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THE FOOD AND FEEDING HABITS OF THE HADDOCK
IN NORTH AMERICAN WATERS.

by

R. E. S. Homans.



**FISHERIES RESEARCH BOARD
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INTRODUCTION

Comparatively few studies on the food and feeding habits of the haddock have been conducted on this side of the Atlantic Ocean. In view of the lack of knowledge concerning this problem the present study was undertaken.

The purpose of the investigation has been, first, to ascertain the relative importance and abundance of the food organisms eaten; second, to ascertain whether or not there was a variation in the kind of food eaten in different localities; third, the determination of a seasonal variation in the kind of food taken; fourth, the evaluation of the proportions of feeding fish at different seasons of the year in an effort to show the existence of a fast at the time of spawning; and fifth, to determine the presence or absence of a variation in the diet of large and small (adult and young) haddock.

Review of the Literature.

During the past fifty years the importance of detailed knowledge of the food and feeding habits of the commercial fishes has gradually come to be realized. Since 1900 a great deal of work has been done on this problem, particularly on the European side of the North Atlantic where Scottish, English and Danish workers have been foremost in this line of investigation. When this work had progressed to the point where the chief types of food eaten by the various species of commercial fishes were known, the question arose as to how much potential fish-food was to be found on the sea-floor and whether or not the quantity varies in different areas. Around 1910, Danish workers under the leadership of Peterson, began an extensive quantitative investigation of the bottom invertebrates in Danish waters in an attempt to evaluate the sea-bottom

and its production of fish-food. The value of such work was quickly realized and to-day it forms an important part of the fishery research program of most maritime countries.

MacIntosh (1874) in his work on the marine fauna of St. Andrews (Scotland) listed a large number of species as commonly occurring in haddock stomachs. His interest, however, was only in the number of species he could collect from stomachs. Brook (1887), Scott (1888 and 1889), and Smith (1889-92), among the earliest investigators on the European side of the North Atlantic, examined the contents of haddock stomachs in an attempt to identify the species present and to show the relative quantity and frequency of the various groups of organisms in fish stomachs collected from different localities. These workers listed the different food organisms and gave the total number of stomachs in which each species occurred. No records of the size, weight, or volume of the stomach contents were made. Nor was any attempt made to correlate a seasonal variation in the type of food taken and the sexual stages of the fish from which the stomachs were taken were not determined.

Todd (1905 and 1907), in carrying out this investigation on the food of fishes in the North Sea, examined the stomachs and intestines of one thousand, seven hundred and sixty-six haddocks. The fish were captured by means of a steam trawl. The number of stomachs in which a particular organism was found to be present as food were recorded according to date and locality. A variation in the type of food on different rounds was observed. Todd found only four empty stomachs among the large number of haddock stomachs examined by him. This observation caused Russel (1914) to make the statement that there was no cessation of feeding among haddock during the winter months. Such an extremely small number of empty stomachs was in all probability due to the method of collection, namely.

A selection of stomachs containing food.

Carr (1907 and 1909) examined a small number of haddock taken in the Irish Sea by steam trawl. It was observed that the majority of empty stomachs were found in fish landed during the period from December to March and the author concludes that fish eat little during the later winter months. The food found in the stomachs was analyzed on a basis of occurrence per stomach only.

Foulsen (1928) examined the contents of a few hundred stomachs taken from haddock caught in the Belt Sea and in the Western Baltic Sea, with a Danish seine. He weighed the contents of each stomach and identified the food organisms present. The relative importance of the different food groups was determined on a basis of percentage weights and from this he attempted to show why haddock in the above mentioned areas had a faster growth rate than haddock in the North Sea.

Idelson (1929) studied the relation between the food of the haddock and the distribution of bottom animals in the Barents Sea. The stomachs were taken from Irish caught by steam trawl. The analyses were based on the frequency of occurrence in the stomachs, of the more important food groups, with no regard for size or weight. The author found that the distribution and the nutrition of the haddock corresponds quite well with the distribution of the bottom organisms.

On the North American side of the Atlantic Ocean study of the food of fishes has, in general, been slow to develop. Atwood (1864) examined the stomach contents of a few dozen specimens caught off the Maine Coast, as a study in the variety of organisms eaten by the haddock. He prepared a list of the different species of animals found in the stomachs but gave no information as to the relative

importance of the different types eaten. Baird (1886) summarized the work done on the food of fishes in the United States up to 1878. A list of the different organisms found in haddock stomachs was given.

