ASPECTS OF THE BIOLOGY OF THE WINTER FLOUNDER PSEUDOPLEURONECTES AMERICANUS (WALBAUM), IN LONG POND, CONCEPTION BAY, NEWFOUNDLAND.

VICTOR S. KENNEDY, B.S.c.

ASPECTS OF THE BIOLOGY OF THE WINTER FLOUNDER, PSEUDOPLEURONECTES AMERICANUS (WALBAUM), IN LONG POND, CONCEPTION BAY, NEWFOUNDLAND.

by

Victor S. Kennedy, B.Sc.

Submitted in partial fulfilment of the requirements
for the degree of Master of Science, Memorial
University of Newfoundland.

March, 1964

This thesis has been examined and approved by

ABSTRACT

From November 1962 to October 1963, samples of winter flounder, Pseudopleuronectes americanus (Walbaum) were taken in Long Pond, Newfoundland. Found in shallow water (1-2 m.) from November until June, the flounder moved into deeper water (7-10 m.) during the summer and returned to shallow water in September and October. These movements out of and into shallow water corresponded with the end of the spawning season and the ripening of the gonads respectively.

Flounder spawned from at least March until early June with the peak of activity in May and early June. Males ripened one or two weeks before females. The females were very fecund and there were great variations in fecundity for different individuals within the length, weight and age groups present.

Most males were mature at age 6 and most females at age 7. 50% of the males and females were mature at 21 and 25 cm. respectively. The growth rates for males and females were similar until age 8 after which females outgrew the males. Growth was slower in Long Pond than in areas to the south. The length-weight relationships for males and females were similar.

No feeding took place in December or January but flounder were feeding in March and continued throughout the summer with a decrease in food intake in the fall. They were omnivorous and the type of food eaten varied with the locality. Polychaetes and molluscs were important throughout the year.

Capelin eggs and fish remains occurred only during a few months of the year but were eaten in great quantities.

Polychaetes, winter flounder eggs and arthropods were not as important to the large fish as they were to the small. Capelin eggs and fish remains were eaten in quantity by the larger fish. The amount of plant material ingested increased and debris decreased with increasing size.

A trematode and a nematode were parasitic in the gut of winter flounder.

CONTENTS

ACKNOWLEDGMENTS

I wish to acknowledge with gratitude all those who have contributed their assistance to the present study. Special thanks is accorded my faculty advisor, Dr. D. H. Steele, Department of Zoology, Memorial University, for his patient supervision, thoughtful advice and encouragement by example during the course of this study. I would also like to thank Captain John Davis for his help in the field work in the fall and winter of 1962-63; Miss Terry McCullough and Messrs. McCullough, Dunn, Roberts, Snow and Schauer for their assistance on field trips using SCUBA; Mr. A. M. Fleming of the Biological Station, St. John's, Newfoundland for information concerning the fishing and biology of winter flounder in Newfoundland and Dr. F. D. McCracken of the Biological Station, St. Andrews, New Brunswick for information concerning the winter flounder in the Bay of Fundy region.

I am grateful to Memorial University for a fellowship granted for the academic year 1962-1963. Financial support was received from the National Research Council in 1963-1964 in the form of a grant to Dr. Steele.

INTRODUCTION

The winter flounder, Pseudopleuronectes americanus (Walbaum) is a common shoal-water flatfish found from Labrador to Georgia (Bigelow and Schroeder 1953). Moiseev (1953) states that it is adapted to cool water and has a boreal distribution. It is an important commercial species in many areas of the United States and small dragger fisheries have been developed in St. Mary Bay, Nova Scotia and at the western end of Northumberland Strait off Richibucto and Escuminac, New Brunswick (McCracken 1963). It is speared for lobster bait in many areas of Newfoundland, but aside from being an incidental species taken by Danish seiners or otter trawlers, there is no fishery in Newfoundland.

Because of the abundance of the fish and their widespread distribution in many offshore areas, there is a strong possibility that a profitable fishery might be established on a small scale.

The amount of knowledge available on the biology of the winter flounder is small. Lobell (1939) reported on flounder in the commercial and sport catches in Long Island waters with an emphasis on distribution and movements. Warfel and Merriman (1940) analysed the flounder populations in an area off Connecticut, and they reported on the winter flounder trawl fishery off Connecticut and Rhode Island (Merriman and Warfel 1948). Perlmutter (1947) discussed the flounder fishery in New England and New York. Their movements have been studied by McCracken (1963) and Saila (1961a, 1962). Aspects of the ecology of estuarine populations have been investigated (Pearcy 1962; Saila 1961b). Growth studies have been carried out in Rhode Island waters (Arnold 1941; Landers 1941; Berry 1959). Feeding of young winter flounder has been described by Linton (1921), Sullivan (1915) and Richards (1963). Breeding and larval distribution have been studied by Saila (1961b), Pearcy (1962), Richards (1959), Perlmutter (1939) and Wheatland (1956) with notes by Breder (1924), Herman (1963), Scott (1929), Brice (1898), Smith (1898) and Tracy (1910). Wolfgang (1954a, b) has studied a trematode of winter flounder which encysts on the body of the fish while Roland (1960) has commented on intestinal parasites.

Bigelow and Schroeder (1953) give a general summary of the results of other workers and present a report on the distribution, relative abundance and significant facts in the life history of the fish.

The present study investigates the age, growth, reproductive cycle, gonad changes over the course of a year, size and age at maturity, fecundity with consideration of its relationship to length, weight and age, seasonal variation in feeding activity, type of food eaten and changes in food eaten with change in size. During the survey, casual observations were made on the type of bottom inhabited, the seasonal movements and the presence of parasites in the stomachs examined.

Four hundred and sixty fish were collected from November 1962 to October 1963 in Long Pond, Conception Bay and 26 fish were taken in August, 1963 from Horse Cove, Conception Bay (Table 1).

TABLE 1

Collections of Winter Flounder in Long Pond, Conception Bay, Newfoundland from November 1962 to October 1963.

Survey	Date	Gear Used	Number of Fish	Temperature °C		Salinity °/	
				Surface	Bottom	Surface	Bot
A	13/11/62	Gill-nets	3	8·5°C	-	-	-
B	14/11/62	"	20	-	-	-	-
C	15/11/62	"	19	-	-	-	-
D	14/12/62	"	21	4	-	18.35	-
E	15/12/62	"	14	3	-	-	-
F	18/1/63	"	5	-0·5	-	-	-
G	26/3/63	"	5	0·0	-	-	-
H	27/3/63	"	17	0·2	-	-	-
I	28/3/63	"	9	1·2	-	-	-
J	29/3/63	"	6	-	-	-	-
K	19/4/63	"	29	6	-	-	-
L	18/5/63	Spear	98	8	-	30·44	-
M	5/6/63	"	2	7·8	-	19·99	-
	8/6/63	"	7	6·9	-	26·35	-
	12/6/63	"	60	9·8	-(1-2m)[+]	31·18	29·
N	27/6/63	"	18	11	-	30·95	-
	28/6/63	"	11	11	-(1-2m)	-	31·
O	11/7/63	"	36	-	8°(7m)	31·78	32·
P	31/7/63	"	13	13·2	-	31·65	-
Q*	21/8/63	"	20	-	11·1(7-10m)	-	31·
*	26/8/63	"	6	-	-	31·46	-

[+] Average depth of the bottom in meters

*Horse Cove Surveys

TABLE 1 (Continued)

Survey	Date	Gear Used	Number of Fish	Temperature $^{\circ}$C		Salinity ^{o}/oo	
				Surface	Bottom	Surface	Botto
R	18/9/63	Spear	20	-	10·6(5m)	-	31·55
S	28/9/63	"	8	-	11·2(5m)	-	31·20
T	26/10/63	"	39	-	9·2(1-2m)	30·35	-

Long Pond (Figure 1) is a small, shallow embayment used by local fishermen as a harbour. A large area near the harbour mouth has been dredged to an average depth of six meters to allow ships to load talc at a wharf. The remainder of Long Pond is one to two meters deep. Tides of an amplitude of one-fifth of a meter to one and one-third meters flow into and out of this area quite freely and so there is a constant turnover of water.

Horse Cove is approximately ten miles from Long Pond. It is not sheltered but is on the open sea. The flounder were fished at a depth of seven to ten meters.

Type of Bottom Inhabited by Winter Flounder

Bigelow and Schroeder (1953) report that most inshore flounder are found on muddy sand, especially where eelgrass is present, but may also be found on cleaner sand, clay or even pebbly or gravelly ground. The flounder in this survey were found mainly on muddy sand during the fall, winter and spring. In July, when they moved into deeper water, they were found on coarser sand, broken by areas of *Lithothamnion* sp., a calcareous alga which encrusts rocks and other objects. The August survey was carried out in an area of coarse sand broken by areas of rocks and boulders. The sand was shallow in depth and covered a rocky bed. During free-diving trips for pleasure, the flounder have been noted inshore on areas of large pebbles and have also been seen at depths of seven to ten meters, lying on rocks.

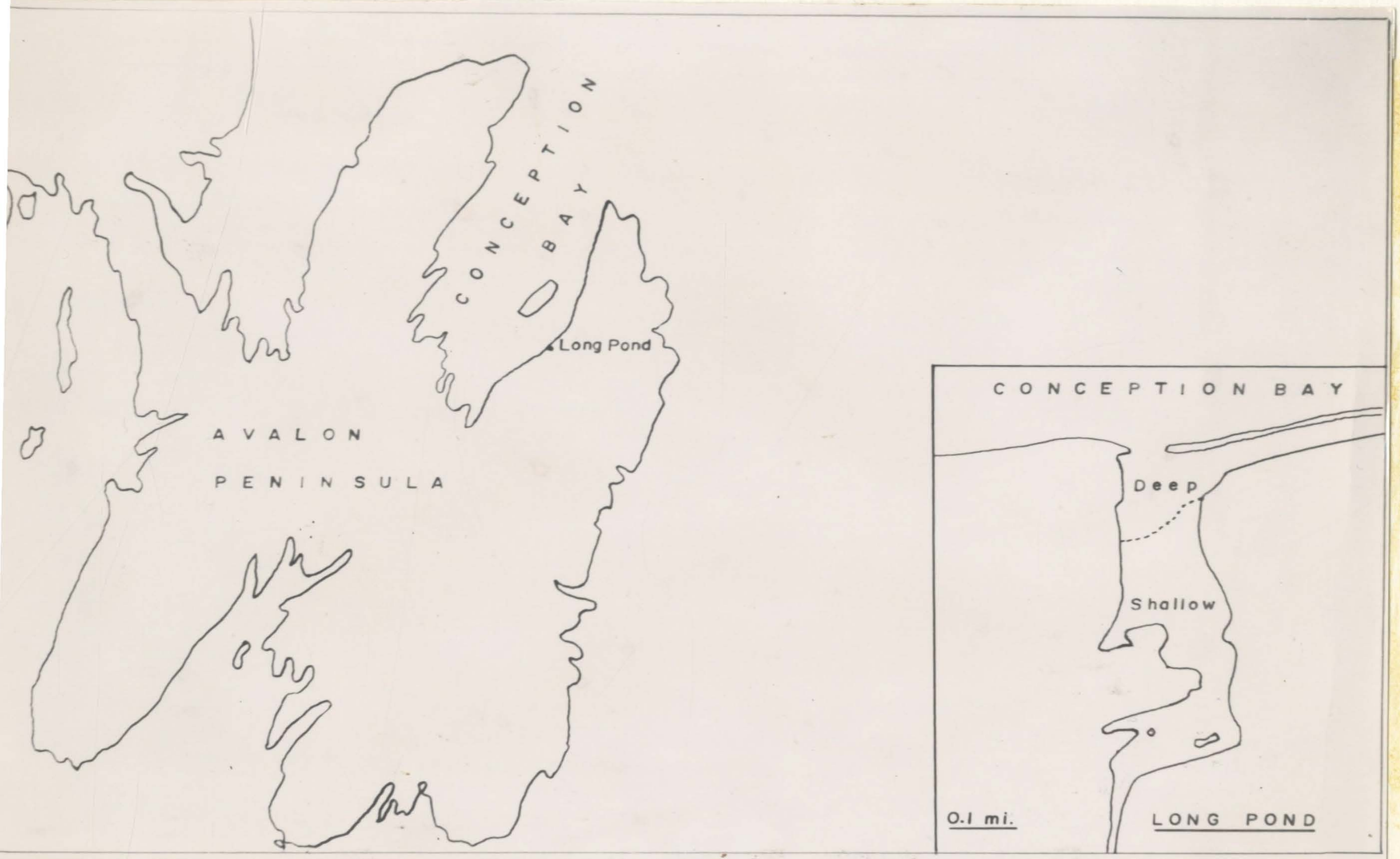

Figure I - Map of the Avalon Peninsula in Newfoundland showing the location of Long Pond. Inset. Long Pond.

They can be found on a wide variety of bottoms. It is not known, however, which environment is most frequented as no attempt was made to judge the relative abundance of flounder in the various areas in which they were found.

METHODS AND MATERIALS

Samples were taken once a month to study seasonal changes. Fishing was carried out using one 2" and one 4½" mesh nylon gill net in November and December 1962 and the 2" mesh alone in January and March. The nets, which were 50 feet long, were attached to the shore and run out into the water, the depth of which was no greater than two meters. They were emptied every twenty-four hours and were left out until a sufficient sample of fish was taken. Fishing was curtailed in January 1963 and had to be discontinued in February because of ice in the fishing area. During April, a 6" mesh gill net was used in place of the 2" and 4½" nets.

In May 1963, free-diving techniques were used to obtain samples of fish which were speared as they lay on the bottom. The area covered using this technique was small and was consistent during all sampling periods. During May, June and October 1963, flounder were caught in one to two meters of water and in July and September in seven to ten meters of water. The August sample was taken from Horse Cove.

Each fish was examined within a few hours after being taken from the water and the following data recorded:

1. Length: The total length, measured from the tip of the mandible to the distal end of the longest caudal fin-ray, was recorded to the nearest centimeter.
2. Weight: Round weight was recorded to the nearest gram using a chemical balance.
3. Sex and Maturity: The gonads were examined visually and

their sex and state of maturity recorded using criteria similar to those of Scott (1954) and Powles (1958). Ovaries were selected throughout the period from December 1962 to May 1963 and stored in Gilson's fluid for fecundity studies.

4. Food: Stomach contents were stored in formaldehyde for later examination. The wet volume was measured by water displacement, the number of the individuals present determined and the organisms identified as fully as time allowed.
5. Age determination: The largest pair of otoliths, the sagittae, were removed by making a deep transverse cut behind the preopercular bone. They were preserved in glycerin and read whole in a drop of glycerin under reflected light against a dark background.

Salinities were taken irregularly. Temperatures were recorded a foot or so below the surface on most sampling trips. Bottom temperatures were taken while diving.

Free-diving Techniques

The use of self-contained underwater breathing apparatus, or SCUBA, in fisheries surveys is a fairly recent innovation. Manfred Taege, in the World Student News (1963) discussed the use of skin diving in scientific research and described how this technique had been employed to collect hitherto unknown or rare species of organisms as well as enabling scientists to study the life in underwater caves and the behaviour of cave-dwelling fish. Poole et al (1963) describe the use of SCUBA in fishery programs and give ten areas of fisheries biology in which the technique is applicable. Northcote and Wilkie (1963) used divers to carry out an underwater census of fish populations in several rivers in British Columbia. Divers have surveyed a herring spawning bed (Tibbo et al 1963), studied the intertidal territory of fish (Carlisle 1961), observed salmon and brook trout (Keenleyside 1962) and used underwater photography to record the behaviour of salmon (Ellis 1961). A modification of the technique has been used to observe zooplankton (Bainbridge 1952, 1953). The author has not seen any papers on the use of SCUBA to collect fish. However, it is quite possible that this technique has been used, especially in the warmer waters around the southern part of the United States.

It is felt that, in view of the novelty of the technique of free-diving to obtain specimens for examination, it would be of interest to discuss the types of bias that can be encountered.

In a survey such as that being discussed in this paper, the type of bias introduced by free-diving techniques is not of great importance although it must be kept in mind. The bias introduced by the gill-nets used should also be considered.

Every technique that can be used to procure specimens for analysis is subject to a certain amount of bias or selectivity. This aspect of fisheries biology is so important that ICNAF, ICES and FAO held a Joint Scientific Meeting in 1957 to discuss this problem, among others. In their report (Clark 1960) they discussed the selectivity of three different kinds of fishing gear - hooks, gill nets and otter trawls. Many factors were presented as having some bearing on the composition of the catches made by these gears. In general, a comprehensive picture of the situation with regard to most fish is gained only by the use of a great deal of diversified equipment, e.g. gangs of gill nets, otter trawls with fine mesh cod-ends etc. Even then it is not always possible to be sure that the samples taken are representative of the population sampled. However, the information derived from these gears is still useful as long as the limitations are kept in mind.

Rather than collecting fish specimens by an impersonal method such as a gill-net or a beam trawl, the researcher who uses free-diving is himself collecting the animals. In many cases, such as the aforementioned survey of the herring spawning bed (Tibbo et al 1963), transects can be made and a standard sampling device can be used to collect the specimens. Obviously such a procedure is impractical for fish because the activity associated with skin diving and disturbances caused by speared fish cause the others to swim away. However, it is possible to stay within a general area and collect only there. This was the case in Long Pond due to the small area of the harbour and the general abundance of fish.

An obvious bias is the selection of the individuals to be speared. Size can play a role here as it is often easier to spear larger fish. The diver tends to dismiss smaller fish as being too difficult to catch and doesn't attempt to do so. This can be overcome by attempting to spear every flounder encountered. It is also limited because many bury themselves in the bottom so it is difficult to judge their size and while buried they are less liable to move unless under strong stimulus. If most flounder seen are speared, the results should not be affected by a bias of this type.

Differences in the behaviour of individuals in the populations can also introduce bias. Large flounder tend to move slowly and those over 25 cm. in length and especially those above 35 cm. in length (these values are estimated) do not move unless stimulated strongly. Often it has been possible to attempt to spear a large flounder again if the first attempt missed. Smaller fish, although they too bury in the bottom, are generally less lethargic. It was difficult to spear many of them, both because of their small size and the speed of their reflexes in avoiding the spear. It will be seen in the length compositions, however, that a number of small flounder, including two individuals 9 cm. in length, were caught in the summer by spearing. Fish on rocks are more alert and actively avoid capture by moving away as the diver approaches.

Because of the range in length provided by this technique and the number of fish taken, it is felt that the information presented in this paper is representative of the situation in the area studied.

MOVEMENTS

During November and December 1962, the shallow part of Long Pond was found to be the habitat of many flounder, both mature and immature. In January, ice formed in the area of the nets and broke them loose from their moorings with the result that they were unable to be hauled until five days after they had been set. Five flounder were taken and further fishing was discontinued because of the ice conditions. When fishing resumed in March, both immatures and matures were taken, but in April a net with larger mesh was used and caught only mature fish. The findings above show that flounder are found in the shallow area of Long Pond in the fall and early spring.

Free-diving techniques were introduced in May and employed for the rest of the year. Table 2 has been drawn up to show the variation in catch per unit effort by SCUBA diving. The number of man-hours per sample using SCUBA was calculated from a log of the various dives and the total per month was divided into the number of flounder caught to give the number of winter flounder caught per man-hour. For May, June and October, the results deal with fish caught in the shallow area of Long Pond. The July and September results are given separately for the shallow and deep ends of Long Pond. The August results are for the deep area of Long Pond and for Horse Cove.

