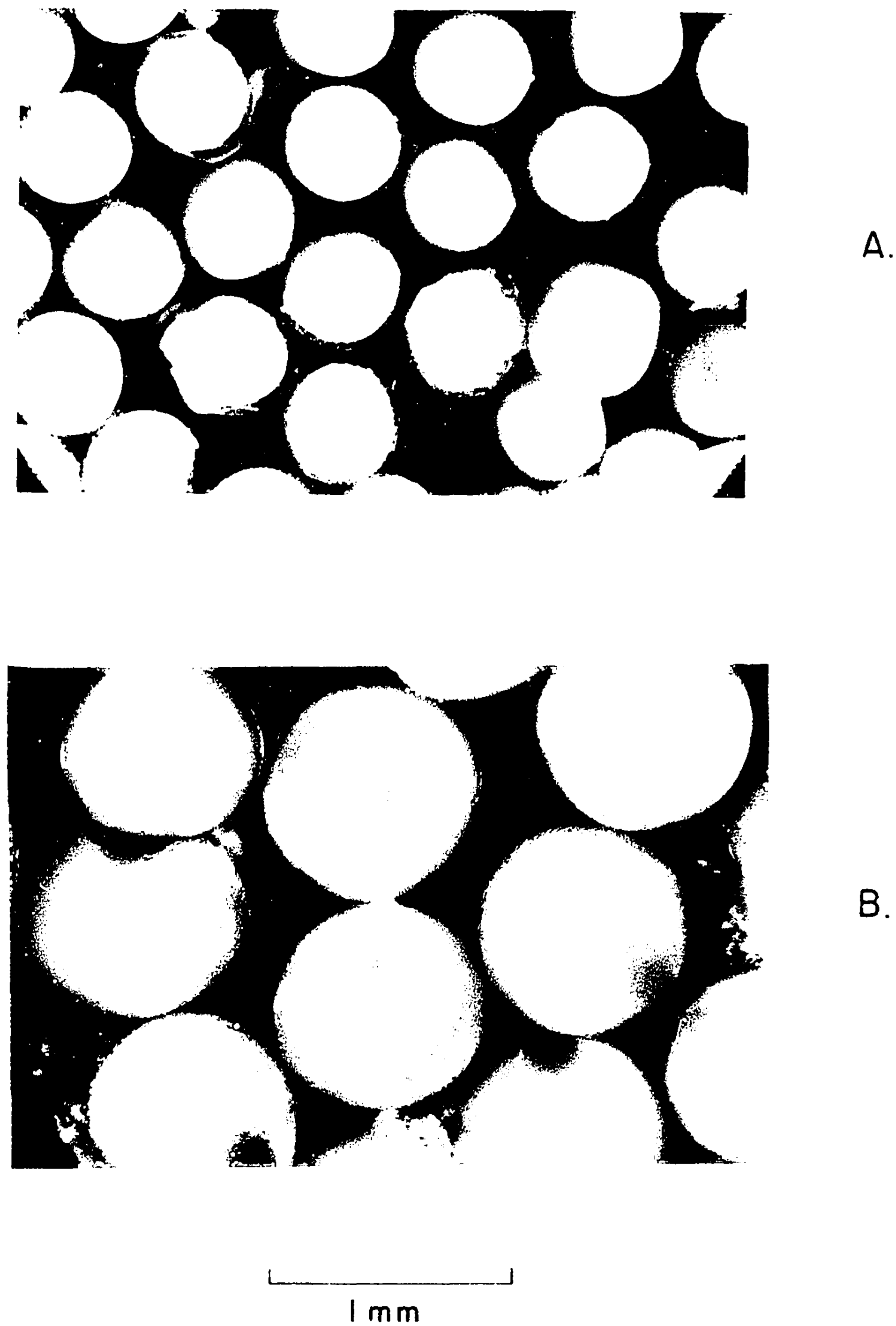

Fig. 19. Photographs of ripening ova (A) and ripe ova (B) of *Urophycis tenuis* Mitch.