A report on the food of the haddock and related species was published by Kendall (1898) giving a long list of species found in the stomachs of haddock caught off the coast of New England. Kendall concluded the food of the haddock and the cod to be, in the main, alike.

Clapp (1912) examined the stomach contents of over fifteen hundred haddock captured by steam trawl on Georges bank and compared the species present as food with dredge hauls made on the same ground at approximately the same time. A marked degree of similarity was found to exist between the species eaten by the haddock and the forms brought up by the dredge.

Heedler (MS 1928) examined the contents of a large number of stomachs taken on hand lines, line trawls, and in trap nets at various fishing centers along the Nova Scotian coast. He determined the approximate proportions of the different food groups eaten by the haddock by making volume measurements, and as far as is known at that time represented the only quantitative investigation on the food of the haddock that had ever been carried out on this side of the Atlantic.

Vladykov (MS 1933) analyzed the contents of a few hundred haddock stomachs taken from fish caught mainly on line trawls and handlines on inshore grounds off the coast of Nova Scotia. His method was to weigh and count the various groups of organisms present

Some results of the present investigation have already been described. Vladykov and Homans (1935) showed that the mature haddock ceases to take food immediately prior to and during the time it is spawning. The same authors (MS 1936) reported on the food of haddock caught by steam trawl on the western banks over a period of one and one-half years.

METHODS

A brief description of the methods used in collecting material and in analyzing the stomach contents.

Collection of Material.

As a rule only the stomachs of haddocks were collected. In the case of trawler caught fish the stomachs were removed from the fish immediately following their removal from the trawl. Random sampling was practiced in that the stomachs were not selected. The stomachs were placed in quart "perfect seal" jars and covered with a six-eight percent solution of formalin, as a preservative. It was found that stomachs preserved in a formalin solution of this strength for a period of two or three days became hardened and were then much easier to handle for purposes of examination than unpreserved stomachs which even when very fresh were soft and flabby, making them extremely difficult to work with. Each jar of stomachs was labelled as to location of capture, date, bottom temperature, depth of water that the fish were caught in, the nature of the bottom, and in some cases correspondence to envelopes containing information on the size of the fish, the sex, and a sample of the scales.

In the case of haddock caught on the inshore grounds, two procedures were followed. The stomachs were removed from the fish at the place of capture and treated in a similar manner as that describ-

ed above for the stomachs removed from trawler fish or the haddock were shipped in a round state and the stomachs removed in the laboratory. In either case full information was obtained concerning location, date, depth of water, nature of bottom, and the kind of bait used, for haddock caught on the inshore areas are mostly captured by line trawls and handlines. A number are caught in trap nets.

METHODS OF ANALYSIS

At the beginning of the investigation the contents of ten stomachs were emptied together into a container and weighed. The mass of food was then sorted out into the different systematic groups that happened to be represented and the specimens in each group were weighed, counted, and measured. This method of analyzing the stomach contents was soon discontinued because it ~~did~~ not yield sufficiently detailed information as to the actual occurrence per stomach of the typical food organisms, since in one sample of ten stomachs specimens of an organism might be present in each of the ten whereas in another sample it could be represented in one stomach only, yet the total weight of the specimens be equal in both cases.

In order to overcome this difficulty the analysis of individual stomachs was resorted to. The food content of each stomach was sorted out into the systematic groups present, and weighed, counted and measured as before. This method, which gives complete information of the food of each stomach examined was used for the remainder of the investigation.

A certain amount of difficulty was encountered in making accurate measurements of the food organisms due to several factors such as, the food being partially digested, broken into pieces etc.

wherever possible the greatest length was measured. This was done in the case of fish, worms, mollusks etc. Echinoderms were measured at their greatest diameter. In the Crustacean group all measurements for crabs were made by measuring the length of the carapace. Shrimps were measured by taking the distance from the eyes to the end of the outspread tail.

In counting partially digested and broken food organisms only some characteristic portion of the organism was counted. (for example in the case of fishes, shrimps etc. the heads were counted).

In many cases where the stage of digestion was advanced it was impossible to count the number of specimens present very accurately.

A record was kept of all empty stomachs. In the text and tables the term "full" is used to represent a stomach containing any food, regardless of quantity.