During May and June, the increasing number of spent and recovering fish indicated that the spawning season was

TABLE 2

Winter flounder catch per unit effort for Long Pond and Horse Cove, May to October, 1963

onth	Depth (m)	Area	No. Caught	Man-hours SCUBA	Catch/man-hour	Surface Temperature range
ay	1-2	Long Pond	98	3	32·6	8°C
une 12	1-2	Long Pond	60	3	20·0	9·8°
une 28	1-2	Long Pond	29	2	14·5	11°
uly	1-2	Long Pond	0	1	0·0	10°-13·2°
uly	5-7	Long Pond	49	3·5	14·0	8° (bottom)
ugust	5-7	Long Pond	0	2	0·0	11° (bottom)
ugust	7-10	Horse Cove	26	1·3	20·0	11·1° (bottom)
eptember	1-2	Long Pond	-	-	-	-
eptember	5-7	Long Pond	28	3	9·3	10·6°-11·2° (bottom)
ctober	1-2	Long Pond	36	1·5	24·0	8-9·2°

coming to a close. The survey of June 28th showed that the flounder were less abundant than they had been on June 12th, at which time they had been less abundant than in May. A survey of the area was made on July 8th by swimming around on the surface in the shallow area of Long Pond and looking for flounder. Only one small flounder less than ten centimeters long was seen in one meter of water and a few small flounder were seen around the edge of the dropoff to the dredged area. SCUBA was then used to search the bottom of this dredged area and many flounder of all sizes were seen. It was obvious that there had been a mass movement into deeper water of all flounder between June 28th when 29 flounder had been speared in the shallow area and July 8th when the reconnaissance survey showed that they had moved into the dredged area. This movement into deep water continued until, by August, few were left in the dredged area, none of which were speared.

The September survey in the deep water of Long Pond showed that the flounder were moving back into this area. Of the twenty fish speared on September 18th, fifteen were males and of these the testes of fourteen were classified as resting. However, it was noticed that the testes were relatively larger than they had been during July and August and it was thought that these fish were in the very early stages of ripening. However, they were classified as resting for want of other evidences of ripening (see Table 8). No such indications of early ripening were noted for the four mature females caught. On September 28th, eight fish were speared, three of which were ripening males and the remainder ripening females. The testes were definitely ripening at this time. In October, the flounder had reentered the shallow area and the gonads of the mature fish of both sexes were ripening.

The movements out of the area corresponded to the end of the breeding season and the appearance of the resting stage in the gonads, while the movements into the area occurred at the time that the gonads, especially those of the male, began ripening. The high male:female ratio of September 18th may indicate that males reenter the breeding area before females.

Lobell (1939) found that winter flounder in Long Island Sound and Block Island Sound moved into cooler offshore waters during the summer and into shallow inshore areas (average depth 4-6 m.) in winter and early spring. Merriman and Warfel recorded that commercial fishing was mainly from deeper water (around 40 m) from June to September and shallower water (20-30 m) for the rest of the year. McCracken (1963) concluded that flounder moved into deeper waters in winter in Passamaquoddy Bay, N.B. and St. Mary Bay, N.S. In spring, flounder were found inshore for all regions sampled in the Candian area. In summer, flounder were abundant in the cool shallow (0-18 m) waters of Passamaquoddy Bay and St. Mary Bay and they left the warm shallows and entered deeper, cooler water (15-24 m) in Northumberland Strait or cooler, shallower (5-9 m) water off Pubnico Harbour, N.S. He also concluded that winter flounder were found offshore in winter north of Cape Cod and inshore south of Cape Cod. The distribution north of Cape Cod resembled that of the Bay of Fundy while that south of Cape Cod was more like that of Long Island Sound. The behaviour of flounder taken in the present survey resembled that of the flounder south of Cape Cod and in the bays of Long Island Sound and Block Island Sound.

McCracken (1963) concluded from a study of these movements in relation to temperature that the flounder were concentrated between 12° and 15°C over a wide geographical range and moved out of areas when the temperature reached 15°C. He also concluded that winter flounder in these areas had a preferred temperature range of 12-15°C.

The flounder in Long Pond were found in waters that were much colder than the waters in which they were found to the south. In January, five were caught when the temperature four feet from the bottom was -0·5°C. Warfel and Merriman (1948) stated that the minimum temperature at which they caught winter flounder was 4·2°C. At no time during the summer surveys was the bottom temperature in the dredged area of Long Pond above 11·2°C. Flounder moved back into the dredged area of Long Pond in September when temperatures ranged from 10·6°-11·2°C which is below the preferred temperature range mentioned by McCracken (1963). The preferred temperature range for flounder in this area may therefore be lower than that for flounder further south.

In addition, few flounder were found in the deep area of Long Pond in August when the bottom temperature was 11°C but during the same month, 26 were caught at nearby Horse Cove in slightly deeper water with a bottom temperature of 11·1°C. This observation casts some doubt on whether or not temperature is the main contributing factor to movements of winter flounder. As McCracken (1963) states, flounder south of Cape Cod would be expected to disperse into deeper water in winter on the basis of similar temperature conditions as the areas north of Cape Cod where flounders do move into deeper water. He suggests that flounder do not withdraw in the southern regions because the mature fish there are in a spawning condition in mid-winter. The same situation exists in Long Pond where the mature flounder begin ripening in early fall (late September). Although the evidence is scanty, there is some indication that, at least for the matures, their movements are governed by the state of their gonads, rather than by temperature.

AGE AND GROWTH

Flounder otoliths are thin and the growth rings were readily seen without grinding. The number of hyaline rings and the condition of the edge of the otolith (whether hyaline or opaque) were recorded. Each pair was read at least twice and in the cases where these readings disagreed, a third reading was taken and a probable age assigned to the specimen. If the otoliths were too opaque to be read, or if both had crystallized, they were discarded. Very few had to be treated in this manner.

Validity of the Otolith Method of Age Determination

In using the otolith for age determination, the assumption is made that a pair of adjacent opaque and hyaline rings represent a year's growth. To verify this assumption, it is necessary to collect samples of fish ranging from larvae to mature individuals over a period of years and analyse the changes in the appearance of the otoliths for fish of various size groupings. Berry (1959) analysed these changes for winter flounder otoliths and found that the rings were formed at the same time each year in mature fish. He concluded that the otolith was a valid structure for age determination.

In order to determine if this were true for the flounder in this area, the percentage of fish having hyaline otolith edges was calculated for each month in which fishing took place (Table 3). Opaque and hyaline margins were found during each of these months, but their frequency varied from month

TABLE 3

Percentage of hyaline rings on the otoliths of winter flounder grouped by monthly samples November 1962 to October 1963.

Month	Percentage of hyaline rings	No. of fish with hyaline rings
November	86	36
December	96	34
January	80	4
February	-	-
March	88	33
April	93	26
May	58	55
June	31	30
July	4	2
August*	79	20
September	86	23
October	90	35

*Horse Cove sample

to month. Hyaline edges were abundant from August to April with a peak in December. The percentage of opaque zones increased rapidly in May and reached its maximum in July. This corresponds with the resumption of feeding and the end of the breeding season. The percentage of opaque zones decreased in August.

There is a suggestion that the main turnover from hyaline to opaque edges occurred in June since, in the sample taken on the 12th of June, 1963, 64% of the males and 60% of the females had opaque edges on their otoliths, whereas, in the sample taken on the 27th of June, 92% of the males and 75% of the females had otoliths with opaque edges.

The changes noted above are in agreement with those noted by Berry (1959) in Rhode Island waters. He found that mature flounder older than two years generally had otoliths with hyaline edges from August to April and opaque edges for the rest of the year. He does not mention what happened to immatures older than two years but those of year two began forming opaque edges in December. The immatures in the present survey generally were like the matures.

It is concluded therefore that one hyaline and one opaque ring are formed per year and on this basis the rings are judged to be useful in determining the age of winter flounder.

Knowledge of the percentage of hyaline edges present each month (Table 3) led to the arbitrary establishment of the flounder's "birthday" as the first day of December, because during this month only one flounder in the sample exhibited an opaque edge while the rest (96%) had hyaline edges. It was therefore decided that for convenience the fish would be judged to be one year older on December 1.

December, January and February were then combined as being representative of that quarter of the year when the majority of otoliths had hyaline edges. Table 4 shows the method of recording the otolith readings and of assigning age groups. This method is the same as that used by Kohler (1958) for haddock.

Size and Age Composition

The flounder in this survey have been shown to move into and out of Long Pond at various periods and as a result the size and age composition in the area varies throughout the year.

For convenience, the data for some months have been combined but data derived from gill-net fishing have not been combined with data collected by spear-fishing. The data are presented in Figure II and Table 5.

(a) Size Composition

During November and December, the size range was 19-45 cm. and two length groups, the 20-22 cm. and the 29-31 cm. groups were most prominent. In March when only the 2" gill net was used, the size range was 18-26 cm. and the catch was composed mainly of the 20-22 cm. group. During April, the 6" gill net was used. The size range was 28-44

TABLE 4

Examples of observed ring counts and edge types in winter flounder otoliths, and the resulting transformation for age.

Time of Capture		Number of hyaline zones	Type and Width of edge	Age group assignation
Quarter of year	Months			
	Dec.	4	narrow hyaline	4
I	Jan.	4	wide hyaline	4
	Feb.	4	narrow opaque	4
		4	wide opaque	4
	March	4	narrow hyaline	4
II	April	4	wide hyaline	4
	May	4	narrow opaque	4
		4	wide opaque	4
	June	4	narrow hyaline	3[a]
III	July	4	wide hyaline	4 (3[a] in Aug.
	August	4	narrow opaque	4
		4	wide opaque	4
	Sept.	4	narrow hyaline	3[a]
IV	Oct.	4	wide hyaline	3[a]
	Nov.	4	narrow opaque	4
		4	wide opaque	4

[a] It is assumed in these cases that a new hyaline zone has been formed before the fish's "birthday" on December 1. This new ring is therefore not counted as a year-zone until December.

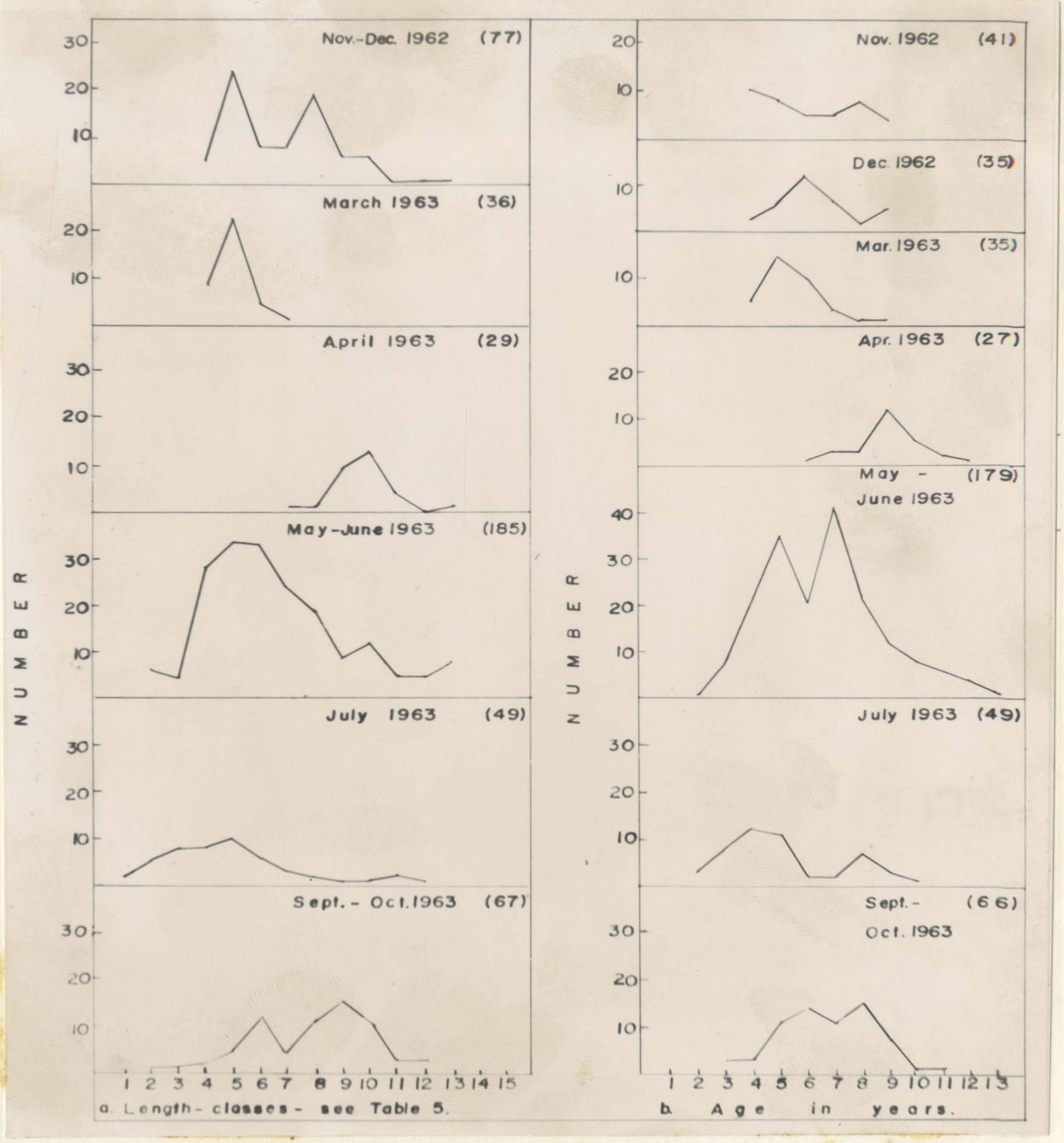

Figure II(a) - Seasonal size composition of Long Pond catches (Numbers of fish in parentheses).

Figure II(b) - Seasonal age composition of Long Pond catches (Numbers of fish in parentheses).

TABLE 5

Size and Age compositions of catches from Long Pond
(Percentages in parentheses).

(a) Size-Composition

Length (cm.)	Length class	Nov-Dec	March	April	May-June	July	Sept-Oct
8-10	1	-	-	-	-	2(4)	-
11-13	2	-	-	-	6(3)	5(10)	1(1)
14-16	3	-	-	-	4(2)	8(16)	1(1)
17-19	4	4(5)	8(22)	-	28(15)	8(16)	2(3)
20-22	5	24(31)	23(64)	-	33(18)	10(20)	5(7)
23-25	6	8(10)	4(11)	-	33(18)	6(12)	12(18)
26-28	7	8(10)	1(3)	1(3)	24(13)	3(6)	4(6)
29-31	8	19(24)	-	1(3)	18(10)	2(4)	11(16)
32-34	9	6(8)	-	9(31)	9(5)	1(2)	15(22)
35-37	10	6(8)	-	13(45)	12(6)	1(2)	10(15)
38-40	11	-	-	4(14)	5(3)	2(4)	3(4)
41-43	12	1(1)	-	-	5(3)	1(2)	3(5)
44-46	13	1(1)	-	1(3)	8(4)	-	-

(b) Age-Composition

Age	Nov.	Dec.	March	April	May-June	July	Sept-Oct
1	-	-	-	-	-	-	-
2	-	-	-	-	1(1)	3(6)	-
3	-	-	-	-	8(4)	8(16)	3(4)
4	10(24)	3(8)	5(14)	-	21(12)	12(24)	3(4)
5	8(20)	6(17)	15(43)	-	35(20)	11(22)	11(17)
6	5(12)	12(34)	10(28)	1(4)	20(11)	2(4)	14(21)

TABLE 5

(b) Age-Composition (continued)

Age	Nov.	Dec.	March	April	May-June	July	Sept-Oct
7	15(12)	7(20)	3(8)	3(11)	41(23)	2(4)	11(17)
8	8(20)	2(6)	1(3)	3(11)	22(13)	7(14)	15(23)
9	4(10)	5(14)	1(3)	12(44)	12(7)	3(6)	7(11)
10	-	-	-	5(18)	18(4)	1(2)	1(2)
11	1(2)	-	-	2(7)	6(3)	-	1(2)
12	-	-	-	1(4)	4(2)	-	-
13	-	-	-	-	1(1)	-	-

cm. with the 35-37 cm. group prominent. The lack of the 23-25 cm. and 26-28 cm. flounder in the catch from November to April may be indicative of a real lack of individuals from these length groups or it may have been caused by mesh selection. In view of the strong representation of these two groups during May-July, it is probably the latter case.

The catches for May and June were taken by spear-fishing and are the most comprehensive. The size range was 12-46 cm. and fish from 17-28 cm. predominate. A number of large fish are present causing the curve to be drawn out to the right. This is characteristic of many unexploited populations where the large fish are not subject to fishing mortality and usually live for many years.

The size range of the July survey was 9-41 cm. and the most abundant fish were those in the 11-25 cm. range. Few large flounder were present. This shows the effect of the movement of larger fish into deeper water.

In August, few fish were seen and none speared in Long Pond. Apparently most had moved into deeper water.

During September and October the larger fish started to reenter the shallow water as evidenced by the large mode on the right of the length-frequency curve. The size range was 13-43 cm. and the two dominant groups of fish are the 23-25 cm. and 32-34 cm. groups. These two groups are each the next highest group to the two groups seen in the curve for November-December 1962. This shows the modal progression possibly caused by the growth of the flounder during the spring and summer.

In general, most fish were in the 17-31 cm. groups with the 20-22 cm. group dominating until July. As will be seen later, the fish had been feeding heavily up until July and growth was rapid (see Table 6) with the result that the mode moved to the 23-25 cm. group. Large winter flounder above 31 cm. were taken but their abundance dropped as they moved into deeper water in July. It increased again in September and October as they reentered the Long Pond area.

(b) Age Composition

During November and December 1962, the age range was 4-9 years with one 11 year old fish caught in November. The December mode occurred at the 6 year point. In March, the 2" mesh net caught a range of 4-9 year old fish with a peak of abundance at 5 years. The 6" net in April took a range of 6-12 year olds with the peak at 9 years.

Spear fishing during the summer and fall took a wide range of ages - from 2-13 years. Two modes are apparent; one at 5 years and the other at 7 years.

July surveys revealed that the older flounder were becoming less abundant in the area at this time. The age range was 2-10 years with peaks at 4 and 8 years of age. The older fish became more abundant in the area during September and October. The age range was 3-11 with modes at 6 years and 8 years of age.

Generally the most abundant age groups were the 4-8 year old fish. Age composition, like size composition, was affected by the movements of the fish. The older and larger fish moved out of the area after June and didn't return until September and October. The younger, smaller fish were found in the dredged area of Long Pond in July but most had moved away by August with the result that few were seen and none were speared. They started to reenter the Long Pond area in September.

Growth

The mean lengths at the various ages of male and female flounder were grouped in different time periods and tabulated (Table 6). They are presented graphically in Figure III. The time periods were chosen for the following reasons: December 1 was arbitrarily established as the "birthday" of the flounder and therefore the fish caught in November would have been placed in a higher year-group if they had been caught two or three weeks later. As a result, a five year old November flounder would have been approximately the same length as a six year old in December, therefore the November and December results were kept separate. March to May included the spawning period, June and July were summer months and the periods during which the fish were feeding, especially during the latter month, and September and October were the months in which feeding decreased and the gonads started to ripen.

At most ages there were a wide range of lengths present and therefore the mean lengths of some age groups with few fish in the sample would possibly not be representative of the mean length at that age.

TABLE 6

ean lengths at each age for male and female flounder arranged for different time periods (Numbers of fish in parentheses).