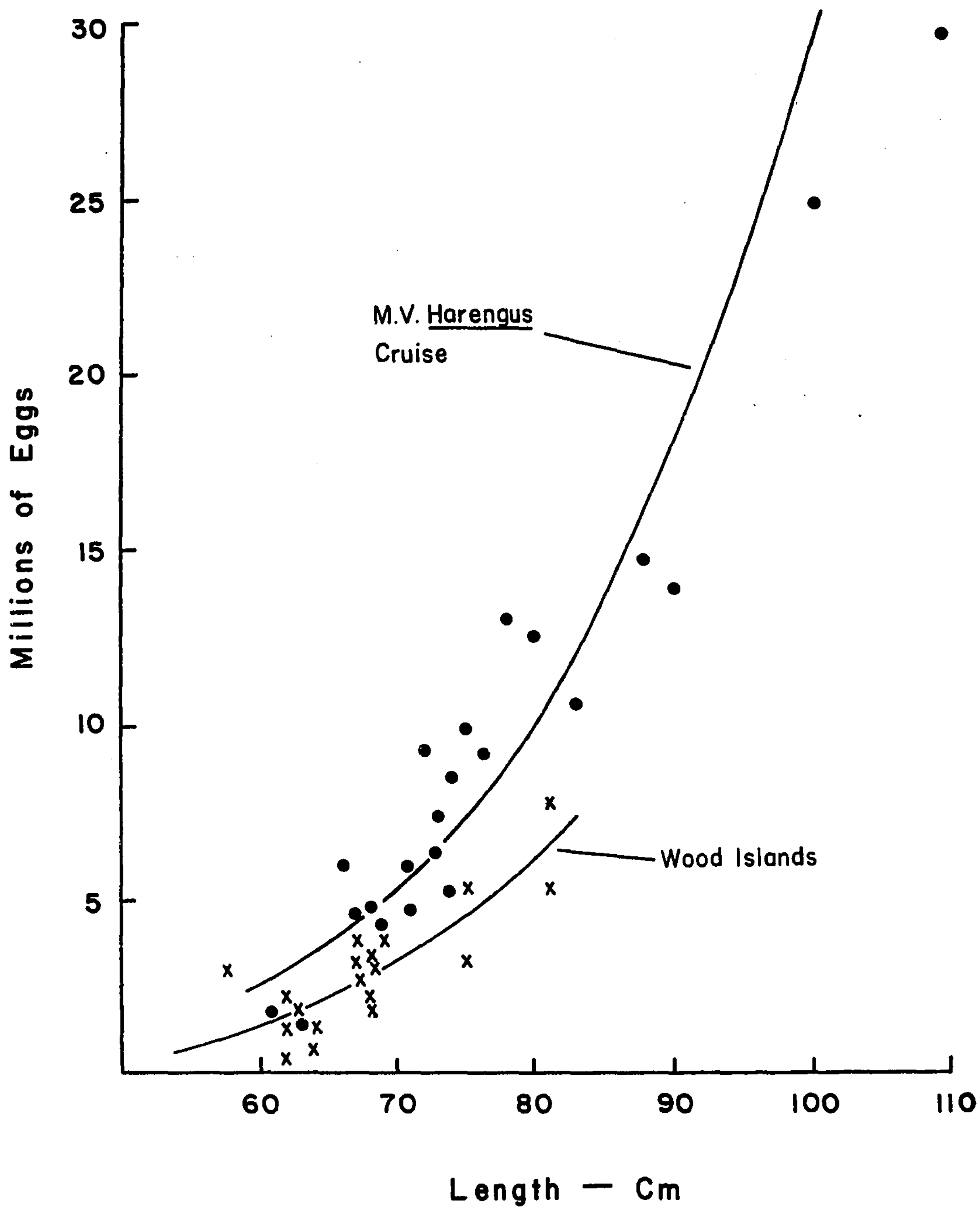

Fig. 20. Length-fecundity relationships of white hake (sexes not differentiated) caught during the M.V. Harengus cruise (●) and off Wood Islands, P.E.I. (x) in the summer of 1966.

apparent that the Wood Islands hake were different from the others. At respective lengths, their fecundities were consistently lower than those caught on the M.V. Harengus. The figures for each set of data were converted to logarithms from which the equations of the regression lines of log fecundity on log length were obtained. The equation of the regression line fitted to the cruise data was:

$$\log F = -2.31344 + 4.89848 \log L$$

or in the exponential form of

$$F = 0.02058\ L^{4.89848}$$

The relationship for the Wood Islands hake was found to be

$$\log F = -2.62180 + 4.94622 \log L$$

or

$$F = 0.04186\ L^{4.94622}$$

Using these equations, values of F were calculated and plotted to produce the curvilinear relationships of Fig. 20. It is apparent that the number of eggs increases rapidly with the increase in length. Fecundity ranged from 541,666 in a hake of 62 cm. length to an extraordinary 29,835,658 for one hake of 109 cm. The hake from Wood Islands had fewer eggs at any given size than those examined on the cruise. For lengths greater than 85 cm. the relationship for the cruise hake overestimates their fecundity but since only four fish were sampled beyond this point, it is not considered serious.