The present is concerned with adult fish of commercial size mostly (varying approximately in length from three hundred millimeters upward). In the commercial fishery, haddock less than five hundred millimetres in length are spoken of as "scrod" fish, while those fish above that length are known as "large" fish.

Certain methods of analyzing the stomach contents that have been used in the past by other investigators were discarded in favour of the one used in the present work. Todd, (1905 and 1907) in his extensive studies of the food of fishes in the North Sea, counted only the number of specimens of each species present, per stomach. This method is obviously inadequate from a quantitative standpoint as nothing is known about either the size or the weight of the organisms present. Needler (MS. 1928), Ritchie (1932) and, Thompson (1923) based their analysis of the food composition of the haddock on the

measurement of volumes. The volume of food present in a stomach was defined as the number of cubic centimetres of liquid displaced in a graduated cylinder when the contents of the stomach was added. This method when used alone lacks information concerning the number and size of the specimens present and in addition it is a very time-taking and tedious method.

Elegvad (1916) and Foulson (1926 and 1928) weighed the different food groups present in the stomach and supplemented their results by counting the individuals of each species present.

Material.

The material collected for the study can be divided into two main groups, those stomachs collected from haddock caught by stram trawl on the fishing banks lying at some distance off the coast of Nova Scotia and which may be called the off-shore grounds and in contrast to this group, the stomachs collected from haddock captured by line trawls, hand lines, and trap nets on the inshore grounds adjacent to the coast.

About ten thousand six hundred stomachs were examined from haddock taken on the off-shore bank areas during the period from September, 1934 to January, 1937. A glance at Table 1 which shows the areas both off-shore and in-shore from which stomachs were collected will serve to indicate the chief areas where samples were obtained. It is to be noted in the case of off-shore samples that the areas named are of very wide limits and samples collected from along the outer edges of a bank area are included in the totals for that particular bank. For instance the region lying immediately to the eastward of Emerald bank well known to fishermen as the "Gully" is included in the Emerald bank area. In addition to the above a number of stomachs were obtained from St. Pierre bank, the Grand banks of Newfoundland (Whale Deep) and from Georges bank.

Table 1.

A list of the localities in which samples were collected.

Offshore Collections.

Locality	Date	No. Stom.
Georges Bank	June, 1935.	179
Emerald Bank	Nov. 1934.	67
" "	Jan. Feb.	
" "	Mar. & Apr. 1935	2149
" "	Jan. 1937.	100
Emerald Bank Region	April, 1935	86
" " "	December, 1935.	70
" " "	Jan. Feb. 1936.	1610
" " "	March 1936	520
" " "	April, 1936	279
" " "	May, 1936	104
Sable Island Bank	Sept. 1934	397
" " "	Oct.-Nov.	301
" " "	July, Sept. Oct. & Nov. 1935;	1476
" " "	May, 1936	29
Middle Ground Region	Oct. Nov. 1934	314
" " "	May, June & Aug. 1935	1368
" " "	August 1936	123
" " "	April- May 1936	392
Bangereau	Nov. Dec. 1934	519
"	December 1935	149
St. Pierre Bank	July, Aug. Sept. October 1936	280
Grand Banks	Sept. 1936	150

TABLE I.

A LIST OF THE LOCALITIES IN WHICH SAMPLES WERE COLLECTED.

Inshore Collections.

Locality	Date	No. Stom.
Fassamaquoddy Bay	Sept. 25, 1933	73
" "	Sept. 18, 1934	7
" "	July, 1936	104
" "	August, 1936	81
" "	October, 1936	91
" "	November, 1936	131
" "	Jan. 2, 1933	19
Digby	December 9, 1933	19
"	Oct. 17, 1934	103
"	Dec. 22, 1936	99
"	May 26, 1936	51
Roseway Ek.	Aug. 8, 1936	108
Lunenburg	Oct. 15, 1936	73
Hubbards)	Aug. 5, 1933	162
French Village) St. Margaret Bay.	May 27, 1935	449
Indian Harbour)	August 30, 1932	2
Frospect)	Aug. 31, 1932	12
Eastern Passage	June 20, Aug. 27, 32.	139
Bedford Basin	July 19, Oct. 30, 32	289
Automatic Buoy (Halifax)	Feb. 18, 1934	6
Halifax Lightship	Nov. 9, 1934	34
" "	May 10, 1935	4
Liscomb)	Nov. 6, 1934	19)
Port Bickerton)	Dec. 12, 1934	17)
Half Island Cove	Aug. 6, 1936	164
Canoe	Dec. 11, 1934	131