	November 1962		December 1962		March-May 1963		June-July 1963		Sept-Oct 1963	
ge	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	10·5 (2)	10·5 (2)	-	-
3	-	-	-	-	-	12·5 (2)	13·3 (3)	15·9 (10)	13·0 (1)	16·5 (2)
4	19·8 (5)	20·5 (6)	-	20·6 (3)	17·0 (2)	18·2 (12)	18·0 (13)	18·4 (11)	22·0 (1)	23·0 (2)
5	24·8 (4)	23·3 (3)	22·0 (3)	22·6 (3)	20·0 (11)	19·9 (22)	21·9 (18)	20·8 (11)	25·4 (7)	23·2 (5)
6	26·7 (3)	32·5 (2)	22·2 (5)	25·6 (7)	22·2 (9)	27·3 (12)	23·3 (8)	25·7 (6)	28·2 (7)	27·9 (6)
7	32·5 (2)	30·3 (3)	30·0 (1)	30·2 (6)	27·1 (16)	28·0 (10)	27·3 (13)	26·8 (10)	31·4 (8)	32·0 (3)
8	34·5 (2)	33·0 (6)	29·0 (1)	30·0 (2)	31·6 (10)	27·6 (7)	31·2 (6)	30·2 (10)	33·0 (10)	33·1 (6)
9	31·5 (2)	38·0 (2)	30·6 (3)	30·0 (1)	31·6 (9)	36·4 (10)	36·0 (2)	39·4 (5)	33·0 (3)	40·8 (3)
0	-	-	-	-	33·2 (6)	40·1 (6)	41·0 (1)	40·8 (5)	37·0 (1)	-
1	-	45·0 (1)	-	-	36·5 (2)	40·0 (3)	-	42·0 (2)	-	41·0 (1)
2	-	-	-	-	-	44·0 (3)	-	46·3 (3)	-	-
3	-	-	-	-	-	-	-	46·0 (1)	-	-

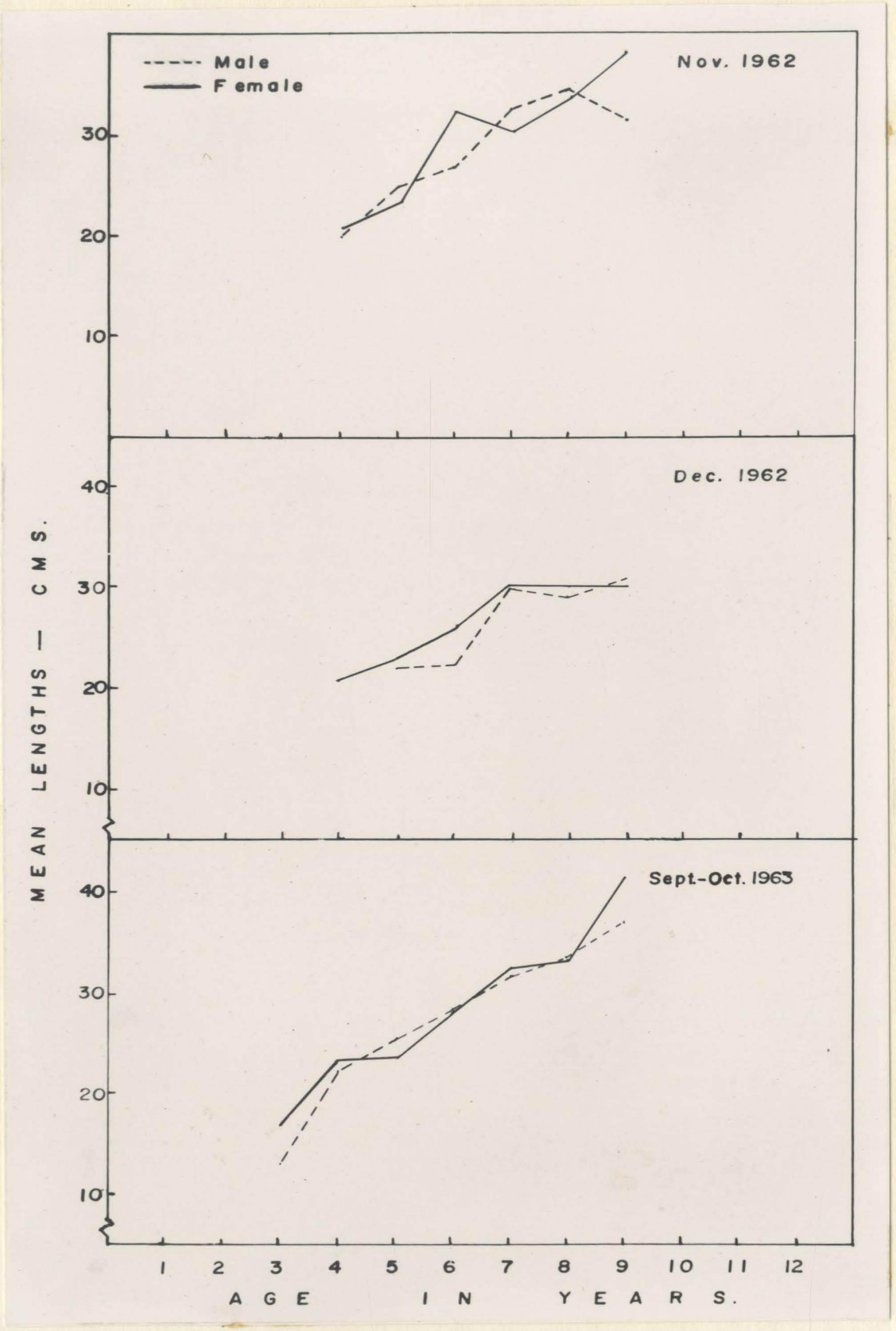

Figure III - Seasonal growth rates of male and female flounder in Long Pond.

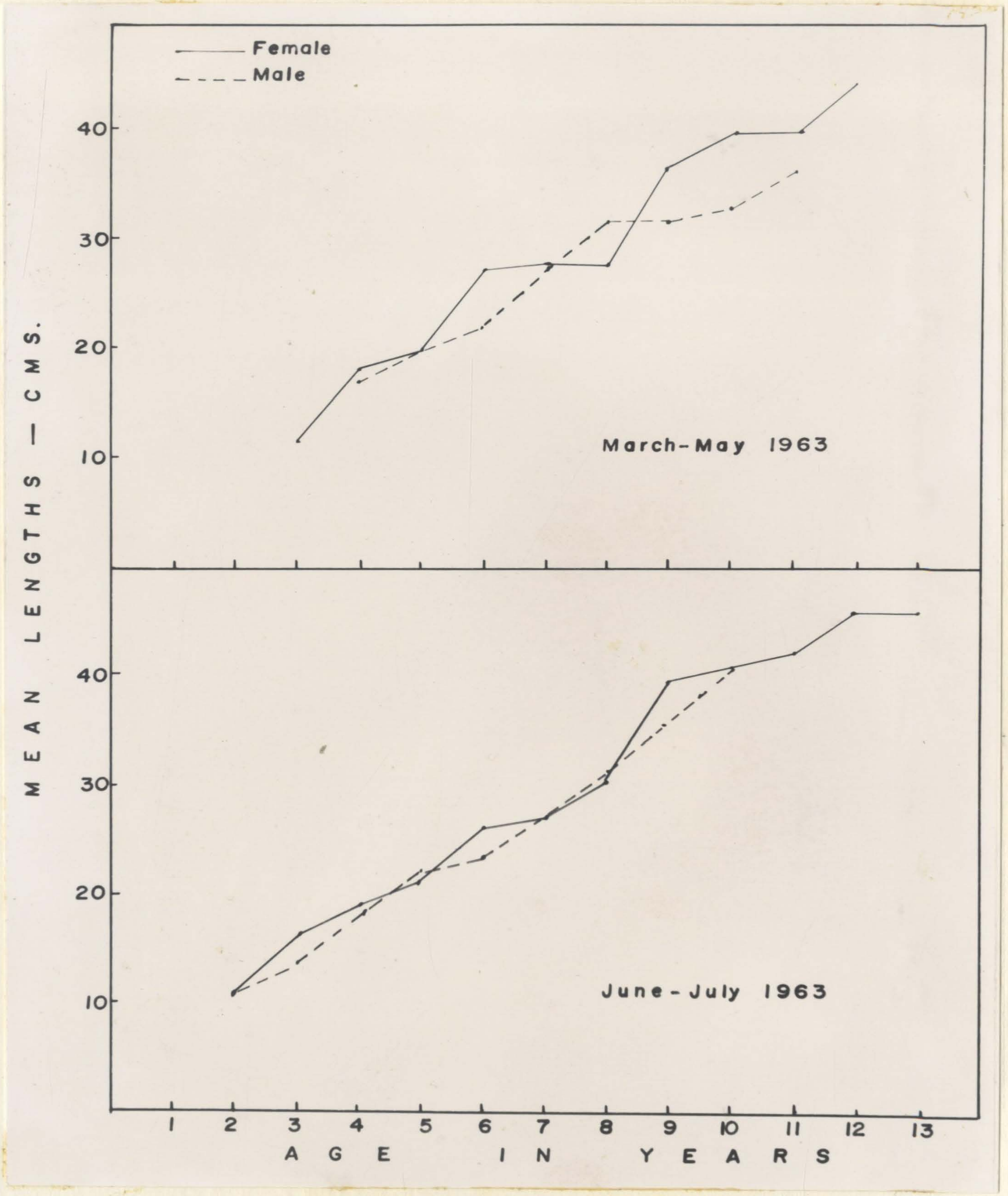

Figure III (continued) - Seasonal growth rates of male and female flounder in Long Pond.

The November mean lengths for the different ages were greater than the mean lengths for the same ages in December. It should be remembered that these November fish would have been placed in the next highest year class if they had been captured a few weeks later (after their "birthday" on December 1).

The number of fish of both sexes in the 8 and 9 age classes for December was small and the mean lengths determined are probably non-representative.

The samples for the period March to October were large. There were differences between the growth of males and females for individual year classes but generally the mean lengths for each sex corresponded closely from class to class until both sexes were 8 years old. At age 9, the female was larger than the male of the same age and from then on it outstripped the male in growth. The male growth rate slowed down after age 9 but few males were found to be over 9 years of age so little can be said with regard to their growth. There were many more females which lived to be older than 9 and in their case, growth continued, although it is not known if it slowed down. No change was noted when flounder matured.

Table 7 compares the average length of Long Pond flounder related to age for the combined months of May and June with data from other areas. These data are found in Table VII in McCracken's paper (1954) and were presented in Berry's paper (1959). As was seen earlier, the mean lengths of males and females in Long Pond corresponded closely until age 8. As the table includes only those fish up to age 8 it

TABLE 7

Comparison of the growth rates of winter flounder in different areas (both sexes combined)

(Adapted from Table VII (McCracken 1954) as quoted by Berry (1959))

ace	Peconic and Gardiner's Bay, R.I. (Perlmutter, 1940)	St. Mary Bay N.S.		Annapolis Bay N.S.	Passamaquoddy Bay, N.B.	Pubnico Bay N.S.	Northumberland Strait	Long Pond, Nfld.
nth	Feb-April	April-June		May	May	May	August	May-June
e	Length (cm)	Length (cm) 1	2	Length (cm)	Length (cm)	Length (cm)	Length (cm)	Length (cm)
1	-	-		-	7·9	8·8	-	-
2	27·9	17·5		15·3	11·8	13·3	-	12·0
3	29·2	26·5		22·5	18·7	19·1	19·5	14·6
4	34·6	31·4	35·0	29·1	23·5	22·9	22·9	17·8
5	37·2	34·9	37·2	33·0	25·7	26·0	28·7	21·0
6	39·1		39·5	35·6	28·2	30·0	29·6	25·0
7	40·6		41·5	38·0	31·0	35·7	32·4	26·9
8	48·2		42·7	40·2	32·4	-	34·3	29·8

- from a small weir
- from commercial landings

was thought reasonable to determine the average lengths for both sexes combined and therefore the values for May and June were combined to give a good sample, and to allow the comparison to be between fish caught in the same general time period as in other areas.

Table 7 shows that the growth rate for Long Pond flounder for that period was much slower than that found in the other, more southerly regions. This may be due to differences in the feeding period which is generally from March to September in Long Pond with little feeding activity at other times. The flounder were found to have begun feeding before spawning was over. Flounder in other areas finish spawning earlier than at Long Pond and may similarly resume feeding before the breeding period ends. They would therefore have a certain amount of time to feed that was not available to Long Pond flounder. Richards (1963) found flounder feeding during all seasons with empty stomachs occurring only in winter and early spring (although the majority of fish caught at this time were one year old and not comparable to fish taken in Long Pond). Flounder in this survey were found in colder water than further south as was stated earlier and this cold may change the metabolic rate resulting in slow growth.

Length-Weight Relationship

The mathematical equation of the form $W = a L^b$ was found for the length-weight relationship for flounder caught during April to June, and July and September combined. The relationships for male and female separately were calculated from the April-June data. In the equation above W equals the weight in grams, L equals the length in centimeters and (a) and (b) are constants. The logarithmic equations of the form $\log W = \log a + b \log L$ were found using the method of least squares and are as follows.

April-June MALE $\log W = 2{\cdot}9833 \log L - 1{\cdot}9042$
107 fish $W = 0{\cdot}012469\ L^{2{\cdot}9833}$
117 fish FEMALE $\log W = 3{\cdot}1441 \log L - 2{\cdot}0702$
$W = 0{\cdot}008508\ L^{3{\cdot}1441}$

As Figure IV shows, there is a very close relationship with the longer female fish being slightly heavier than male fish of the same size. Because of this close relationship, both sexes were combined for April-June, and July and September. The equations for these periods were as follows;

April-June 1963
224 fish $\log W = 3{\cdot}1086 \log L - 2{\cdot}0674$
$W = 0{\cdot}008562\ L^{3{\cdot}1086}$

July and September 1963 $\log W = 3{\cdot}1797 \log L - 2{\cdot}1497$
76 fish $W = 0{\cdot}007084\ L^{3{\cdot}1797}$

As figure V shows, these lines are very similar with the July and September curve indicating that the fish in this sample were slightly heavier than flounder of corresponding lengths in the April-June sample. This is to be expected since most of the feeding took place in May-July, the results of which would be seen in the July and September equation.

Berry (1959) combined the sexes by removing the gonads before weighing and reached the following length-weight

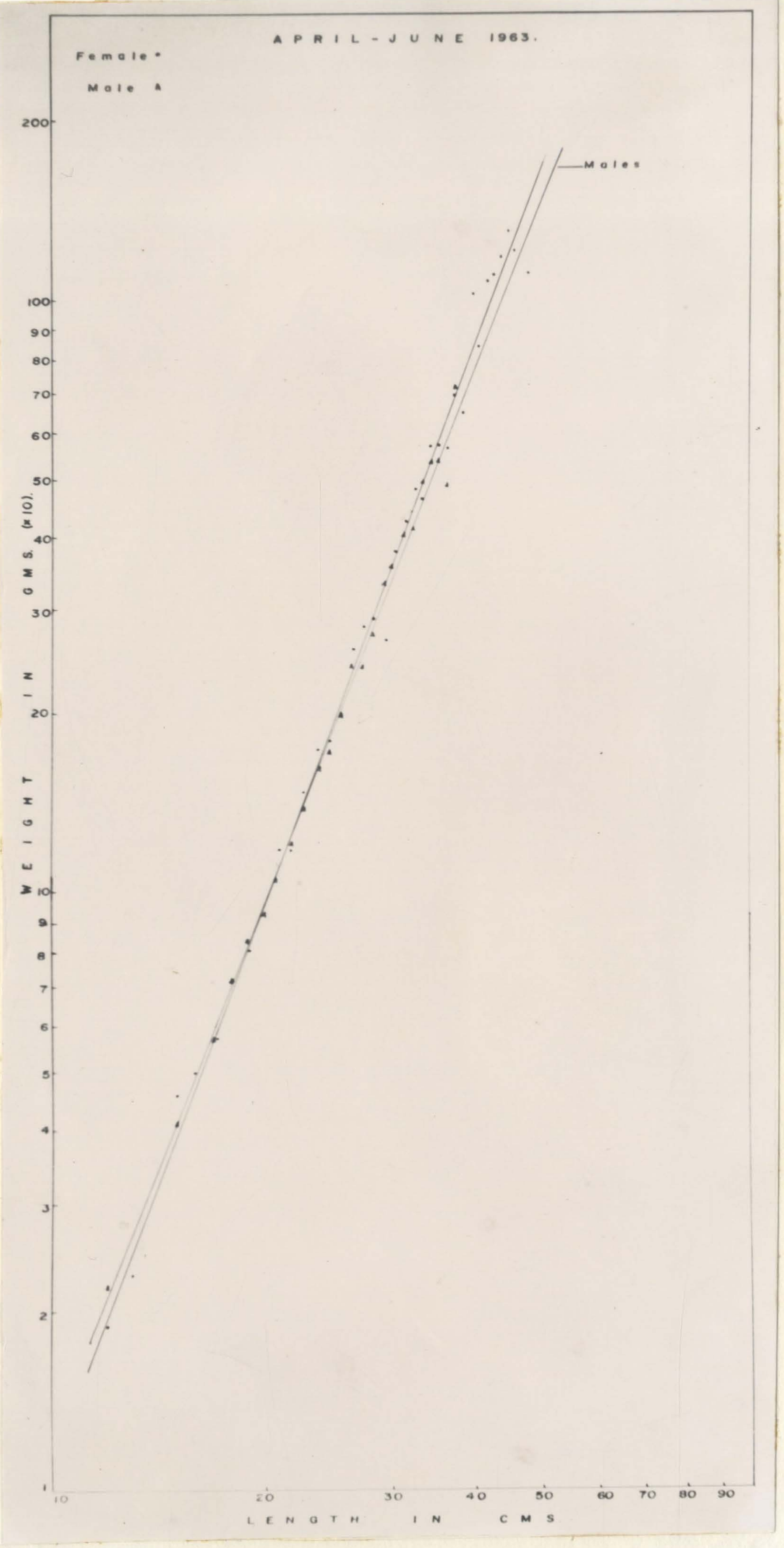

Figure IV - Length-weight relationships of male and female flounde
in Long Pond, April-June 1963. (Points are mean
weights at each length).

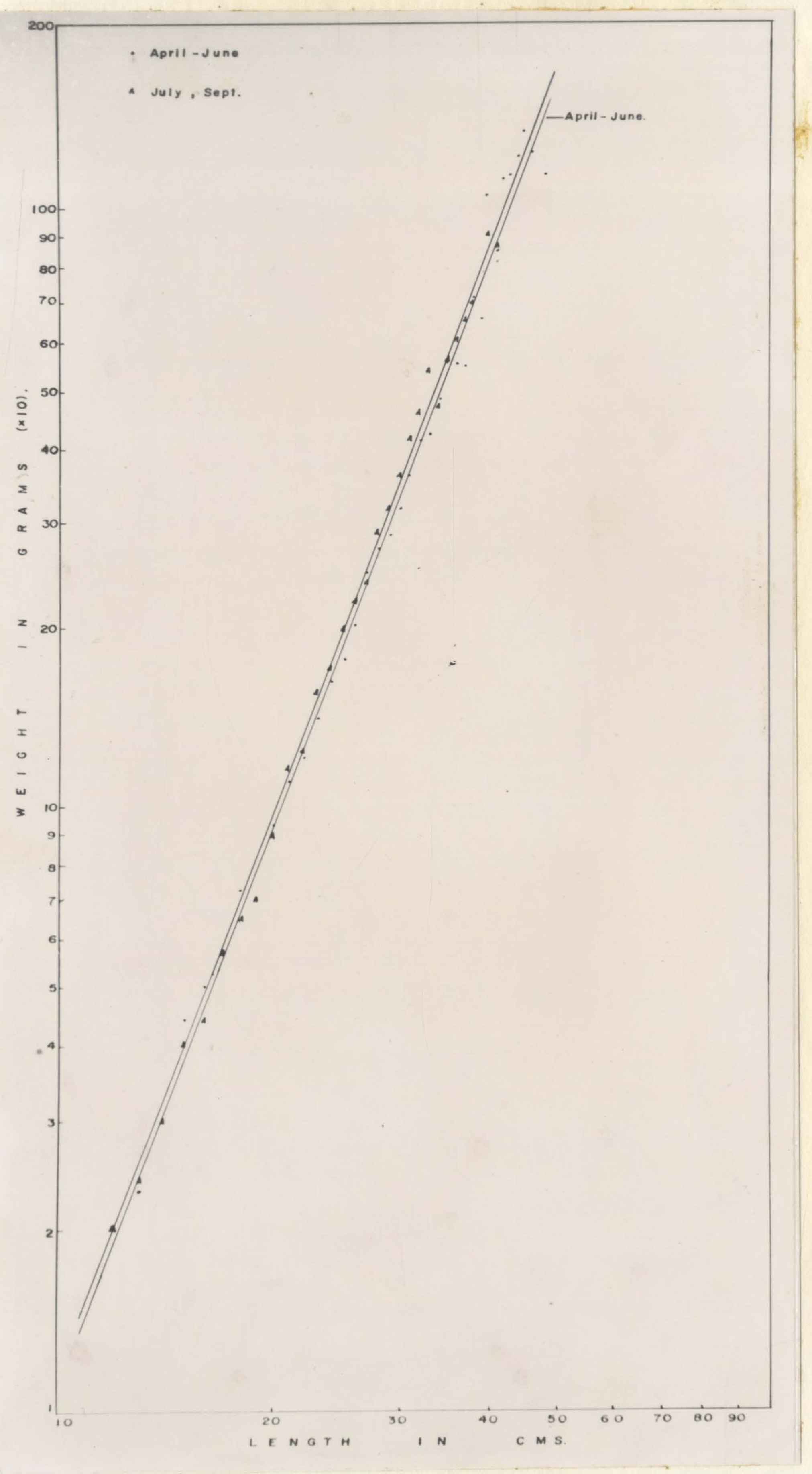

Figure V - Length-weight relationships for Long Pond males and females combined. Data collected for April-June and July and September 1963. (Points are mean weights at each length).

relationship for 107 fish

$$W = 0 \cdot 000982\ L^{3 \cdot 0151}.$$

The slope (3·0151) of this equation is similar to that of the equations cited for combined data above.