7. DISCUSSION OF RESULTS

The findings revealed in this investigation into the biology and fishery of Urophycis tenuis Mitch. will be discussed. Since a good portion of the time was spent on the study of the fecundity of this species, emphasis will tend to this area. Some suggestions for future investigation and perfection of technique will also be included in the appropriate places.

The fishery statistics of hake in the Maritimes and Quebec showed a decrease in landings over recent years. This does not mean, however, that the white hake are decreasing in number. Since there is confusion in distinguishing the white hake (Urophycis tenuis Mitch.) from the very similar red hake (Urophycis chuss Walb.), the published statistics of hake landings cannot be regarded as entirely correct for both species. However, those figures for the hake landed in the Gulf of St. Lawrence can be considered quite authentic since it is believed from this study that the majority of hake caught in this area are white hake. Although further investigation is necessary to distinguish between the two species with certainty, it is then imperative to classify them accordingly in the statistical records. Then, with these statistics a better knowledge of the distribution of both species could be ascertained. Another means of studying the distribution and migration is through the use of tagging experiments. A difficulty with the white hake is that their stomachs evert when they are brought to the surface in the otter trawl net. However, slow decompression and catching them in shallow waters may solve this problem. Such preliminary tagging experiments have begun on the hake of the Gulf of St. Lawrence (Kohler, personal communication). If these studies are successful, they will provide some insight into the behaviour of this species.

The growth rates of hake from Cape Bear and Cheticamp are similar. Although otoliths were found to be the best structures to use as valid age indicators, many more readings for each age group must be obtained to verify the growth rates obtained in this study. Hake from the Banquereau region (Rojo, 1955) provided some comparison but not a truly valid one since Rojo had fewer samples than in this study. Using the growth rates of the present study and referring to the length distributions of hake caught (Figs. 8-12), it is seen that they begin to enter the commercial offshore fishery when approximately two years old and the inshore fishery at slightly less than two years. As will be shown later the age of recruitment into the fishery has some effects on the general fishery.

From the length-maturity relationships (Fig. 17), it was observed that the male hake became mature at shorter lengths than the females. The length distribution data reveals that the female hake are found at the larger length groups. Therefore, it seems that since the male fish mature earlier, their overall growth is retarded because of gonad development (Le Cren, 1951). According to Alm (1959), however, the fast growing individuals which mature earlier continue to show increased growth throughout life. Therefore, early attainment of maturity may not have an effect on the growth rate. Although the growth rates for the two sexes of white hake were not established, an approximation of the age at maturity for the Cape Bear fish can be obtained by using the data from that region (Figs. 14 and 17). The respective ages at which males and females were 50% mature were approximately 4 years and 5 years of age. Battle (1951), using scales for determination and studying gonad development of hake collected at St. Andrew's, N.B., Digby and Halifax, N.S., found that the gonads are immature in hake to approximately 4 years of age. Since the hake enter the commercial fishery at 2 years of age and they reach 50% maturity when 4 or 5 years old, the immature fish which are potential adults are being withdrawn from the population. Although the female hake enter the fishery at larger lengths (Figs. 9 and 11), many are caught and their reproduction potential lost.

Although the fecundity was found to increase exponentially with an increase in length, it appeared to be higher than fecundities of other gadoids such as cod in the Gulf of St. Lawrence (Powles, 1958) and from Labrador (May, 1966). Fulton (1891) reported that the ling, Molva vulgaris, was "supposedly the most fecund of all sea fish". Of four specimens from the North Sea, the largest of 155 cm. length had a fecundity of 28,261,904. The white hake with this same fecundity would be approximately 100 cm. in length (see Fig. 20). Therefore, so far as this present study shows the white hake seems to be the most fecund of all sea fish.

The very small size of the hake ova (Fig. 19) can account, in part for their enormous fecundities. This seems to agree with the suggestion of Svardson (1949) that the more fecund fish lay smaller eggs and the fish which lay fewer eggs lay larger ones. Also, the large larvae resulting from the large eggs of the less fecund races can presumably survive the adverse conditions much better than the offspring of more fecund fish. Fulton (1891) felt that the great fecundity of most marine fishes was a measure of the destruction of the eggs which took place after they were shed. The environmental factors were not known in this hake study but they undoubtedly have an indirect influence on the regulation of egg numbers, rate of maturation, spawning time and place and the general age structure of the population. The availability of food which in turn is related to the density of the fish population are very important factors influenced by the environment (Bagenal, 1966).