Locality	Date	No.stom.
Arichat	June 5, 1935	57
Arichat	November 23, 1935-	56
Arichat	June 9, 1936	145
Ingonish	June 8-10, 1935	240
Fort Hood	August 19, 1936	96
East Point, P. E. I.	November 24, 1934	135
Souris, P. E. I.	November 23, 1935	117
Souris	August 15, 1936	83
North Point, P. E. I.	November 3, 1936	72
		<u>3,393</u>

Considerably more than three thousand stomachs obtained from fish caught on the fishing grounds lying adjacent to the coastline of the Maritime Provinces were analyzed for stomach contents. The in-shore area can be further divided into three geographical areas, namely,

- (1) Bay of Fundy area. Samples from Passamaquoddy Bay, N. B. and Digby, N. S.
- (2) Outer coast of Nova Scotia. Samples from Roseway Bk. & Lunenburg St. Margarets Bay, Halifax harbour, Liscomb, Canso, Queensport, Petit de Grat, and Ingonish were examined.
- (3) Gulf of St. Lawrence. Samples examined from Port Hood, East Point and Souris and North Point, P. E. I.

The above inshore samples were collected somewhat irregularly over the period from June, 1932 to January, 1937. The details can be seen from Table 1.

GENERAL FOOD COMPOSITION

The examination of over fourteen thousand haddock stomachs has yielded the following information about the food of this fish, both in the off-shore and in-shore waters.

Table 11 shows a comparison of the principal food groups making up the diet of off-shore and in-shore haddock. The figures are percentages calculated from the total weight of material present in the stomachs.

The food composition of the haddock taken on Western bank is based on the examination of ten thousand and fifty-three stomachs. The results are summarized in Table 11.

It is seen from this table that the group designated fish, constitutes by far the chief part of the haddock's food on the Western banks. A single species, the sand-launce, (Ammodytes americanus DeKay) composes this fish diet to the extent of almost

one hundred percent. Other species of fish Sebastes marinus Linnaeus, Hippoglossoides platessoides Fabricius, Triglops pingeli Fabricius, Merluccius bilineatus Mitchill and Argentina silus Ascanius, is very rare in our region, the only other capture being reported a good many years ago (Goode and Bean 1895).

Worms, mostly Pectinaria and common marine Polychaetes, rank a very poor second.

The next group in order of importance, the Echinoderms, is represented mainly by sanddollars, Echinarachinus parva Lamarck, followed by Sea-urchins, Strongylocentrotus drobachiensis C. F. Muller, and brittle-stars, Ophiopholis aculeata Linnaeus, and a few Ophiura robusta Ayres in the order named.

The echinoderms are closely followed by the crustaceans which group, although ranking only fourth in the haddocks diet from a quantitative basis, is represented by far more species than any of the preceding groups, some thirty-five species having been found. Hermit crabs, Paguridae, and amphipods form about equal parts by weight of the crustacean diet, comprising between them over two thirds. The former group is represented by two species, Pagurus acadianus Benedict and P. Kroyeri Stimpson. The commonly occurring amphipods are Aegina longicornis Kroyer, Themistocompressa Goes forma compressa Goes, Unicola irrorata Say, Monoculodes edwardsi Holmes, and Tmetony nobilis Stimpson. For a complete list of the amphipod species see Table X. The remaining part of the Crustacean diet is made up by shrimps and prawns (Macura). The species commonly represented are Grazo septempinosus Say, Pandulus proximus Ge.O. Sars, Bichelerandulus lentocerus Smith and Spirontocaris spina

TABLE II.

Percentage composition Stomach Contents

of

Offshore and Inshore Haddock

Locality	Fish	Worms	Echino- derms	Crust- aceans	Mollusks	Miscellaneous	
Offshore	53.0	11.2	9.4	9	9.0	4.2	12.2
Inshore	3.1	3.0	44.0	5.7	33.6	10.8	

(Sowerby). The pelagic shrimp Meganctiphanes norvegica M. Sars was present in a number of instances, frequently in large numbers.

The mollusks are the least important of the major food groups although some thirty-seven species are represented in the molluscan diet. Gastropods comprise the greater portion of this group on the Western banks. Polynices heros Montfort and Haminea solitaria Dall are eaten most commonly. Other species eaten in considerable quantities are Margarita obscura Gould, Margarita cinerea Gould, Sipho pyramaeus Couthuoy, Scala Groenlandica Chemn., Bala cancellata, Stimpson, and Cylichna alba, Stimpson.