REPRODUCTION

Many authors (Saila 1961b, 1962; McCracken 1963; Pearcy 1962a, 1962b; Perlmutter 1939, 1947) have pointed out that winter flounder spawn in shallow inshore waters such as bays and estuaries. This was found to be true for the flounder in the Long Pond area, and made for convenient sampling of the population.

In this thesis, age and size at maturity, and the spawning cycle were determined, and the fecundity was analysed in relation to the age, length, and weight of the fish.

Little published material is available concerning the reproduction of the winter flounder. Brief references are found concerning the spawning behaviour (Breder 1922), the development of the egg (Brice 1898; Scott 1929; Breder 1923) and the larvae (Sullivan 1915, Breder 1923). The incidence of larvae in the plankton population has been recorded (Perlmutter 1939; Wheatland 1956; Richards 1959; Herman 1963). Pearcy (1962a) described the larvae and juveniles of estuarine winter flounder. Saila (1961b) presented estimates of the fecundity of 46 Rhode Island flounder.

Age and Size at Maturity

The sex and stage of maturity were determined by visual examination of the gonads. The classification used in this study was similar to that of Scott (1954) for female *Limanda ferruginea* and Powles (1958) for *Gadus morhua* (= *callarias*) L. As the study progressed, notes were made on the characteristics of the different stages, a description of which appears in Table 8.

The percentages of immature and mature fish of either sex in each age group are shown in Figure VI, which is based on data collected during the spawning period and therefore includes only those fish that had spawned or would have spawned during that time. Figure VI shows that 43% of the males were mature at age 5 and 87% were mature at age 6. Only about 35% of the females were mature at age 6 whereas 74% were mature at age 7. All individuals of both sexes were found to be mature at age 9.

The curve of size at maturity was fitted by probit analysis, following the method used by Fleming (1960) for cod. The 50% maturity point was 21 cm. for males and 25 cm. for females (Figure VII).

Bigelow and Schrœder (1953) thought that flounder in New York waters matured at 3 years of age since most of the spawners were upwards of 8 inches (20·3 cm.) long which is comparable to Long Pond males. As was seen earlier, the flounder in Long Pond grow more slowly than do flounder further south and if maturity is governed by length, i.e. if the flounder mature when they reach a certain length, they will reach this length at a greater age in Long Pond than further south.

Reproductive Cycle

Figure VIII presents the percentages of fish in four main phases of the reproductive cycle from November 1962 to

TABLE 8

Definitions of the sexual stages of winter flounder used in the present study.

	FEMALE	MALE
Immature	Ovary small, transparent and triangular in shape, with an elongated posterior portion extending back into the body region. In larger fish the contents are golden with a translucent membrane.	Slender, translucent and triangular in shape. No elongated posterior portion.
Ripening	Ovary large. Small yellow eggs visible to the naked eye. Blood vessels apparent on ovary wall.	Larger. White, with pasty texture. Posterior end beginning to push back into body cavity. No milt expressed when compressed.
Ripe	Ovary very large. Individual eggs now larger and many are transparent. A few eggs are extruded under pressure	Large and white. Pressure causes a small amount of milt to be extruded.
Spawning	Ovary very flaccid and jelly-like. Eggs are clear and transparent. They are freely expressed under the slightest pressure.	Testes are densely white and the milt runs freely at the touch.
Spent	Ovaries shrunken. Ovarian material red or orange. Wall thick and white. The internal tissue has a watery texture.	Shrunken. White-brown colouration. Grey blotches are often found.
Recovering	Wall clear and thick. The interior is firm and brown-yellow in colour.	Testes small and rounded at posterior end. Wall thin and opaque. There may be a milt residue in the vas deferens in early stages

TABLE 8 (continued)

FEMALE	MALE
Resting	
As immature but wall more opaque	No milt in vas deferens. Testes small and dark.

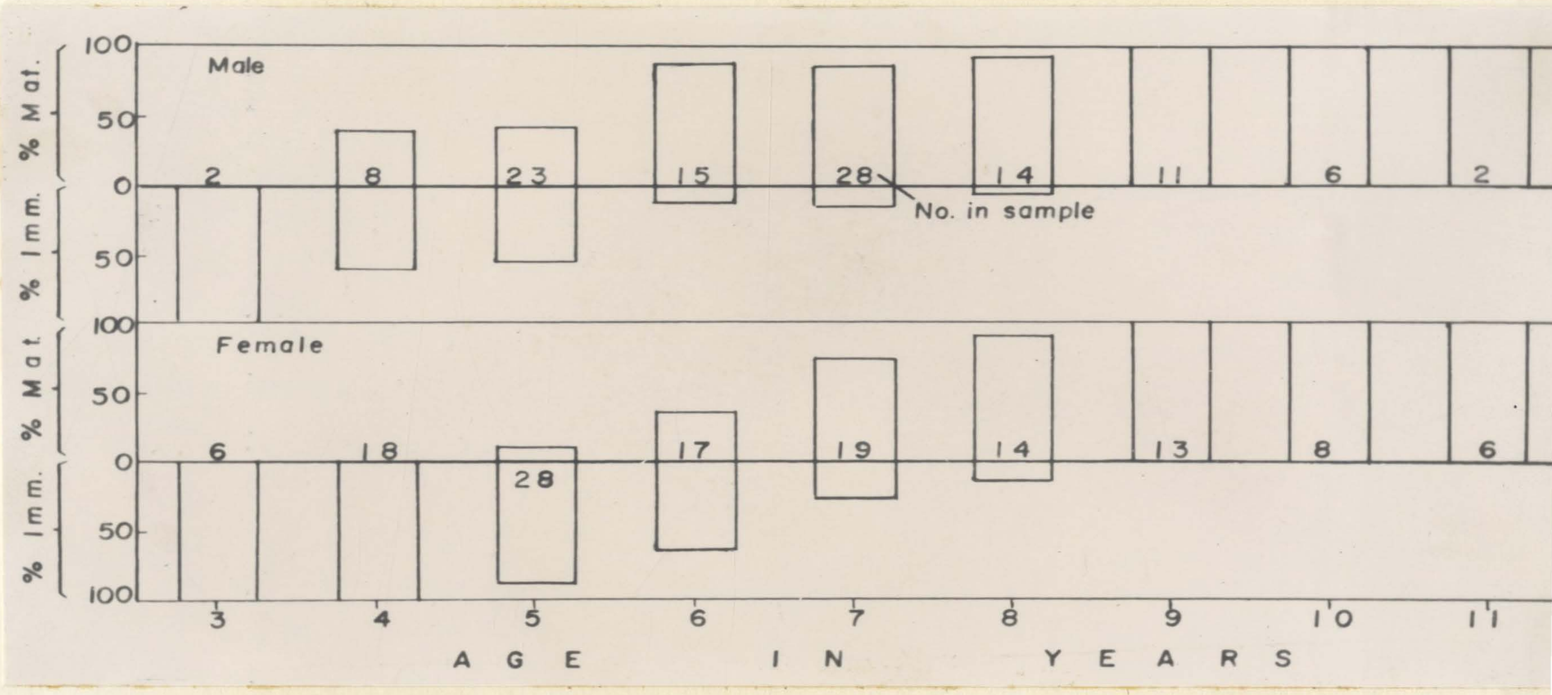

Figure VI - Age at maturity of winter flounder in Long Pond
(March-July 1963).

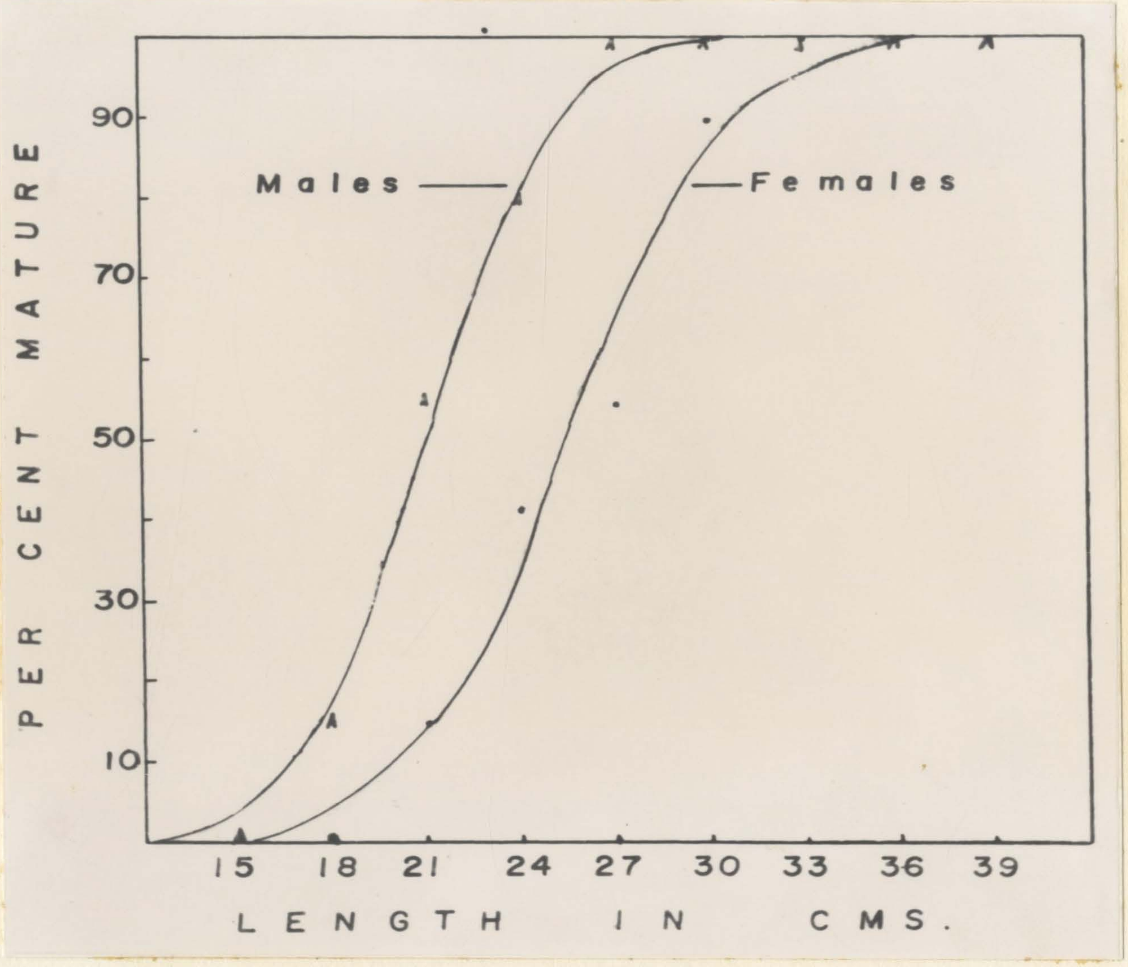

Figure VII - Length at maturity of winter flounder in Long Pond (March-June 1963).

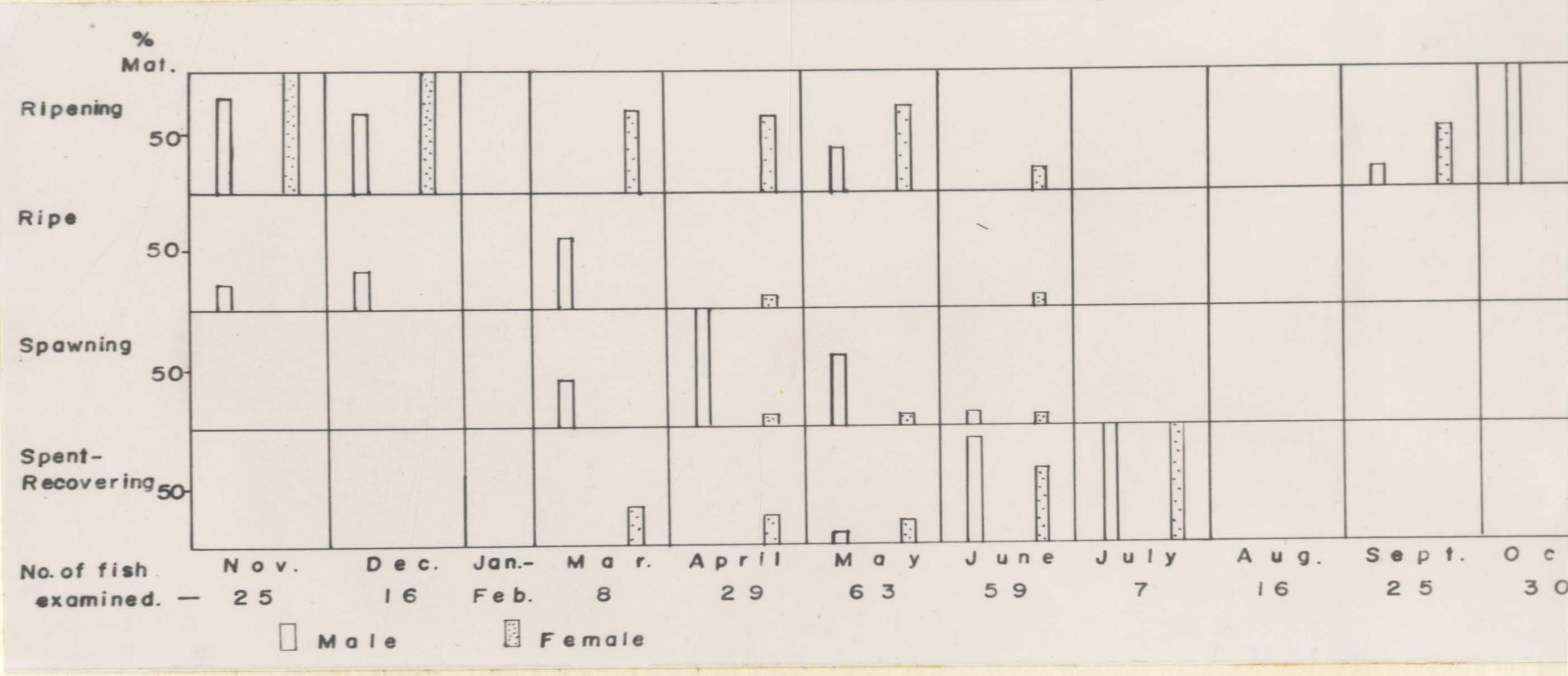

Figure VIII - Percentages of four main phases in the winter flounder reproductive cycle from November 1962 - October 1963 in Long Pond and Horse Cove.

October 1963. When the survey began in November, the eleven mature females and eleven of the fourteen mature males captured were ripening while the remaining mature males were ripe. This ripening process continued throughout December and presumably January and February. When fishing resumed in March 1963, 40% of the males were in a spawning condition but no females were classified as ripe or spawning although a recovering female was collected. In April all the males were in a spawning condition and ripe, spawning and spent females were caught. The first spent males were taken in May with the percentage rising in June while the percentage of spawning males dropped during May and June, until in July all mature male flounder were spent, recovering or resting. No obvious peak of spawning is seen for females from April to June. However, the percentage of ripening females decreased from May to June, while the percentage of spent and recovering females rose in the same period. This would suggest that the maximum spawning period was of short duration and occurred between May and June. The flounder were found to be eating winter flounder eggs during May and June. Eggs were found in the stomachs of flounder taken on June 12th but only one flounder was observed to have eggs in its stomach on June 27th and then only two eggs were present. Eggs were available as food during May and early June, and they may have hatched before June 27th and thus have ceased to be available as a food substance.

One female flounder was found to be in the resting condition in July and by August all mature flounder were resting.

On the 18th of September it was noted that the testes of speared males, although dark grey in colour, were becoming noticeably enlarged. At this time all were recorded as resting. A survey on the 28th of September showed that all the mature fish caught, both male and female, were ripening and this condition was also found during October.

Male flounder were ripening or ripe during the late fall and winter and they had reached spawning condition by the early spring. The first spent males were observed in May with the percentage increasing until all were spent or recovering in July. The testes were in a resting condition for August and early September. By October they had once again started to ripen.

Female flounder were ripening for a long period of time (from November until May). A few were spawning in March and April but the peak of spawning activity seemed to be during May and early June. During August and early September only resting females were noted but evidence of ripening was seen during late September and October.

It was observed that males started to ripen a few weeks before the females and that they reached the ripe and spawning conditions earlier and remained in a spawning condition for a longer period of time. A. M. Fleming (personal communication) of the Fisheries Research Board in St. John's found that during the last week of October 1963, in Bonavista, a town one degree north of the Long Pond area, all the mature males in a catch made by a beach seine were ripening and almost running and that all the mature females, while showing evidence of ripening, lagged behind the males.

The extent of the spawning period and the time of maximum spawning recorded in the literature is given in Table 9, together with the data from this study. It can be seen that these periods vary with the area and generally become progressively later from South to NOrth.

Fecundity

To determine the fecundity, the paired ovaries of 23 mature females were taken during the period from December to June. Only those ovaries were used which did not yet contain the large translucent eggs found prior to spawning. The pairs of ovaries were carefully removed, cut into small pieces and placed in Gilson's fluid. The method of obtaining the eggs was the same as that used by Simpson (1951) in determining the fecundity of North Sea Plaice and followed his modification of doubling the amount of acetic acid used. The bottles were shaken several times at different intervals to aid the process of breaking down the intra-ovarian connective tissue.

After some time (ranging from a few weeks to a few months) the contents of the individual bottles containing a pair of ovaries were strained through a fine-mesh nylon bolting cloth containing 70 meshes per inch. The cloth was stretched tightly over the mouth of a large plastic funnel which was suspended over a sink. The eggs and ovarian tissue were sprayed with water through a small glass pipette at the end of a piece of flexible rubber tubing which was connected to a water faucet. This process broke down the masses of

TABLE 9

The spawning season for winter flounder arranged from South to North

Range of spawning season	Maximum spawning	Region	Authority
Mid December - May	Varies with area	S. New England and New York	Perlmutter (1939, 1947)
February - April	-	S. New England	Tracy (1910), Smith (1898)
January - March	-	S. New England	Bigelow and Welsh (1925)
December 15 - May 30	-	Long Island	Lobell (1939)
Mid February - April	March	Mystic River, Connecticut	Pearcy (1962a)
December - March	-	Green Hill Pond, R.I.	Saila (1961a)
Larvae found Feb-June (hatch 15-18 days after spawning)	-	Narragansett Bay, R.I.	Herman (1963)
January - May	February - March	Cape Cod South	Bigelow and Schroeder (1953)
March 1 - May 10	March 30 - April 20	Boothbay, Me.	"
-	Late April - early May (50% spawning)	Passamaquoddy Bay, N.B.	McCracken (personal communication)
seems to be earlier than Passamaquoddy Bay	many spent in late April	St. Mary Bay, N.S.	"
March? - early June	May - early June	Long Pond, Nfld.	

eggs and washed the traces of ovarian tissue, as well as any minute second generation eggs, through the meshes of the cloth. Large pieces of ovarian tissue which were noted were removed with forceps.

Such a detailed method as the above was necessary because of the high fecundity of the flounder, the smallness of the eggs concerned and the necessity of excluding second generation eggs from the sample. It would have been too time-consuming to separate the eggs from the ovarian tissue manually and decanting was found to be inefficient.

The eggs were placed on filter paper and dried in an electric oven for 24-30 hours at a temperature around 60°C (Nagasaki, 1958; Thomson 1961). After drying, 3 subsamples of varied size were chosen at random from the main body of eggs. The total weight of all the eggs of a pair of ovaries was found to the nearest hundredth of a gram (0·01 g.) and the weight of the individual subsamples was found to the nearest thousandth of a gram (0·001 g.) on analytical balances.

The subsamples were spread on a piece of white paper ruled into a grid of 72 one-inch squares. The number of eggs in each square was counted under a large, mounted magnifying glass. The numbers in the individual squares were totalled to give the total number of eggs in the subsample.