For each length group sampled there was an evident variation in fecundity. May (1966) showed for cod that this variation is explained in terms of length alone. Age does not necessarily have a significant effect on fecundity. The variations of fecundity within age can be explained in terms of length variation within age. Any changes in fecundity can also be caused by the mixing of different groups of the same fish species which differ in their total egg-mass (Hempel, 1965).

A peak spawning time was observed to occur during the second half of June. Although it is suggested by Fulton (1891) that fish with high fecundities release their eggs in successive batches and not all at once, this is not definitely known to occur in the white hake. It was recognized that because of the large size of the translucent cod ova (1.5 mm.), the fish could not possibly contain all such eggs that it would produce in a year. Therefore shedding had to begin soon after the first clear ova were produced (May, 1966). During the breeding season of southern (boreal) forms of fish species, enough food is available for the adults to support the successive batches of eggs. Northern forms, however, spawn at a season unfavourable for feeding and, therefore, the females place all their reserves into a single egg batch (Qasim, 1956). The spawning period for cod was of a relatively long duration and that at least three separate periods of release occurred (May, 1966). The hake most probably also sheds successive egg batches. However, the smaller translucent (0.88 mm.) and intermediate ova permit the accommodation of more ova and thus resulting in a higher fecundity.

To conclude, the white hake is a highly fecund fish but the reason for this fecundity can only be guessed. There is a need for many more females to be sampled from different localities to substantiate these preliminary results. Techniques for counting and calculating fecundities need to be improved so that quicker and more accurate results will be obtained. Selection for high fecundities is obviously important in the evolution and survival of this species.

8. SUMMARY

1. The characters for the identification of the fish studied as Urophycis tenuis Mitchill are based on the observations of Musick (personal communication). Other workers feel that both red and white hake are present in the Gulf of St. Lawrence. However, those hake landed and examined at Souris, P.E.I. and in the study area are believed to be Urophycis tenuis Mitchill.
2. The white hake is exclusively an Atlantic water species found as far north as Newfoundland and south to Cape Hatteras. In the Gulf of St. Lawrence it is found off the Gaspé coast, along the edge of the Laurentian Channel and is quite common in the study area.
3. Landing statistics show a fairly consistent catch of hake in the Maritimes and Quebec from 1942 to 1959. However, the catches have diminished in recent years but this may be due to the confusion of recording white and red hake catches. The greatest abundance of white hake is caught in ICNAF division 4T and less so in divisions 4W and 4X.
4. Both inshore and offshore vessels fish for hake. The most important offshore fishing grounds are located off Cheticamp, N.S. and Cape Bear, P.E.I. The sizes of the hake landed by the offshore boats are predominantly 50-70 cm. in length. Inshore fishing is concentrated around Souris, North Lake and

Murray Harbour, P.E.I. The hake landed by these boats are generally smaller, with the greater proportion being in the 40-55 cm. size range. Female fish caught by both inshore and offshore fishermen are generally larger than males.

5. Otoliths were used to determine the age of the fish. The ageing technique used by other investigators for the cod fish was also considered valid for use with this species. The rate of growth for the hake from Cape Bear and Cheticamp seemed very similar. An increase of 7-9 cm. a year was estimated from the growth curves.

6. Female hake from Cape Bear were only slightly heavier than males of the same length. Weights of eviscerated hake from Souris showed an almost isometric growth with little or no change in body form or specific gravity with length increase.

7. The peak spawning time was found to occur during the second half of June. The 50% maturity points for female hake from Cape Bear and Souris were found to be 59.0 cm. and 60.2 cm. respectively. Males matured at smaller lengths. Those from Cape Bear had a 50% maturity point at 52.5 cm. while it was at 55.0 cm. for those from Souris. The hake caught on the M.V. Harengus cruise in June, 1966 had a 50% maturity point of 48.0 cm. for males and 52.4 cm. for females.

8. Fecundities were calculated from the ovaries of female hake caught on the M.V. Harengus and at Wood Islands, P.E.I. In both cases fecundity increased with increase in length but the

heterogenous sampling of the cruise fish resulted in them having a greater fecundity than the Wood Islands fish at the same size. The fecundity varied from 541, 666 for a 62 cm. fish to 29,835,658 for a hake of 109 cm. length.

9. ACKNOWLEDGMENTS

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