Among the pelecypods eaten Yoldia myalis Gould, Astarte elleptica Brown and Macula tenuis Michels occur in the stomachs regularly while Leda tenuisulcata Couthuoy, Cardium pinnatum Conrad, and Glycimerus pilicua Lamarck are consumed less regularly.

Two chitons (Trachydermon albus Linnaeus and Tonicella marmorea Fabricius) were eaten occasionally. A small squid, Illex illicebrosus was found in the stomach of a large haddock. Several other items such as fish eggs, chiefly eggs of Clupea harengus Linnaeus, and Tunicates, chiefly Helonia corrugata Goodsir and Forbes, Bostrichobranchus pilularis Verrill etc. were occasionally found, but they play a very negligible role as food for haddock. On the other hand, inanimate material such as mud, sand, gravel and pebbles etc. was found quite frequently in stomachs. Some of this no doubt is swallowed attached to regular food material, while it is possible that small pebbles may be mistaken by their size and color for food. This material has been included under the heading "miscellaneous" in all tables.

The stomachs from three thousand three hundred and ninety-three haddock caught in inshore waters were examined. Table II

shows the percentage weights of the food composition for the major groups, covering the period during which samples were collected. From the table it is seen that the dominant haddock food, fish, of the Western banks is a negligible factor in the food of shore haddock.

The meagre fish diet is composed of Menidia notata Mitchell and Clupea harengus Linnaeus.

Echinoderms are the principal food here, comprising almost one-half of the total food weight eaten. Ninety-five percent of this group is represented by one species, the brittle-star, Ophiopholis aculeata Linnaeus. Several other species, Thyone Briareus Lesueur, Stegophiura nodosa, Psolus phantopus Sturssenfeldt and Cucumaria calagera Blainville were eaten in the order given.

Mollusks, the least important major group in the diet of Western banks haddock, is preceded only by echinoderms in the diet of inshore haddock. These two important constituents comprise between them over seventy-seven percent of all material taken by the inshore fish. The most noteworthy feature about the mollusk diet is that whereas the Western banks haddock favoured gastropods, the inshore haddock exhibited a partiality towards Pelecypods. Yoldia myalis Couthuoy, Cardium pinnatulum Conrad, Astarte elliptica, Brown, Mucula tenuis Mighels, Macoma fusca Gould, and Macoma calcarata Gmelin, in order of importance.

Gastropods usually found present in the stomachs are Lol-
vices heros Montfort, Margarita obscura Gould, Tarritella
grossa Couthuoy, Nassa trivittata Say, and Bela cancellata Stimp-
son, in the order names.

The crustaceans are of comparatively small importance in the food composition of inshore haddock. Amphipods are the most important constituent of the inshore crustacean diet, followed by shrimps. Uncilla irrorata Say, Leptocheirus pinguis Stimpson, Maera loveni Bruzelius, Neohela monstrosa Boeck, are the chief amphipods eaten. Spirontocaris pusiola Kroyer, Sclerocrangon boreas Phipps and Pandalus montague Leach are the shrimps eaten most commonly by haddock. The pelagic shrimp, Thysanoessa Sp.? inermis Kroyer is eaten in quantities by haddock caught in Passamaquoddy Bay.

Worms are of comparatively little importance in the diet, being present only at odd times. The species represented are the common marine Polychaetes.

In addition to the above, the examination of two hundred and eighty stomachs taken from haddock caught on St. Pierre bank over a period of four months in the summer of 1936 revealed that the haddock on this ground were feeding on the brittle star (Ophiopholus aculeata) exclusively.

A sample of one hundred and fifty stomachs of haddock taken in the Whale Deep Area on the Grand banks of Newfoundland when examined showed that these haddock had been feeding mainly on crustaceans (chiefly the hermit crab, Pagurus Kroyeri Stimpson, living in Epizoanthus paguriphilus and the pelagic euphausiid Thysanoessa inermis Kroyer. One species of prawn, Pandalus propinquus G. O. Sars, and several species of amphipods (Untiola irrorata Say, Themisto compressa Goes, Forma compressa Goes, Monoculodes edwardsi Holmes, and Hyperia galba Montagu were also present in small quantities.