The total weight of the eggs in the pair of ovaries was divided by the weight of each of the subsamples to give a factor which was multiplied by the corresponding number of eggs in the subsample concerned. This produced three different estimates of the total number of eggs in the pair of ovaries. The mean of these was calculated and taken as the fecundity of that individual fish.

Eschmeyer (1954) in studying the fecundity of lake trout, evaluated the accuracy of one volumetric and two gravimetric methods for estimating egg number. He concluded that the dry-weight gravimetric method (similar to that used in this study) produced estimates with the smallest range in error and had the smallest mean deviation of the three methods tested. Because of the difference in egg size and the number of eggs produced by trout and flounder, this method may be subject to greater error when used in a study of the latter. Some indication of the deviation of the estimates of fecundity derived from the subsamples from the mean fecundity for each fish was therefore obtained by calculating the percentage deviations from the mean for each of the three samples used in the estimate of fecundity.

The frequency distribution of these percentage deviations (Table 10) shows that all the 69 observations deviated from their means by less than 5% (the one observation in the 4-5·9% class was a deviation of 4·4%). Because of this, the fecundity estimates obtained in this survey were judged to be reliable.

TABLE 10

Frequency of the percentage deviations from the mean fecundity

Range of percentage deviation	Number of observations deviating
0 - 1·9	50
2 - 3·9	18
4 - 5·9	1
6 - 7·9	-

Table 11 gives the length, weight, age and fecundity of each of the 23 flounder studied.

Fecundity Related to Length

A scatter diagram of fecundity against body length indicated that the fecundity increased at a rate greater than the length of the fish.

The equation of the form $F = a\,L^b$ was computed where F is the fecundity, L is the length, (a) is a constant which gives the Y-intercept and (b) the value of the slope of the line.

A logarithmic transformation of the form $\log F = \log a + b \log L$ was determined by the method of least squares and the relationship between log fecundity and log length was expressed in the equation:

$$\text{Log } F = 4{\cdot}0631 \log L - 0{\cdot}4517$$

$$F = 0{\cdot}3534\, L^{4\cdot0631}$$

Saila (1961b) presented fecundity estimates for 46 mature flounder in Rhode Island. Using the data from Table I in his paper, a logarithmic equation was derived for length and fecundity.

$$\text{Log } F = 3{\cdot}2507 \log L + 0{\cdot}8026$$

$$F = 6{\cdot}3476\, L^{3\cdot2507}$$

The curves for both logarithmic equations as applied to Long Pond data were plotted on double-logarithmic paper and they correspond closely to one another (Figure IX). There is an indication that in Long Pond, the larger fish are more fecund and the smaller fish are less fecund than in Rhode Island, but this may not be statistically significant.

TABLE 11

Data for fecundity studies of winter flounder in Long Pond, December 1962 - June 1963.

Survey	Length (cm.)	Weight (g.)	Age (years)	Fecundity estimates
D	31	361	7	313,237
D	31	338	6	164,886
D	29	272	7	191,102
D	35	544	7	340,484
E	33	446	6	314,754
E	34	480	8	405,552
I	24	142	9 (?)	196,784
K	44	1240	12	1,669,834
K	35	647	10	1,455,697
K	37	604	9	483,558
L	29	322	7	351,308
L	23	148	6	154,486
L	44	1309	12	1,508,665
L	25	197	8	136,197
L	44	1300	10	2,603,661
L	42	1116	11	1,476,645
L	33	489	7	646,986
L	22	111	5	99,304
L	29	340	11	348,507
L	34	495	9	587,940
M	39	681	10	1,016,504
M	45	1390	15 (?)	2,448,409
M	32	435	8	603,933

Fecundity Related to Weight

The weight recorded for all flounder in this survey was round weight. A regression equation similar to that used in the length-fecundity section was determined for the weight-fecundity relationship.

$$\text{Log } F = 2{\cdot}3894 + 1{\cdot}2403 \log W$$

$$F = 245{\cdot}1\ W^{1{\cdot}2403}$$

Saila (1961b) computed a similar logarithmic equation for the weight-fecundity relationship for Rhode Island flounder.

$$\text{Log } F = 2{\cdot}6712 + 1{\cdot}1383 \log W$$

$$F = 469{\cdot}0\ W^{1{\cdot}1383}$$

In Figure X, the curves for these two areas are plotted using the Long Pond data and show a close relationship. The fecundity for Long Pond flounder is seen to be higher for large fish and lower for small fish than for Rhode Island flounder but again this may not be statistically significant.

Fecundity Related to Age

The data were insufficient to enable any definite conclusions to be reached. A graph of the fecundity and age is presented in Figure XI. It shows the large variations within age groups. It also shows that fecundity increases with age, but this is probably more related to length than to age.

The values found in this study vary from 99,000 eggs for a 22 cm. flounder weighing 111 grams to 2,603,000 eggs from a 44 cm. flounder weighing 1300 grams. The average was 590,000 eggs for a mean fish length of 34 cm. Bigelow and Schroeder (1953) state that the average fecundity is about 500,000 eggs annually and that nearly 1,500,000 have been found in a fish weighing 3-5/8 lbs. (1644 grams). Saila (1961b) found that the fecundity of Rhode Island flounder varied between 193,000 eggs for a 24·9 cm. fish and 1,340,000 eggs for a 42·8 cm. fish. His grand average was 610,000 eggs for a mean fish length of 33·4 cm. In order to eliminate the variations caused by individual fish, fecundity values for a 25 cm. and a 45 cm. flounder were calculated using the length-fecundity curves for Long Pond and Rhode Island (Figure IX). A 25 cm. flounder would have a fecundity of 228,000 eggs by the Rhode Island curve and 165,000 by the Long Pond curve. A 45 cm. flounder would have 1,530,000 eggs by the Rhode Island curve and 1,775,000 eggs by the Long Pond curve.

The data is not comprehensive enough to indicate whether the fecundity differs widely from area to area, although the above results indicate that there are similarities.

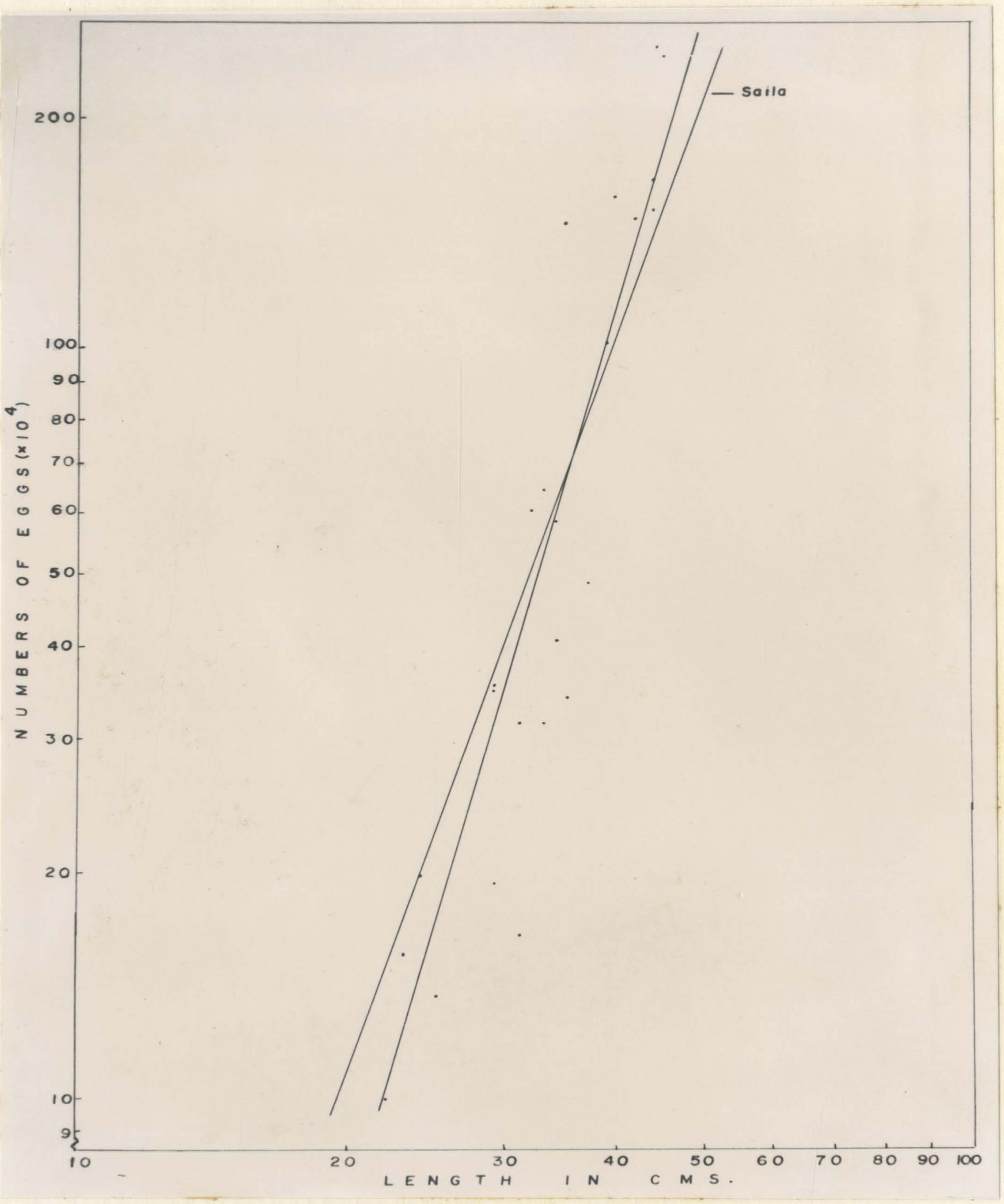

Figure IX - Relationship between fecundity and length of winter flounder in Long Pond compared with the length-fecundity curve computed using Saila's data (1961b). (Points represent individual females in Long Pond).

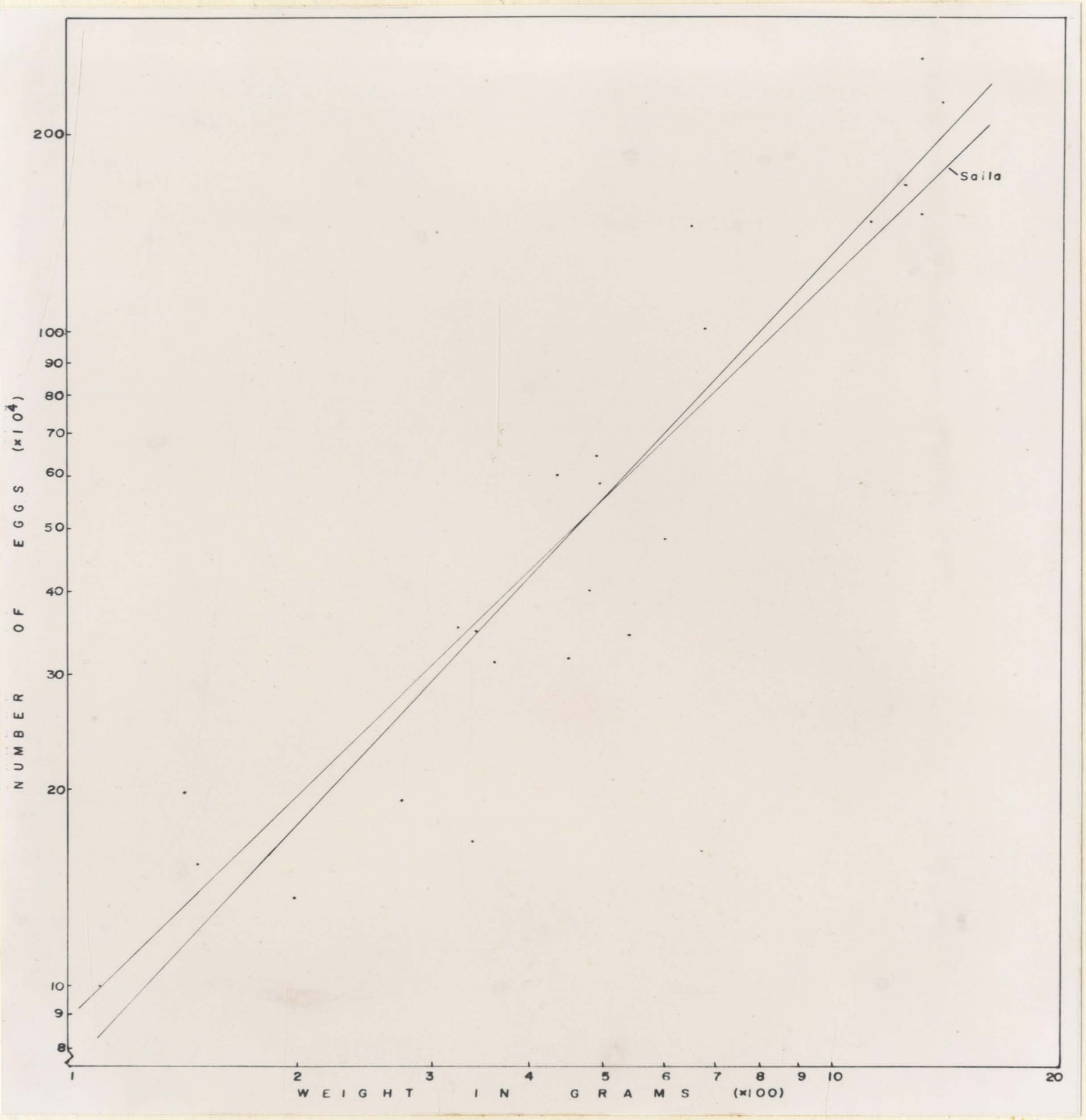

Figure X - Relationship between fecundity and weight of winter flounder in Long Pond compared with the weight-fecundity line computed by Saila (1961b). (Points represent individual females in Long Pond).

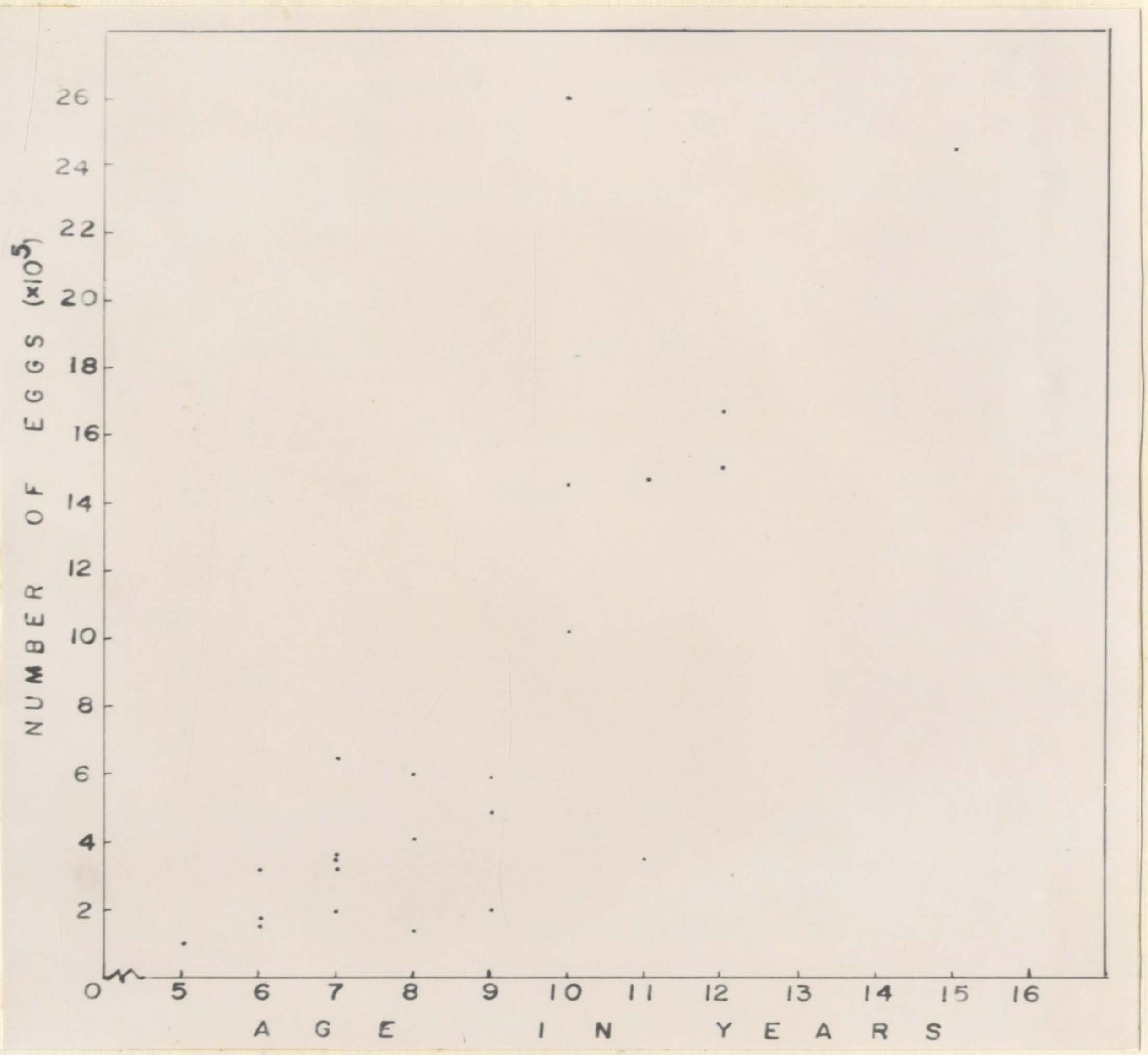

Figure XI - Relationship between fecundity and age in Long Pond. (Points represent individual females).

FOOD AND FEEDING HABITS

The stomachs of all fish taken were preserved in formaldehyde for later examination with the exception of the survey in May when a random sample of 59 stomachs of the 98 fish caught were preserved. A total of 441 stomachs were examined, 26 of which were taken from Horse Cove flounder and are treated separately and three of which had been cut during capture and consequently discarded. The stomachs were removed by cutting them across the pyloric sphincter and the area where the esophagus opened into the stomach.

Hynes (1950) reviewed different methods of analysing stomach contents and discussed some of the shortcomings involved. Similarly, Reintjes and King (1953) described various methods and reviewed the advantages and disadvantages of these methods. These references were used as guides during the present study and were modified where necessary.

Each stomach was examined as follows:

(1) The degree of fullness of each stomach was estimated by a points system as follows (Ball 1961):

Visual estimate of fullness	Points
Empty	0
Trace	½
¼ full	1
½ full	2
3/4 full	3
Full	4

In using this estimate of fullness, Ball (1961) considered not only the approximate volume occupied by the food in the stomach, but also such factors as the hardness of the wall or the type of pleats formed by the inner surface of the stomach wall. In the present survey, only the volume of the food contents was estimated visually as the food lay in the stomach but the resulting rough estimate is felt to be sufficient for comparison purposes.

(2) The stomach contents were sorted and identified under a binocular microscope. Identification of the main food items was taken as far as was practical.

The annelids were identified using the key compiled by Treadwell (1948). This was supplemented by Eales (1950) and Pratt (1951). Bousfield (1960) and Abbott (1954) were used to identify molluscs. The amphipods were identified using Stephensen's key (1935-42) and the plates drawn by Sars (1895). The echinoderms were identified using Bousfield (1960) and Pratt (1951).

The food items were recorded as follows:

(1) Occurrence of organisms. All the food elements present were listed and the number of occurrences of each in all the stomachs examined was determined. The results are expressed as a percentage of the total number of stomachs that contained food.

(2) Numerically. The individual items of each food element present in each stomach were counted, or, where there were large numbers involved, estimated by determining the number in a subsample.

(3) Wet volume. The various food elements were separated

from one another and placed on filter paper to eliminate excess water. The volume of each element in c.c. was determined by water displacement to two places of decimals. In many cases, however, it had to be estimated to three places of decimals due to the extremely low volumes of some individual organisms. The total volume of the food in all stomachs was determined and used to calculate the percentage total volume of each food element.

These three methods of analysing the food were used because it was felt that this was necessary in order to give a good estimate of the importance of the various food elements. One method alone would present an incomplete picture. The numerical count of some organisms may be high but they may be unimportant volumetrically whereas a large individual might represent a high percent of the total volume.

The results were analysed for monthly variations of food elements in both volume and frequency of occurrence. Total variations in the main food groups for the year were analysed for three arbitrary length groups.