The remainder of the stomach contents consisted of common marine polychaetes and a few sipunculids.

As the offshore and inshore areas discussed above (excepting St. Pierre bank and the Grand banks of Newfoundland from which areas not enough material has been collected to make possible any deductions.) show quite definite regional variations in the type of food eaten by the haddock caught on particular grounds, such a comparison of large areas and total samples as was made above may give a misleading interpretation of the dominant food group in any localized region within the large areas discussed. To avoid such a possibility a discussion of these local areas or regions is necessary. Table III shows the percentage weights composition of the chief food groups eaten by the haddock on different regions of the Western banks. This table shows rather significant differences for some of the regions. Thus sand-lance was the dominant type of food eaten on the whole of Emerald bank, the region west of Emerald bank, and also on the western portions of Sable Island bank and on Middle ground. Haddock caught on the south side of Sable Island and on the north side of the Island, were found to be feeding plentifully on worms. Isolated patches where worms also formed the dominant food groups are situated north-west of Emerald bank and on the western part of Quercou bank. Haddock feeding on great quantities of echinoderms were caught on the region between Sable Island bank and on the Middle Ground; and were also the dominant food in an area off the north Western part of Sable Island bank known as the "Cow-pen". Crustaceans are the characteristic food group of haddock taken from the Gully, situated between Emerald and Sable Island banks. North of Emerald bank there is an area where the haddock feed primarily upon mollusks. Due to the extremely wide areas covered in sampling and the wide range of species eaten, the species occurring in each of the main groups is not given.

Percentage Composition (by weight) of the Stomach Contents of Western bank Saddle.

Bank Area	Fish	Echinoderms	Mollusks	Worms	Crustaceans	Tunicates	Miscellaneous
E. W. of Emerald	12.2	1.2	14.1	18.2	7.3	-	47.0
E. of Emerald	-	18.6	19.8	10.6	-	-	54.1
Emerald	99.5	-	-	-	-	-	0.5
W. of Emerald	92.5	7.5	-	-	-	-	-
Gully between Emerald & Sable Island bank.	6.1	14.0	4.8	14.9	21.2	6.0	31.2
E. W. of Sable Island bank	6.1	44.3	2.5	3.5	17.2	0.7	23.7
W. of Sable Island bank	71.0	3.3	4.2	9.4	7.0	-	4.3
S. W. of Sable Island bank	37.0	2.6	13.4	10.0	6.8	-	31.2
E. of Sable Island	5.6	13.7	10.8	36.6	12.1	0.8	18.75
S. of Sable Island	-	6.2	10.6	22.4	17.6	10.6	14.4
Between Middle Gr. & Sable Island bank	13.7	24.0	5.3	12.4	19.4	3.7	21.5
West of Middle Grd	29.4	7.9	0.4	15.7	4.6	-	42.0
Middle Ground	65.4	17.2	1.4	1.4	4.4	-	10.2
South of Middle Grd	87.5	0.1	1.6	1.7	4.0	-	5.1
Quereau	6.6	3.6	11.5	48.5	19.2	-	15.4
St. Quer. & Sable Island bank	45.7	3.2	16.4	13.1	6.5	-	15.1

The various inshore localities from which samples were collected show quite clear-cut variations in the dominant types of food eaten by haddock on those grounds. The percentage weights composition of the food eaten for the chief regions is given in Table IV.

Passamaquoddy Bay.

The stomachs of six hundred and ten haddock caught on line trawls were examined. Two hundred and ninety-four contained food. Sixty-one percent of the food present was made up by one species of pelecypod (Yoldia myalis Couthuoy). As an illustration of the enormous numbers of this species that are eaten it may be mentioned that one sample of seventy-three stomachs from this locality contained approximately fourteen thousand specimens of the above mentioned pelecypod ranging in length from five to twenty-seven millimetres, and weighing over fifteen hundred grams. Echinoderms, all Ophiopholis aculeata, and crustaceans (Euphausiids and true shrimps) accounted for most of the remainder of the food (see Table IV).

Digby.

All (272) stomachs examined were taken from haddock caught on line trawl. One hundred and eighty-four contained food. Pelecypods are the dominant food group, but the dominancy is much less than that shown in the Passamaquoddy Bay samples, and several species are common, Yoldia myalis Couthuoy, Cardium pinnatulum Conrad, Saxicava rugosa Linnaeus, and Macoma galcarena Gmelin. The molluscan Bilvaves are closely followed by crustaceans (mostly amphipoda) in order of importance. The largest portion of the stomach contents consisted of mud and sand (55%). Fish, echinoderms, and worms occurred in negligible quantities, Needler (MS 1928) analyzed samples

TABLE IV.

Percentage Food Composition of Haddock on Inshore Grounds

Location	Fish	Echino- derms	Mollusks	Worms	Crust- aceans	Misc.	No. Stom. Examined.
Passamaquoddy Bay	0.8	14.2	71.5	0.4	9.5	3.6	610
Digby	0.8	2.1	21.8	2.7	16.3	56.3	272
Roseway Bank	-	100.0	-	-	-	-	108
Lunenburg	-	100.0	-	-	-	-	73
St. Margarets Bay	25.1	67.7	0.2	1.3	2.6	3.1	615
Halifax Harbour	-	65.7	10.4	5.1	0.4		218
Liscomb	-	85.0	0.8	3.0	-	11.2	36
Cans0	-	84.0	1.3	10.5	1.3	2.9	131
Queensport	-	95.0	2.8	1.1	1.1	-	164
Petit de Grat	-	80.0	-	0.2	-	19.8	258
Ingonish	4.0	32.5	-	5.1	44.1	9.5	240
Fort Hood	-	8.8	21.8	26.2	31.2	8.0	96
East Point	-	68.0	6.4	11.1	6.4	8.1	236
North Point	-	37.0	11.3	13.6	2.2	35.9	72

from this locality in 1927 and found crustaceans to form about forty percent by volume of the stomach contents and pelagic crustaceans about twenty percent.

Runway bank (Off Lockeport)

One hundred and eight stomachs taken from haddock caught on line trawl examined. Seventy contained food. The brittle star, Ophiophilis aculeata, composed the entire stomach contents.

Lunenburg.

Seventy-three stomachs taken from haddock caught on line trawl were examined. Fifty-four contained food. The stomach contents consisted entirely of brittle stars, (Ophiophilis aculeata).

St. Margaret Bay.

Samples from three localities were analyzed from this area. The details are given in Table V. Of the six hundred and eleven stomachs examined from St. Margaret Bay, four hundred and forty-nine (from French Village) were taken in mackerel nets. The remainder were caught on hook and line. One hundred and thirty-one contained food. The haddock taken off French Village were in a spawning condition and all but four of the stomachs were empty. (Vladykov and Homans, 1935). Each of these four stomachs contained a herring varying in length from one hundred and seventy to two hundred millimetres, and having a total weight of two hundred and sixty-six grams. Speaking for the whole area (See Table IV) echinoderms (mostly brittle stars) are the most important food group, accounting for sixty-eight percent of the total food weight. Fish were present to the extent of twenty-five percent of the total, the four herring mentioned above, representing this total. The occurrence of these specimens, by the way, was the only occasion on which haddock were found to be feeding upon herring.

Mollusks (Cardium pinnatum, Margarita obscura, Polynices heros) and crustaceans (Spirontocaris pusiola Kroyer, amphipods) occurred in very small amounts, as did also worms (common marine polychaetes).

Halifax Harbour

In this area all stomachs examined were taken from fish caught by hook and line or by line trawl. One hundred and twenty two contained food. Here as in the above area, echinoderms (brittle stars) constituted the greater portion of the stomach contents (68%) Mollusks, Cardium pinnatum, mostly, form a somewhat more important part of the diet than they did in St. Margaret Bay, amounting to approximately ten percent (see Table IV). Worms accounted for a small percentage (5.4) other groups were relatively unimportant. Dr. V. D. Vladykov examined a number of haddock stomachs during the summer of 1933 and found that brittle stars comprised over eighty percent of the total weight. Crustaceans (shrimps, crabs and amphipods) constituted about ten percent of the food. Dr. Vladykov also caught by hook and line during the month of August, 1932, twelve haddock in the lower reaches of the harbour whose stomachs were crammed full of herring eggs. On the same date a nine pound haddock was captured, the stomach of which contained a small dogfish pup (Squalis acanthias). The above observations made by Dr. Vladykov have been taken from unpublished data. As was the case in St. Margaret Bay the stomach samples have been collected from three distant localities. Table VI gives the details. It will be noticed that Mollusks, mostly Cardium, are of most importance in Bedford Basin and of least importance off the mouth of the Harbour, whereas exactly the opposite is true of echinoderms (mostly brittle-stars).