During the month of August, few winter flounder were seen in the area around Long Pond and none were speared. A sample of 26 fish was taken at nearby Horse Cove, **ten miles** away from Long Pond. The food eaten in these two areas was found to be different so the Horse Cove results are analysed separately.

Composition of the Diet during the Year

Table 12 presents the results of the surveys taken during the year at Long Pond and Table 13 gives the results for Horse Cove (see Appendix I. See also Figure XIII(a)).

Flounder are omnivorous and eat a wide variety of food (54 identified prey). Errant and sedentary polychaetes, pelecypods, fish eggs (in season), amphipods, copepods, fish remains and plant material were most important. Errant polychaetes were eaten by 50% of the flounder throughout the year and constituted 10% of the total volume of food eaten. *Eteone arctica* was the most abundant polychaete and occurred in a greater percentage of stomachs than other Errantia but was not as important volumetrically as either of the two nereid species, *N. pelagica* or *N. virens*. The family *Polynoidae* and *Anaitides* sp. were regularly encountered while *Eulalia* sp. was found in only one stomach.

Sedentary polychaetes were not as common as were the errant polychaetes. They were eaten by 38% of the flounder and made up 4% of the total volume. *Cistenides gouldi* was found most frequently and was the major item volumetrically. *Arenicola marina* was as important volumetrically but was not as frequent in occurrence. The large number of specimens (418) was due to the fact that one 19 cm. female had eaten 360 small *A. marina*. The remaining abundant sedentary polychaete was identified to the family Ariciidae and may have belonged to the genus *Scoloplos*. The remaining families occurred in very few stomachs. The results show that, as Richards (1963) pointed out, all polychaetes, whether free-swimmers, crawlers or tube-dwellers, were liable to be eaten. One specimen of *Echiurus* sp. occurred in a 21 cm. male.

Molluscs occurred more frequently (in 76% of all stomachs containing food) than did any other food group. Pelecypods were more abundant than were gastropods. The main species of pelecypod was *Arctica islandica* which was found in 40% of the stomachs and constituted 3% of the total volume. *Macoma balthica* and *Mya arenaria* occurred frequently and were important volumetrically while the family Mytilidae was found in 31% of all stomachs. *Mytilus edulis* was the main species in this family, but because of the extremely small size of these organisms, it was difficult to separate *Mytilus edulis* from *Volsella* sp. In addition, their small size caused them to be unimportant volumetrically although they were found in many stomachs and in fairly substantial numbers in some cases. The remaining pelecypods occurred intermittently. Five siphons from pelecypods were found in five stomachs; the presence of these in other flounder has been noted before (Linton 1921; Bigelow and Schroeder 1953).

In general, gastropods were of little importance volumetrically. However, a few like *Littorina* sp. or *Hydrobia minuta* were fairly common (in 15% of all stomachs containing food). The remaining species occurred irregularly. Most of the gastropods were very small in size.

Winter flounder eggs were found in 12% of the stomachs and made up 7% of the total volume. Capelin eggs were found in only 6% of the stomachs but made up 22% of the total volume.

Amphipods of the suborder Gammaridea occurred in 30% of the stomachs but only accounted for 0·5% of the total volume. Harpacticoid copepods were the most numerous organisms and occurred in 35% of the stomachs but they made up

0·3% of the total volume.

Fish remains were found in few flounder (4%) but constituted 15% of the total volume. The presence of this material demonstrates the scavenging behaviour of the winter flounder. Dead fish, probably cod or flounder that had been discarded by fishermen, had been noticed in the area in which the fish were speared.

Plant material was present in 24% of the stomachs and made up 13% of the total volume. It was composed mainly of filamentous green algae, with an occasional piece of Ulva sp.? present. A distinction was made between the obviously recently ingested living material and plant material that had been rotting on the bottom. The latter was colourless and obviously had not been "grazed" upon as the green material had been. It was included in the category "debris".

Debris was present in 80% of the stomachs and made up 14% of the total volume. It was composed of occasional fish scales, sand, stones, decaying plants, etc. In one stomach some raisins were observed.

Over the period of a year, annelids and molluscs were the most important food groups eaten. Crustacea occurred frequently but were unimportant volumetrically. Food such as fish eggs and fish remains were found during a few months as will be seen later but large quantities were eaten during these times and as a result these food substances were important volumetrically. Plant material was important and debris was common.

Horse Cove Area - Annelids were eaten by 92% of the flounder and made up 30% of the total volume. Sedentary and errant polychaetes were found in the same percentage of stomachs (88%) but the Sedentaria were much more important volumetrically. Of the errant forms, the species *Eusyllis tubifex* which was not present in the diet of Long Pond flounder was fairly common, *Eteone trilineata* occurred in one stomach but no *Eulalia* sp. were observed. The remaining Errantia were of the types eaten by Long Pond flounder.

Two families of the Sedentaria, Maldanidae and Sabellidae, and one species, *Polydora* (*gracilis*?) present in Long Pond samples, were not seen in stomachs from Horse Cove. Two new forms, *Amphitrite* sp. and *Ophelia radiata*, were observed. The remaining forms were found in Long Pond samples but they were less important there than at Horse Cove.

The Mollusca were less frequent in occurrence but nearly as important volumetrically as they were at Long Pond. Chitons appeared in more stomachs (32%) than at Long Pond (0·3%) and made up the bulk of molluscs. Gastropods were represented by only four forms of which *Acmaea testudinalis* was the most important. Pelecypods were represented by only four forms and of these the family Mytilidae was the most important.

Harpacticoid copepods were more frequent in occurrence but were of negligible value volumetrically. The suborder Gammaridea was more frequent in occurrence and more important volumetrically. Caprellid amphipods, which were uncommon in Long Pond samples, were found in 12% of the Horse Cove samples. In addition, three small spider crabs were observed in two fish (8%).

Echinoderms were more important than they were at Long Pond, occurring in 88% of the stomachs and composing 8% of the volume.

Sea anemones and tunicates were common, especially the latter. There were no fish eggs or fish remains. Plant material was more common than at Long Pond and of greater importance volumetrically. Debris was nearly as frequent in occurrence but more important volumetrically.

Annelids, amphipods and echinoderms were more important at Horse Cove than Long Pond with molluscs remaining at the same level of importance. The food elements such as fish eggs and fish remains which had figured so heavily in Long Pond samples were not found during this survey. However, this sample was taken in August when winter flounder and capelin had finished spawning, so it is possible that the eggs of these fish were eaten as voraciously by Horse Cove fish as they were by Long Pond fish. Plant material and debris were more important at Horse Cove.

The differences cited above may be due to the availability of food in the different habitats. The bottom at Horse Cove might be more suited for polychaetes, especially the Sedentaria, than for molluscs. Few conclusions can be reached on this matter in the absence of knowledge of the abundance of these food items.

The winter flounder has been found by many authors (Bigelow and Schroeder 1953; Pearcy 1962a; Richards 1963) to be omnivorous. Annelids, both sedentary and free-swimming, are abundant in food lists. Amphipods are more important in waters to the south (Smith 1950; Richards 1963) than they were in Long Pond or Horse Cove, although they were more commonly eaten by flounder in the latter locality. Molluscs are also important (Richards 1963; Bigelow and Schroeder 1953).

Pearcy (1962a) lists the eggs of the four-spined stickleback, Apeltes guadracus among the items of food found in the stomachs of juvenile winter flounder but doesn't consider them in his text so they must have been unimportant in the diet of the flounder being studied. Linton (1921), Bigelow and Schroeder (1953) and Richards (1963) do not record winter flounder feeding on the eggs of any fish. Tibbo et al (1963) reported that flounder preyed heavily on herring eggs in Chaleur Bay, N.B. Aside from this reference the author has not noted any other mention of this type of food being eaten by winter flounder. The gorging of the four mature flounder on capelin eggs found only in July indicates an ability to concentrate their feeding on an opportune food supply.

The presence of specimens of Cistenides gouldi in their tubes as well as quantities of sand and debris in stomachs indicates that the flounder rooted in the bottom upon occasion. They also "grazed" upon algae and hydroids.

Seasonal Variation in Food Intake

Figure XII and Table 14 (Appendix I) give the monthly variation in food intake based on the mean volume of food in the stomachs (including empty stomachs) and the mean fullness index of all stomachs for each month. The data is first presented for all fish together and is then analysed for variations in mature and immature fish. In the figure the values

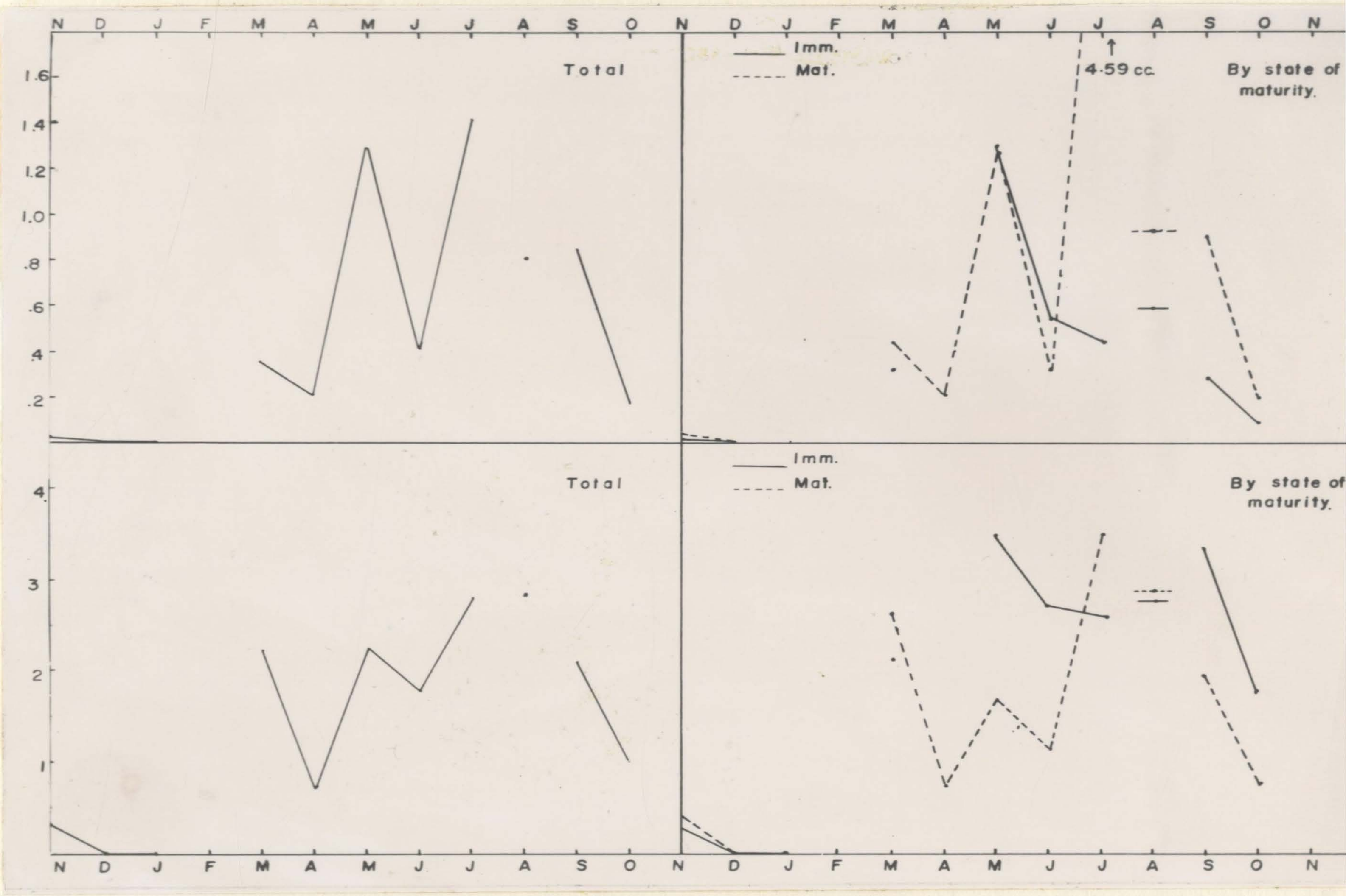

Figure XII - Seasonal variation in food intake from November 1962-October 1963 for all flounder analysed and for mature and immature flounder.

for the August Horse Cove sample are plotted as points. No attempt was made to incorporate them in the main curve of the graph because of the possibility of different feeding habits in Long Pond and Horse Cove.

Both the mean fullness index (m.f.i.) and the mean volume (m.v.) were low in November and had fallen to zero in December. Only one fish, a 28 cm. female, had a trace of material (debris) in its stomach in December. None of the five fish caught in January was feeding. By March both matures and immatures had resumed feeding. The former had slightly fuller stomachs containing more material than the latter. No immatures were taken in April. The matures showed a drop in m.f.i. and m.v. during this month. In May there was an increase in m.v. to nearly the same value for both matures and immatures but the immatures evidenced twice the m.f.i. of the matures which suggests that they were feeding relatively more heavily than the matures.

Both groups showed a drop in both indices in June and during July this drop continued for the immatures. For the matures, there was a sharp increase in the m.f.i. during July. The m.v. showed an increase to a mean value of 4.59 cc. It will be seen later that this is due to the larger matures gorging themselves on capelin eggs.

No sample was taken in Long Pond during August. Both matures and immatures showed a decline from September to October in both indices. The immatures were feeding more heavily than the matures but were consuming a smaller volume of food.

In general the curves for immatures and matures show a decrease in feeding activity and volume of food ingested during the fall until no food is consumed in December and January. Although there were only five fish in January's sample, it is probable that flounder don't feed during this month. Bigelow and Schroeder (1953) and Smith (1950) have noted that they don't feed in late winter and early spring. Feeding has resumed by March and continues during the summer until it begins to diminish during September and October.

Seasonal Variation in Food Groups

Tables 15(a) and (b) are presented to show the percentage volumes and percentage frequencies of occurrence respectively for the main food groups each month. The most apparent features are that the food groups that had strong effects on the variations in the mean volumes discussed previously were found during very few months of the year. Winter flounder eggs were eaten in May and June along with the bulk of fish remains that were eaten during the year. Figure XII shows that there was an increase in m.v. and m.f.i. during May which was caused by these two components being eaten in quantity. The July increase for mature fish in Figure XII was due to capelin eggs being eaten during this month.

McCracken (personal communication) found that flounder taken alongshore (Bay of Fundy area?) in May and June had fed heavily on green algae but as the season progressed this became a less important item of the diet. His records suggested that 50% of the flounder had been feeding on algae during May and June but less than 10% were eating algae in

TABLE 15(a)

Percentage volume per month of the main food groups eaten by winter flounder in Long Pond, Nov. 1962 - Oct. 1963.

Food group	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oc
Polychaeta	44	0	0	-	73	4	14	19	5	-	9	
Errantia	43	0	0	-	67	3	14	9	0·6	-	0·5	
Sedentaria	1	0	0	-	4	0·3	0	9	4	-	8	
Mollusca	24	0	0	-	2	20	2	22	2	-	4	
Pelecypoda	22	0	0	-	2	14	2	21	2	-	2	
Gastropoda	2	0	0	-	0·3	6	0·1	0·7	0·1	-	2	0·
Crustacea	9	0	0	-	2	0·3	0	0·3	0·4	-	1	
Copepoda	0	0	0	-	0	0·1	0·8	0·3	0·1	-	0	0·
Echinodermata	0	0	0	-	0	0	0	0·1	0	-	5	
Winter flounder eggs	0	0	0	-	0	0	19	9	0	-	0	
Capelin eggs	0	0	0	-	0	0	0	0	76	-	0	
Fish	0	0	0	-	0	0	40	17	0·2	-	0·4	
Plant material	4	0	0	-	5	57	6	9	10	-	31	
Debris	18	100	0	-	17	15	20	25	6	-	2	

TABLE 15(b)

Percentage frequency of occurrence per month of the main food groups eaten by winter flounder in Long Pond Nov. 1962 - Oct. 196

Food group	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	O
Polychaeta	46	0	0	-	97	40	51	58	61	-	90	
Errantia	23	0	0	-	97	30	44	44	54	-	48	
Sedentaria	23	0	0	-	50	30	21	35	45	-	90	
Mollusca	79	0	0	-	28	100	86	82	77	-	81	
Pelecypoda	69	0	0	-	25	70	79	79	77	-	57	
Gastropoda	23	0	0	-	6	60	40	36	25	-	38	

TABLE 15(b) (continued)

Food group	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct
Crustacea	8	0	0	-	22	20	16	24	48	-	71	25
Copepoda	0	0	0	-	0	30	67	27	50	-	57	13
Echinodermata	0	0	0	-	0	0	0	2	7	-	38	0
Winter flounder eggs	0	0	0	-	0	0	46	17	0	-	0	0
Capelin eggs	0	0	0	-	0	0	0	0	36	-	0	0
Fish	0	0	0	-	0	0	5	11	2	-	5	0
Plant material	8	0	0	-	25	50	16	12	30	-	57	25
Debris	92	100	0	-	84	70	98	82	82	-	62	63

July and August. In Long Pond, 50% were feeding on algae in April but during May and June 14% were taking algae and during July 30% were consuming this material. In the August Horse Cove sample, 44% were feeding on algae.

Feeding and Size

Table 16 shows the total variations of the combined data from November 1962 to October 1963 as reflected in the volumes and the frequency of occurrence. The August data have not been included. The data have been divided into three length groups (8-19 cm.; 20-31 cm.; 32-46 cm.) which have been chosen arbitrarily with the purpose of providing a good sample for each group. The results have been presented graphically in Figure XIII(b).

(1) 8-19 cm. group.

The polychaeteswere the most important food group volumetrically. The Errantia composed the bulk of the group both volumetrically and in frequency of occurrence.

Molluscs occurred more frequently than did polychaetes but they were much less important volumetrically. Pelecypods were more frequent in occurrence and composed the greater part of the volume of molluscs present.

Winter flounder eggs in May and June and capelin eggs in July were important items of the diet during these months and the large volumes consumed at these times are reflected in the annual totals. Winter flounder eggs were more important in the food of this length group than in the two larger groups.

Amphipods and copepods were not very important

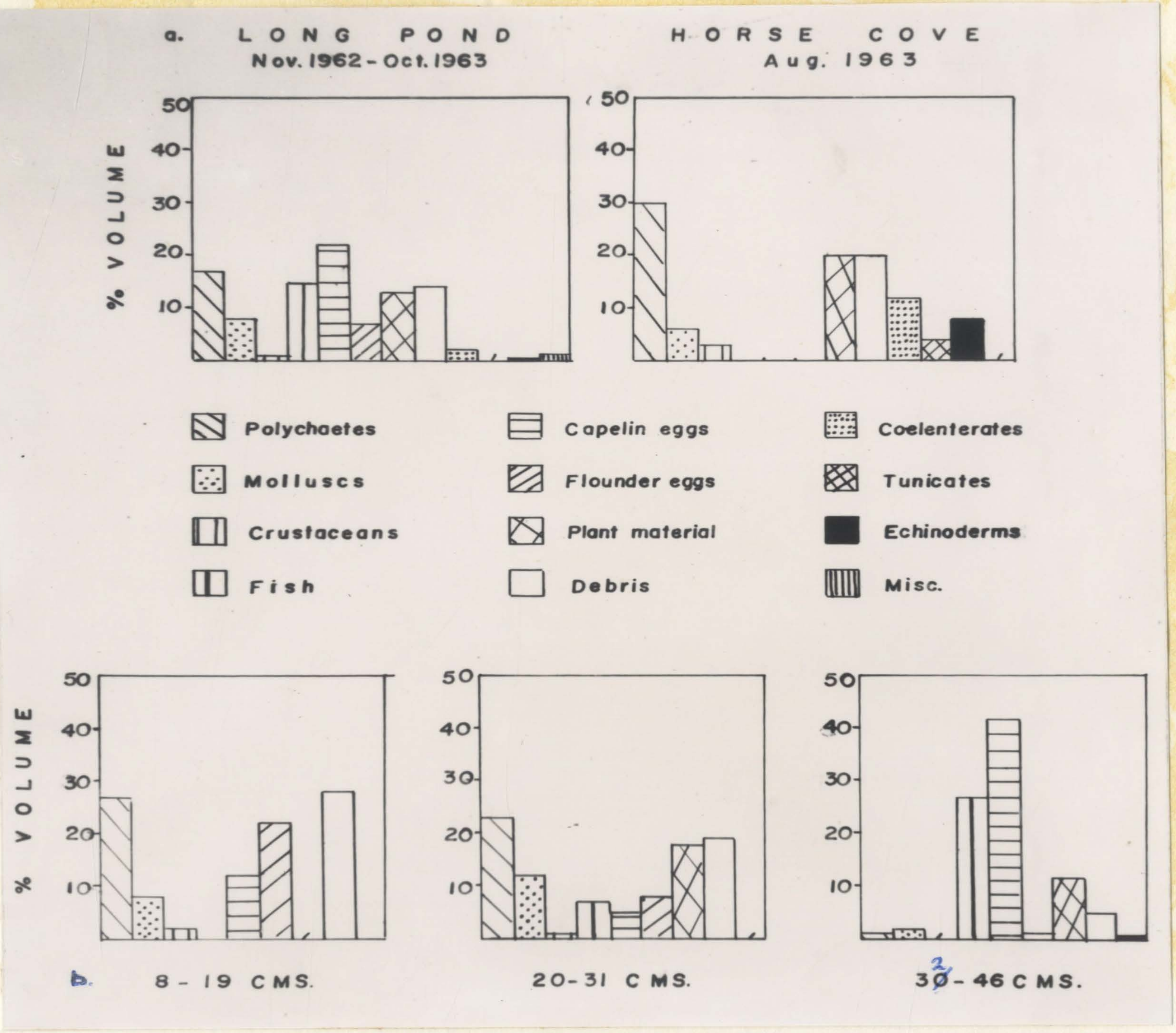

Figure XIII(a) - Percentages of the main food elements eaten by flounder in Long Pond, November 1962-October 1963, and Horse Cove, August 1963.

Figure XIII(b) - Percentages of the main food elements eaten by three different length groups in Long Pond, November 1962-October 1963.

volumetrically to this length group but both occurred more frequently in this group than in the other two. No echinoderms or fish remains were eaten by this length group. Plant material was not an important item. Debris was found in nearly all stomachs and was volumetrically the most prevalent item.

Linton (1921) compiled data on the food of young winter flounder found in the vicinity of Woods Hole during the summers of 1915 and 1916. He found that for flounder in the size range 76 mm. - 175 mm., annelids, amphipods and other small Crustacea were important. Molluscs were eaten to some extent. Fish and crabs were eaten although they composed only a small part of the total volume. Plant material was found in only 5% of the fish examined. No fish eggs were eaten and debris composed a large part of the total volume.

In general, fish in this length group eat a varied diet. The types of organisms included in the diet may be governed only by the availability of food items in any particular area.

(2) 20-31 cm. group.

In this group, as in the first, polychaetes were the most important food items. Once again, the errant polychaetes occurred more frequently and made up a greater percentage of the total volume than did the sedentary polychaetes.

Molluscs were more important volumetrically than they were in the first group although they occurred in approximately the same percentage of stomachs. Pelecypods were many times more important than gastropods.

TABLE 16

A comparison of the diet of three length-groups of winter flounder in Long Pond, Nov. 1962 - Oct. 1963.

Food eaten	Length-group (cm.)	Stomachs in which occurred		Aggregate Total Volume	
		Nos.	%	cc.	%
Polychaeta	8-19	44	71	9·83	27
	20-31	98	70	22·08	23
	32-46	17	33	1·45	1
Errantia	8-19	36	58	7·19	20
	20-31	82	58	15·56	16
	32-46	9	18	0·49	0·5
Sedentaria	8-19	23	37	2·50	7
	20-31	68	48	6·00	6
	32-46	13	25	0·91	1
Mollusca	8-19	48	77	2·82	8
	20-31	106	75	11·12	12
	32-46	37	72	2·17	2
Pelecypoda	8-19	48	77	2·64	7
	20-31	100	72	10·21	11
	32-46	28	55	1.70	2
Gastropoda	8-19	18	29	0·19	0·5
	20-31	43	30	0·91	1
	32-46	16	31	0·47	0·5
Crustacea (except Copepoda)	8-19	24	39	0·44	1
	20-31	43	30	0·74	1
	32-46	8	16	0·15	0

TABLE 16 (continued)

Food eaten	Length-group (cm.)	Stomachs in which occurred		Aggregate Total	Volume
		Nos.	%	cc.	%
Copepoda	8-19	29	47	0·39	1
	20-31	47	33	0·38	0
	32-46	11	22	0·10	0
Echinodermata	8-19	-	-	-	-
	20-31	10	7	0·47	0
	32-46	2	4	0·72	1
Winter flounder eggs	8-19	9	14	7·99	22
	20-31	19	13	7·40	8
	32-46	3	6	1·24	1
Capelin eggs	8-19	9	14	4·43	12
	20-31	3	2	4·82	5
	32-46	4	8	41·80	42
Fish remains	8-19	-	-	-	-
	20-31	8	6	6·96	7
	32-46	3	6	28·10	28
Plant material	8-19	4	6	0·18	0
	20-31	35	25	17·37	18
	32-46	21	41	11·49	12
Debris	8-19	57	92	10·22	28
	20-31	116	82	18·09	19
	32-46	31	61	4·57	5

Eggs were a less important item of the diet than they were for the smaller length group. Winter flounder eggs were found in approximately the same percentage of stomachs in both groups but the percentage volume found in the first group was almost three times greater than that found in the 20-31 cm. group. Capelin eggs were less important to this group than to the other two groups. Fish remains were eaten, but not to any great extent and amphipods and copepods were of little importance. Echinoderms were consumed by a few individuals. Plant material was more important volumetrically than it had been for the 8-19 cm. group. Debris was less frequent and present in smaller amounts than it had been for the smaller fish.

(3) 32-46 cm. group.

Polychaeteswere not as important to this group as to the previous two. Molluscs occurred in approximately the same percentage of stomachs as in the smaller length-groups, but were less prominent volumetrically. They had, however, become more important than the polychaetes. Pelecypods were less common and made up a smaller percentage volume than they did for the previous two groups while gastropods were as important as before. Crustacea and copepods were unimportant. Few flounder in this group ate winter flounder eggs to any great extent. In July, capelin eggs were consumed in great quantities and became the most important food element for this group.

Although fish remains occurred in the same percentage (6%) of stomachs as they did in the 20-31 cm. group, they were much more important volumetrically. Echinoderms were of little importance. Plants occurred in a greater percentage of stomachs than in the other groups but made up a smaller percentage volume than they did in the 20-31 cm. group. Debris was less important than it had been in the previous two groups.

Polychaetes decreased in importance for the larger length-groups as did winter flounder eggs and arthropods. Molluscs were more important to the second group than to the other two. Capelin eggs were eaten in quantity by the smallest and largest groups with the 32-46 cm. flounder feeding voraciously on them. Fish remains were eaten to a great extent by this group but to a lesser extent by the smaller fish. Plant material was more important to the larger groups than to the smaller one and the amount of debris ingested decreased with an increase in the size of the fish.

PARASITES

During the course of this survey it was noted that there were parasites present in the stomachs of some of the flounder. Two main types were identified, one of which was a trematode of the genus Podocotyle sp and the other a nematode of the genus Axonolaimus sp. A record was kept of their percentage occurrence and is given in Table 17.

TABLE 17

Monthly percentage occurrences of Podocotyle sp and Axonolaimus sp in the stomachs of winter flounder in Long Pond, Nov. 1962 - Oct. 1963.

Month	Podocotyle sp	Axonolaimus sp
November	12%	5%
December	0	0
January	0	0
February	-	-
March	11	19
April	7	3
May	6	17
June	13	3
July	24	24
August	8	8
September	7	7
October	5	5

DISCUSSION

Winter flounder were common in one or two meters of water during the fall, winter and spring, moved into deeper water during late June, July and August, and started to move back into shallower water in September until, by October, they were in the shallow part of Long Pond again. This behaviour was similar to that of the flounder south of Cape Cod and in Long Island waters (McCracken 1963). McCracken noted a correlation between movements and temperature and found that flounder in Maritime waters and along the New England coast had a preferred temperature range of 12°-15°C. In Long Pond, the highest recorded bottom temperature in the dredged area (5 m.) was 11·2°C. Flounder were found to be moving back into the deep part of Long Pond during September when the temperature range on the bottom was 10·6°-11·2°C. These values are below those of the preferred temperature range mentioned above. Also, in August, few flounder were seen in Long Pond when the bottom temperature was 11°C but during the same month 26 were caught at Horse Cove where the bottom temperature was 11·1°C. These observations indicate that temperature may not be the controlling factor governing movements in this area.

McCracken (1963) noted that in early winter, flounder south of Cape Cod should have behaved like the flounder north of Cape Cod on the basis of temperature conditions and moved into deeper, warmer waters, but he observed that mature flounder south of Cape Cod had reached spawning condition at this time while those to the north had not. A similar situation existed in Long Pond. By late June and July when the flounder moved out of the shallow area, the spawning season had ended and all mature flounder were either spent, recovering or resting. During early September males began moving back into the Long Pond area before females and it was observed that their testes were enlarging although they did not as yet exhibit all the characteristics of the ripening stage. The mature females taken at this time showed no evidence of ripening. In late September, females had increased in relative abundance and both sexes showed evidence of ripening. In October, males and females were found in shallow water (1-2 m.) and all the mature individuals were ripening. There are therefore indications that for mature flounder, gonad condition and movements were related. The immatures behaved in the same manner as the matures.

The flounder in Long Pond were spawning when fishing resumed in March and spawning ended in early June with the peak of activity in May and early June. These periods are later than those observed by many authors for flounder in more southern waters and Table 9 shows that these times are progressively later from south to north. This may be due to a slower metabolic rate caused by progressively colder water to the north.

The females in Long Pond were found to be very fecund, as they are in other areas. A comparison of the length-fecundity and weight-fecundity relationships for Long Pond and Rhode Island (Saila 1961b) revealed similarities over the size range considered. There were indications that flounder in the area of this study were more fecund at the greater lengths and weights and less fecund at the smaller lengths and weights than were Rhode Island flounder although these observations may not be statistically significant.

Long Pond flounder matured at a greater age than do more southerly flounder. The size at maturity reported by Bigelow and Schroeder (1953) is comparable to that of Long Pond males and if maturity is governed by length, then the flounder in this area would mature at a greater age than the flounder to the south because growth in the region of this study was found to be slower than that of flounder in other areas. This may be due to a slower metabolic rate caused by the low temperatures encountered. No change in growth rate was observed for males or females after sexual maturity though this was observed by Berry (1959) for Rhode Island flounder. There may be such a change for Long Pond flounder but the slow growth rate may obscure it. Berry's (1959) observation that males reach a smaller maximum size than females was found to be true for the flounder in this survey.

The length-weight relationships for males and females were similar, an observation that was also made by Saila (1959) for Rhode Island flounder. The length-weight relationship for males and females combined was slightly higher for July and September than for April-June which shows the effect of the resumption of feeding during the spring on the length and weight of the flounder.

Feeding had begun by March and continued until a general decrease was noted in September. The spawning period had not yet reached the peak of activity noted in May and early June and the matures were found to be feeding to a slightly greater extent than the immatures. Feeding activity, as judged by the m.f.i. was lower for matures during April, May and June than during March or July although the m.v. was high in May. This decrease in food intake may be due to the increase in spawning activity which continues until early June. Data for some months is not available for immatures but a general decrease in feeding is noted in June and this continues throughout the summer although the m.f.i. is high in September. As was noted, the slow growth in this area may be influenced by the effect of the low water temperatures on the metabolic rate. However, if feeding for the matures is inhibited by the onset of spawning, flounder in more southern waters would be able to resume feeding earlier than those in Long Pond since they spawn earlier. They would therefore have a longer period of growth.

The flounder were found to be omnivorous as they are in other areas and it would seem that the type of food eaten is governed only by its availability. Annelids are important to flounder in most of the areas surveyed in the literature as are molluscs and crustaceans. The latter food element is not as important to Long Pond flounder as it is to the south. Fish eggs were eaten by flounder but the only other reference seen which indicates that such food is important to winter flounder is that of Tibbo et al (1963) who reported that flounder fed heavily on herring eggs in Chaleur Bay.

SUMMARY

(1) Flounder in the Conception Bay area of Newfoundland were found on muddy sand, coarse sand broken by rocky areas encrusted with <u>Lithothamnion</u> sp., pebbles and rocks.

(2) They were found in shallow water (1-2 m.) from November until early June. At the end of June and during July they moved into deeper water until, in August, few flounder were seen in the dredged area (7-10 m.) of Long Pond. They moved back into this area in September and into the shallow water by October. The movements out of and into the shallow water corresponded with the end of the spawning period and the ripening of the gonads respectively.

(3) Winter flounder spawned inshore in the spring with the period of maximum spawning activity in May and early June. Males started to ripen one or two weeks before females which generally ripened slowly from October to May, although some spawned in March and April. The spawning period was found to be progressively later in the year from south to north.

(4) The winter flounder is very fecund. In Long Pond, fecundity was higher at greater lengths and weights and lower at smaller lengths and weights than in Rhode Island. There was great variation in fecundity for different individuals within different length, weight and age groups.

(5) 87% of the males were mature at age 6 while 74% of the females were mature at age 7. All fish were mature at 9 years of age. The 50% maturity point was 21 cm. for males and 25 cm. for females.

(6) One hyaline and one opaque ring were laid down in the otoliths over the period of a year with the result that the number of hyaline rings was judged to be a valid indication of age.

(7) Males and females had similar rates of growth until age 8. At age 9 the female was larger than the male and grew faster from there on. Females had a larger maximum size than males. The length-weight relationships for males and females were found to be very similar.

(8) The growth rate up to age 8 was slower than that for flounder further south. The slope of the length-weight relationship for gutted flounder in Rhode Island was similar to that for uneviscerated flounder in Long Pond.

(9) Flounder were feeding in March and continued until September when a drop in feeding intensity occurred for matures and continued until they ceased to feed in December. Immatures exhibited a similar drop in June which continued until they also ceased feeding in December.

(10) Flounder were found to be omnivorous and the type of food eaten was found to vary with the locality. Molluscs were eaten most frequently with polychaetes second in occurrence. Polychaetes were more important volumetrically than molluscs but were in turn less important than capelin eggs and fish remains which were eaten only during a few months of the year but which were ingested in large quantities.

(11) Differences were noted in the feeding of different length groups. Polychaetes, winter flounder eggs and arthopods were not as important to the larger fish as they were to

the smaller flounder. Molluscs were important to the medium-sized flounder and capelin eggs were eaten in quantity by the small and large groups. Fish remains were eaten to a great extent by the larger fish and plant material was more important to the medium and large fish than to the smaller fish. The amount of debris ingested decreased with an increase in the size of the fish.

(12) A trematode, Podocotyle sp. and a nematode, Axonolaimus sp. were observed in the stomachs of some flounder.

APPENDIX I

TABLE 12

Stomach content analysis, Long Pond, November 1962- October 1963

Food Organisms	No. of Organisms	Stomachs in which occurred*		Aggregate total volume+	
		Number	%	cc.	%
ANNELIDA	1145	159	62·5	39·486	17·1
POLYCHAETA	1144	159	62·5	32·886	14·3
Polychaeta Errantia	419	128	50·3	23·596	10·2
Anaitides sp.	94	40	15·7	0·540	0·2
Eteone arctica	202	64	25·1	1·888	0·8
Nereis pelagica	32	25	9·8	10·870	4·7
Nereis virens	15	12	4·7	7·150	3·1
Eulalia sp.	1	1	0·3	0·007	0·0
Polynoidae	75	20	7·9	0·584	0·2
unidentified Nereids		19	7·4	1·425	0·6
unidentified Errantia		40	15·7	1·132	0·4
Polychaeta Sedentaria	725	96	37·7	9·290	4·0
Cistenides gouldi	235	35	13·7	2·378	1·0
Arenicola marina	418	10	3·9	2·368	1·0
Polydora (*gracilis*?)	2	2	0·7	0·010	0·0
Ariciidae (*Scoloplos* sp.?)	77	29	11·4	0·259	0·1
Cirratulidae	3	2	0·7	0·004	0·0
Sabellidae	1	1	0·3	0·005	0·0
Maldanidae	2	2	0·7	0·006	0·0
unidentified Sedentaria		60	23·6	4·211	1·8

*Number of stomachs containing food = 254

+Total volume = 229·643 cc.

TABLE 12 (continued)

Food Organisms	No. of Organisms	Stomachs in which occurred		Aggregate total volume	
		Number	%	cc.	%
Echiurida					
Echiurus sp.	1	1	0·3	6·600	2·8
ARTHROPODA		126	49·6	2·737	1·1
CRUSTACEA		123	48·4	2·731	1·1
Copepoda					
Harpacticoida	5017	88	34·6	0·876	0·3
Cirripedia					
Balanus balanoides	1	1	0·3	0·020	0·0
Cumacea	5	5	1·9	0·045	0·0
Amphipoda	401	76	29·9	1·321	0·5
Gammaridea	395	76	29·9	1.290	0·5
Caprellidea	6	3	1·1	0·031	0·0
Decapoda					
Pagurus sp.	1	1	0·3	0·400	0·1
Cancer irroratus	1	1	0·3	0·100	0·0
Pycnogonida	2	2	0·7	0·006	0·0
MOLLUSCA	3463	193	75·9	15·365	6·6
AMPHINEURA					
Ischnochiton ruber	17	1	0·3	0·01	0·0
GASTROPODA	207	78	30·7	1·863	0·8
Opisthobranchiata					
Nudibranchiata	7	3	1·1	0·040	0·0
Prosobranchiata					
Acmaea testudinalis	19	5	1·9	0·400	0·1

TABLE 12 (continued)

		Stomachs in which occurred		Aggregate total volume	
Food Organisms	No. of Organisms	Number	%	cc.	%
Puncturella noachina	1	1	0·3	0·010	0·0
Hydrobia minuta	84	38	14·9	0·256	0·1
Littorina sp.	65	38	14·9	0·499	0·2
Lacuna vincta	22	9	3·5	0·301	0·1
Lacuna pallidula neritoidea	1	1	0·3	0·004	0·0
Margarites helicinus	1	1	0·3	0·007	0·0
Buccinum undatum	1	1	0·3	0·250	0·1
Lunatia sp.	1	1	0·3	0·070	0·0
unidentified Gastropods	3	2	0·7	0·010	0·0
PELECYPODA	3239	177	69·6	13·492	5·8
Mytilidae					
(Mytilus sp. and Volsella sp.)	453	78	30·7	0·360	0·1
Crenella sp.	7	7	2·7	0·043	0·0
Arctica islandica	2391	101	39·7	7·719	3·3
Serripes groenlandicus	1	1	0·3	0·080	0·0
Hiatella arctica	85	3	1·1	0·038	0·0
Macoma balthica	87	38	14·9	2·668	1·1
Mya arenaria	156	55	21·6	2·244	0·9
Mya truncata	19	8	3·1	0·060	0·0
Spisula polynyma	5	4	1·5	0·025	0·0
Cerastoderma pinnulatum	6	5	1·9	0·095	0·0
Clinocardium ciliatum	1	1	0·3	0·010	0·0

TABLE 12 (continued)

Food Organisms	No. of Organisms	Stomachs in which occurred		Aggregate total volume	
		Number	%	cc.	%
unidentified Pelecypods		2	0·7	0·040	0·0
Siphons	5	5	1·9	0·390	0·1
ECHINODERMATA	30	11	4·3	1·194	0·5
Strongylocentrotus drobachiensis	17	7	2·7	0·863	0·3
Asterias vulgaris	7	2	0·7	0·300	0·1
Echinarachnius parma	4	2	0·7	0·030	0·0
Amphiuridae	1	1	0·3	0·001	0·0
COELENTERATA		9	3·5	4·246	1·8
HYDROZOA					
Campanularia		6	2·3	0·226	0·0
ANTHOZOA					
Actinaria		4	1·5	4·020	1·7
ECTOPROCTA		1	0·3	1·210	0·5
Bugula sp.		1	0·3	1·210	0·5
CHORDATA		14	5·5	35·106	15·2
ASCIDIACEA	6	4	1·5	0·046	0·0
Fish remains		11	4·3	35·060	15·2
Eggs - flounder		32	12·5	17·012	7·4
- capelin		15	5·9	51·050	22·2
- lumpfish		1	0·3	0·006	0·0
- unidentified				0·080	0·0
Miscellaneous					
Chironomid larvae	12	9	3·5	0·060	0·0

TABLE 12 (continued)

Food Organisms	No. of Organisms	Stomachs in which occurred Number	%	Aggregate total volume cc.	%
Plant material		61	24·0	29·040	12·6
Debris (sand, stones, dead plants)		202	79·5	33·031	14·3

TABLE 13

Stomach content analysis, Horse Cove, August 1963.

Food Organisms	No. of Organisms	Stomachs in which occurred* Number	%	Aggregate total volume+ cc.	%
ANNELIDA		23	92	5·394	30
Polychaeta Errantia		22	88	0·686	4
Anaitides sp.	20	11	44	0·060	0·3
Eteone arctica	11	9	36	0·072	0·3
Eteone trilineata	1	1	4	0·002	0·0
Nereis sp.	13	5	20	0·175	0·9
Eusyllis tubifex	15	8	32	0·050	0·2
Polynoidae	40	16	64	0·299	2·0
unidentified Errantia		4	16	0·028	0·1
Polychaeta Sedentaria		22	88	4·708	26.0
Cistenides gouldi	22	7	28	0·115	0·6
Arenicola marina	15	5	20	3·413	19·0
Amphitrite sp.	23	5	20	0·115	0·6
Ophelia radiata	1	1	4	0·180	0·9
Ariciidae (*Scoloplos* sp.?)	22	8	32	0·111	0·6
Cirratulidae	49	17	68	0·126	0·6
unidentified Sedentaria		21	84	0·648	4·0
ARTHROPODA		19	76	0·582	3·0
CRUSTACEA	317	19	76	0·582	3·0
Copepoda	62	10	40	0·019	0·0

*Number of Stomachs containing food = 25

+Total volume = 18·048 cc.

TABLE 13 (continued)

		Stomachs in which occurred		Aggregate total volume	
Food Organisms	No. of Organisms	Number	%	cc.	%
Amphipoda	252	19	76	0·523	3·0
Gammaridea	204	19	76	0·466	2·0
Caprellidea	48	3	12	0·057	0·2
(TRIBE) Oxyrhyncha	3	2	8	0·040	0·2
MOLLUSCA	54	16	64	1·152	6·0
Ischnochiton ruber	17	8	32	0·514	3·0
GASTROPODA	27	5	20	0·283	2·0
Acmaea testudinalis	10	7	28	0·250	1·0
Margarites helicinus	3	3	12	0·005	0·0
Hydrobia minuta	2	1	4	0·006	0·0
Littorina sp.	11	2	8	0·012	0·0
unidentified Gastropods	1	1	4	0·010	0·0
PELECYPODS		7	28	0·355	2·0
Mytilidae (*Mytilus* sp. and *Volsella* sp.)	548	4	16	0·305	2·0
Crenella sp.	2	2	8	0·020	0·0
Mya arenaria	2	1	4	0·010	0·0
Mya truncata	2	2	8	0·010	0·0
unidentified Mollusca		1	4	0·010	0·0
ECHINODERMATA		22	88	1·465	8·0
Strongylocentrotus drobachiensis	98	16	64	0·293	2·0
Asterias vulgaris	43	9	36	0·450	2·0
Amphiuridae	19	14	56	0·722	4·0

TABLE 13 (continued)

Food Organisms	No. of Organisms	Stomachs in which occurred		Aggregate total volume	
		Number	%	cc.	%
COELENTERATA		8	32	2·260	12·0
Campanularia	1	1	4	0·070	0·3
Actinaria		7	28	2·190	12·0
CHORDATA	47	18	72	0·718	4·0
ASCIDIACEA	47	18	72	0·718	4·0
Miscellaneous					
Fly	1	1	4	0·020	0·1
Gastropod egg case	1	1	4	0·030	0·1
Plant material		11	44	3·600	20·0
Debris (sand, stones etc)		18	72	3·545	20·0

TABLE 14

Seasonal variation in food intake for winter flounder, November 1962 - October 1963 (Percentage of empty stomachs in parentheses).

(a) Seasonal Variation in Volume for all Fish

Month	Total volume (cc.)	No. stomachs	(% empty)	Mean volume/stomach (cc.)
November	0·916	42	(69)	0·02
December	0·003	35	(97)	0·00
January	0·000	5	(100)	0·00
February	-	-	-	-
March	12·557	36	(11)	0·35
April	5·929	29	(69)	0·20
May	69·819	54	(22)	1·29
June	39·442	96	(31)	0·41
July	66·738	47	(6)	1·42
August*	20·984	26	(4)	0·81
September	23·360	28	(25)	0·83
October	6·783	39	(38)	0·17

(b) Seasonal Variation in Volume for Immature and Mature Fish

Immature

Month	Total volume (cc.)	No. stomachs	(% empty)	Mean volume/stomach (cc.)
November	0·238	17	(65)	0·01
December	0·003	19	(95)	0·00
January	0·000	4	(100)	0·00
February	-	-	-	-
March	9·040	28	(11)	0·32
April	-	-	-	-
May	22·172	17	(0)	1·30

TABLE 14 (continued)

Month	Total volume (cc.)	No. stomachs	(% empty)	Mean volume/stomach (cc.)
June	20·966	38	(3)	0·55
July	16·195	36	(6)	0·45
August*	5·977	10	(10)	0·60
September	0·859	3	(0)	0·29
October	0·788	9	(11)	0·09

Mature

Month	Total volume (cc.)	No. stomachs	(% empty)	Mean volume/stomach (cc.)
November	0·678	25	(72)	0·03
December	0·000	16	(100)	0·00
January	0·000	1	(100)	0·00
February	-	-	-	-
March	3·517	8	(12)	0·44
April	5·929	29	(69)	0·20
May	47·647	37	(32)	1·29
June	18·476	58	(50)	0·32
July	50·543	11	(9)	4·59
August*	15·007	16	(0)	0·94
September	22·501	25	(28)	0·90
October	5·995	30	(47)	0·20

TABLE 14 (continued)

(c) Seasonal Variation in Mean Fullness Index for all Fish

Month	Total fullness index	No. stomachs	(% empty)	Mean fullness index/stomach
November	13·0	42	(69)	0·31
December	0·5	35	(97)	0·01
January	0·0	5	(100)	0·00
February	–	–	–	–
March	80·5	36	(11)	2·24
April	20·5	29	(69)	0·71
May	121·0	54	(22)	2·24
June	168·0	96	(31)	1·75
July	131·5	47	(6)	2·80
August*	73·5	26	(4)	2·83
September	58·0	28	(25)	2·07
October	39·0	39	(38)	1·00

(d) Seasonal Variation in Mean Fullness Index for Immature and Mature Fish

	Immature				Mature			
Month	Total fullness index	No. stom.	(% empty)	Mean fullness index/ stomach	Total fullness index	No. stom.	(% empty)	Mean fullness index/ stomach
Nov.	3·5	17	(65)	0·20	9·5	25	(72)	0·38
Dec.	0·5	19	(95)	0·03	0·0	16	(100)	0·00
Jan.	0·0	4	(100)	0·00	0·0	1	(100)	0·00
Feb.	–	–	–	–	–	–	–	–
March	59·5	28	(11)	2·12	21·0	8	(12)	2·62
April	–	–	–	–	20·5	29	(69)	0·71
May	59·0	17	(0)	3·47	62·0	37	(32)	1·68
June	103·0	38	(3)	2·71	65·0	58	(50)	1·12

TABLE 14 (continued)

	Immature				Mature			
Month	Total fullness index	No. stom.	(% empty)	Mean fullness index/ stom.	Total fullness index	No. stom.	(% empty)	Mean fullnes index/ stomach
July	93·5	36	(6)	2·60	38·0	11	(9)	3·45
Aug.*	27·5	10	(10)	2·75	46·0	16	(0)	2·88
Sept.	10·0	3	(0)	3·33	48·0	25	(28)	1·92
Oct.	16·0	9	(11)	1·78	23·0	30	(47)	0·77

*Horse Cove sample

REFERENCES

(1) Abbott, R. T. 1954. American seashells. Van Nostrand. New York and Toronto. 541 pp., 40 pl., 100 fig.

(2) Arnold, E. L. 1941. Validity of scale analysis as a means of age determination of the winter flounder. M.S. Thesis, R.I. State College, Kingston, R.I.

(3) Bainbridge, R. 1952. Underwater observations on the swimming of marine zooplankton. J. Mar. Biol. Ass. U.K., 31:107-112.

(4) __________ 1953. Studies on the interrelationships of zooplankton and phytoplankton. J. Mar. Biol. Assoc. U.K., 32:385-447.

(5) Ball, J. N. 1961. On the food of the brown trout of Llyn Tegid. Proc. Zool. Soc. Lond., 137:599-622.

(6) Berry, R. J. 1959. Critical growth studies of winter flounder, Pseudopleuronectes americanus (Walbaum) in Rhode Island waters. M.S. Thesis, University of Rhode Island. 52 pp.

(7) Bigelow, H. B., and W. C. Schroeder. 1953. Fishes of the Gulf of Maine (First Revision). U.S. Fish and Wildlife Serv., Fish. Bull., 53:1-577 (Fish. Bull. No. 74).

(8) Bigelow, H. B., and W. W. Welsh, 1925. Fishes of the Gulf of Maine. Bull. U.S. Bur. Fish., vol. 40, Part 1, 567 pp.

(9) Bousfield, E. L. 1960. Canadian Atlantic sea shells. National Museum of Canada, 72 pp.

(10) Breder, C. M. Jr. 1922. Copeia, No. 102, pp. 3-4. Not seen but quoted by Bigelow and Schroeder (1953).

(11) __________ 1923. Bull. U.S. Bur. Fish., vol. 38, p. 311. Not seen but quoted by Bigelow and Schroeder (1953).

(12) __________ 1924. Some embryonic and larval stages of the winter flounder. Bull. U.S. Bur. Fish. (1921-22), 38 (Doc. No. 927):311-315.

(13) Brice, J. J. 1898. Development of Pseudopleuronectes americanus eggs (Manual of fish culture). Rep. U.S. Comm. Fish. and Fisheries, Part XXIII, p. 217.

(14) Carlisle, D. B. 1961. Intertidal territory in fish. Animal Behaviour, 9:106-107.

(15) Clark, J. R. 1960. Report on selectivity of fishing gear. *Spec. Publ. I.C.N.A.F.* (2). pp. 27-36.

(16) Eales, N. B. 1950. *The littoral fauna of Great Britain.* Cambridge University Press. 308 pp. (2nd ed.).

(17) Ellis, D. V. 1962. Diving and photographic techniques for observing and recording salmon activities. *J. Fish. Res. Bd. Canada*, 18(6):1159-1166.

(18) Eschmeyer, P. H. 1955. The reproduction of lake trout in southern Lake Superior. *Trans. Am. Fish. Soc.*, vol. 84 (1954), pp. 47-74.

(19) Fleming, A. M. 1960. Age, growth and sexual maturity of cod (*Gadus morhua* L.) in the Newfoundland area, 1947-1950. *J. Fish. Res. Bd. Canada*, 17(6):775-809.

(20) Herman, S. S. 1963. Planktonic fish eggs and larvae of Narragansett Bay. *Limnol. Oceanogr.*, 8(1):103-109.

(21) Hildebrand, S. F., and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. *Bull. U.S. Bur. Fish.*, 43:1-366 (Doc. No. 1024).

(22) Hynes, H.B.N. 1950. The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. *J. Anim. Ecol.*, 19:36-58.

(23) Keenleyside, M.H.A. 1962. Skin-diving observations of Atlantic salmon and brook trout in the Miramichi River, New Brunswick. *J. Fish. Res. Bd. Canada*, 19(4):625-634.

(24) Kohler, A. C. 1958. The validity of otolith age determinations for haddock (*Melanogrammus aeglefinus* L.) from the Lockeport, N.S., area. *J. Fish. Res. Bd. Canada*, 15(6):1229-1238.

(25) Landers, W. S. 1941. Age determination of the winter flounder of Narragansett Bay by otolith analysis. M.S. Thesis, R.I. State College, Kingston, R.I.

(26) Linton, E. 1921. Food of young winter flounders. *U.S. Bur. Fish.*, Doc. No. 907:1-14.

(27) Lobell, M. J. 1939. A biological survey of the salt waters of Long Island, 1938. Report on certain fishes. Winter flounder (*Pseudopleuronectes americanus*). *Suppl. to 28th Annual Rept. N.Y. State Conserv. Dept.*, Pt. I:63-96.

(28) McCracken, F. D. 1954. Seasonal movements of the winter flounder, Pseudopleuronectes americanus (Walbaum), on the Atlantic coast. Ph.D. Dissertation, University of Toronto. Not seen but quoted by Berry (1959).

(29) __________ 1963. Seasonal movements of the winter flounder, Pseudopleuronectes americanus (Walbaum), on the Atlantic coast. J. Fish. Res. Bd. Canada, 20(2):551-586.

(30) Merriman, D., and H. E. Warfel. 1948. Studies on the marine resources of southern New England. VII Analysis of a fish population. Bull. Bingham Oceanogr. Coll., 11(4):131-164.

(31) Moiseev, P. A. 1953. [Cod and flounders of far eastern seas] Izvestiia Tikhookeanskovo N. - I. Inst. Rybnovo Khoziaistva i Okeanografii, 40:11 - 287 (FRB. Translation No. 119).

(32) Nagasaki, F. 1958. The fecundity of Pacific herring (Clupea pallasi) in British Columbia waters. J. Fish. Res. Bd. Canada, 15(3):313-330.

(33) Northcote, T. G., and D. W. Wilkie. 1963. Underwater census of stream fish populations. Trans. Am. Fish. Soc., vol. 92(2):146-161.

(34) Pearcy, W. G. 1962(a). Ecology of an estuarine population of winter flounder, Pseudopleuronectes americanus (Walbaum). Parts I-IV. Bull. Bingham Oceanogr. Coll. 18(1):1-78.

(35) __________ 1962(b). Distribution and origin of demersal eggs within the Order Pleuronectiformes. Jour. du Conseil, 27(3):232-235.

(36) Perlmutter, A. 1939. A biological survey of the salt waters of Long Island, 1938. Section I. An ecological survey of young fish and eggs identified from tow-net collections. Suppl. to 28th Annual Rept., N.Y. State Conserv. Dept., Pt. II:11-71.

(37) __________ 1940. Should the legal size limits on winter flounders and weakfish be increased? In: a study of certain marine fishery problems of Suffolk County, Long Island, N.Y. A survey conducted by the U.S. Dept. of the Interior, Bur. of Fish., in cooperation with the Board of Supervisors, Suffolk County, N.Y., pp. 13-26.

(38) __________ 1947. The blackback flounder and its fishery in New England and New York. Bull. Bingham Oceanogr. Coll., 11(2):1-92.

(39) Poole, R. L., D. R. Kuester and A. Witt, Jr. 1963. The status of spearfishing and the use of SCUBA in fish management programs in the freshwaters of the United States. Trans. Am. Fish. Soc., vol. 92(1): 30-33.

(40) Powles, P. M. 1958. Studies of reproduction and feeding of Atlantic cod (*Gadus callarias* L.) in the southwestern Gulf of St. Lawrence. J. Fish. Res. Bd. Canada, 15(6):1383-1402.

(41) Pratt, H. S. 1948. *Manual of the common invertebrate animals, exclusive of insects*. P. Blakiston's Sons, Philadelphia, 854 pp. (3rd ed.).

(42) Reintjes, J. W., and J. E. King. 1953. Food of yellowfin tuna in the central Pacific. U.S. Fish and Wildlife Serv., Fish. Bull. 54:87-110. (Fish. Bull. 81).

(43) Richards, S. W. 1959. Oceanography of Long Island Sound. VI Pelagic fish eggs and larvae of Long Island Sound. Bull. Bingham Oceanogr. Coll., 17(1):95-124.

(44) __________ 1963. The demersal fish population of Long Island Sound. Parts I-III. Bull. Bingham Oceanogr. Coll., 18(2):1-101.

(45) Roland, K. 1960. The Metazoan parasites of the Heterosomata of the Gulf of St. Lawrence. VI. Digenea. Can. Jour. Zoo., 38:923-937.

(46) Saila, S. B. 1959. Some aspects of the breeding biology of winter flounder, *Pseudopleuronectes americanus* (Walbaum) in Rhode Island (Manuscript). Not seen but quoted in Berry, R. J. 1959.

(47) __________ 1961(a). A study of winter flounder movements. Limnol. Oceanogr. , 6(3):292-298.

(48) __________ 1961(b). The contribution of estuaries to the offshore winter flounder fishery in Rhode Island. Proc. Gulf and Caribbean Fish. Inst., Fourteenth Annual Session, pp. 95-109.

(49) __________ 1962. Proposed hurricane barriers related to winter flounder movements in Narragansett Bay. Trans. Am. Fish. Soc., vol. 91(2):189-195.

(50) Sars, C. O. 1895. *An account of the Crustacea of Norway*. Vol. I. *Amphipoda*. Christiania and Copenhagen. I-III plus plates.

(51) Scott, D. M. 1954. A comparative study of the yellowtail flounder from three Atlantic fishing areas. J. Fish. Res. Bd. Canada, 11(3):171-197.

(52) Scott, W.C.M. 1929. A note on the effect of temperature and salinity on the hatching of eggs of the winter flounder (*Pseudopleuronectes americanus* Walbaum). *Contrib. Canad. Biol.*, 4(11):137-141.

(53) Simpson, A. C. 1951. The fecundity of the plaice. *Min. Agric. and Fish., Fish. Invest., Ser.* 2, 17(5):1-27.

(54) Smith F. E. 1950. The benthos of Block Island Sound. Ph.D. Dissertation, Yale University. 213 pp. & appendices.

(55) Smith, H. M. 1898. The fishes found in the vicinity of Woods Hole. *Bull. U.S. Fish. Comm. for 1897*, 17: 85-111.

(56) Stephensen, K. 1935-1942. The Amphipoda of N. Norway and Spitsbergen with adjacent waters. *Tromsø Museums Skrifter*. Vol. III: I-IV. 526 pp.

(57) Sullivan, W. E. 1915. A description of the young stages of the winter flounder (*Pseudopleuronectes americanus* Walbaum). *Trans. Amer. Fish. Soc.*, vol. 44:125-136.

(58) Taege, M. 1963. Skindiving science practice. *World Student News*. 17:4 pp. 19-22.

(59) Thomson, J. A. 1962. On the fecundity of Pacific cod (*Gadus macrocephalus* Tilesius) from Hecate Strait, British Columbia. *J. Fish. Res. Bd. Canada*, 19(3): 497-500.

(60) Tibbo, S. N., D. J. Scarratt and P.W.G. McMullon. 1963. An investigation of herring (*Clupea harengus* L.) spawning using free-diving techniques. *J. Fish. Res. Bd. Canada*, 20(4):1067-1079.

(61) Tracy, H. C. 1910. Annotated list of fishes known to inhabit the waters of Rhode Island. *40th Rep. R.I. Comm. inl. Fish.*, 35-176.

(62) Treadwell, A. L. 1948. Canadian Atlantic Fauna. 9. Annelida. 9b. Polychaeta. *Fish. Res. Bd. of Canada*. 1-69.

(63) Warfel, H. E. and D. Merriman. 1944. Studies in the marine resources of southern New England. I. An analysis of the fish population of the shore zone. *Bull. Bingham Oceanogr. Coll.*, 9(2):1-91.

(64) Wheatland, S. B. 1956. Oceanography of Long Island Sound, 1952-1954. VII Pelagic fish eggs and larvae. *Bull. Bingham Oceanogr. Coll.*, 15:234-314.

(65) Wolfgang, R. W. 1954(a). Studies on the trematode *Stephanostomum baccatum* (Nicoll, 1907): I. The distribution of the metacercaria in eastern Canadian flounders. *J. Fish. Res. Bd. Canada*, 11(6): 954-962.

(66) ———————— 1954(b). Studies on the trematode *Stephanostomum baccatum* (Nicoll, 1907): II. Biology, with special reference to the stages affecting the winter flounder. *J. Fish. Res. Bd. Canada*, 11(6): 963-987.