TABLE V.

ST. MARGARETS BAY.

Percentage Food Composition

	Hubbards	French Village	Peggys
Fish	-	95.0	-
Worms	0.7	3.3	-
Echinoderms	92.0	-	78.0
Crustaceans	3.6	-	19.5
Mollusks	-	-	2.5
Miscellaneous	3.7	1.7	-

TABLE VI.

HALIFAX HARBOUR.

Percentage Composition Stomach Contents.

	Bedford Basin	Eastern Passage	Off Mouth of Har.
Fish	-	-	-
Worms	19.8	7.0	-
Echinoderms	7.3	46.5	99.0
Crustaceans	2.8	-	-
Mollusks	32.1	25.4	-
Miscellaneous	38.0	21.1	1.0

Liscomb

The stomachs of thirty-six haddock, caught on line trawl off this locality were examined. Twenty-six contained food. Eighty-three percent of the food taken was composed of brittle-stars, some of the stomachs being greatly distended with them. Small numbers of worms and crustaceans (amphipods) were found in the stomachs of the smaller sized fish.

Canso.

Haddock caught near Canso and on Canso bank by line trawl were found to be feeding largely on brittle-stars. Over one hundred and thirty stomachs were examined of which sixty-seven contained food. Eighty-four percent of the total contents was made up of brittle-stars. Worms accounted for approximately ten percent. Negligible amounts of mollusks (Pelecypods) and crustaceans (amphipods) comprised the remainder.

Queensport.

One hundred and sixty-four stomachs from haddock caught on line trawl were examined. Fifty-six contained food. Ninety-five percent of the entire contents was brittle-stars. The remaining portion being gravel.

Petit de Grat.

Two hundred and fifty-eight stomachs taken from fish caught on line trawl were examined. Only nine contained food, of which brittle-stars comprised over seventy percent. Mollusks, (Turritella grossa, etc.), worms, (polychaetes) and crustaceans (amphipods) were present in very small quantities.

Ingonish

Stomachs from two hundred and forty haddock captured in

TABLE VII.

Percentage Food Composition of Inshore Haddock by Regions

<u>Locality</u>	<u>Fish</u>	<u>Worms</u>	<u>Echinoderms</u>	<u>Crustaceans</u>	<u>Mollusks</u>	<u>Misc.</u>
Bay of Fundy	0.8	100	11.6	10.8	60.9	14.9
Outer Coast	4.4	2.7	57.8	3.6	23.6	7.9
Nova Scotia						
Gulf of St. Lawrence		13.6	47.8	7.3	12.9	18.4

TABLE VIII.

Percentage Composition of Stomach Contents (by weight).

PASSAMAQUODDY BAY AREA

Date	Total No. stomachs.	No. of Full stom.	Fish	Worms	Echino- derms	Crust- aceans	Moll- usks	Misc
July, 1936	104	61	2.5	-	29.5	7.5	60.5	-
August	81	50	2.4	-	20.1	67.5	-	10.1
October	91	45	1.0	-	-	2.0	66.0	31.0
November	131	34	-	24.9	12.6	23.5	26.0	15.0
January 1937.	123	24	-	-	100.0	-	-	-

trap nets were examined from this locality. Only twenty-nine contained food. Crustaceans, represented by decapods, (Crabs and shrimps), amphipods and isopods, Aega psora Linneus, comprised about forty-five percent of the stomach contents. Echinoderms accounted for approximately thirty-two percent, sanddollars, Echinarachnius parma, accounting for this percentage, not brittle-stars. Needler (MS 1928) during 1937 and 1928 examined over twelve hundred stomachs from this region. The majority were empty. Echinoderms (mostly sanddollars), a few worms, crustaceans (chiefly amphipods and cumaceans), a few mollusks, eelers (glass eels) and mackerel entrails (from rotting mackerel gilled in the trap net leaders,) completed the food list.

Fort Hood.

Ninety-six stomachs taken from haddock caught on hand lines, were examined. Fifty-three contained food; Crustaceans, consisting entirely of amphipods, comprised the greater portion (31.2 percent) of the stomach contents. Worms (Polychaetes), ranked next, amounting to twenty-six percent of the total. Mollusks, all gastropods (T. exosa, P. Heros and Bela cancellata) accounted for twenty-two percent. Echinoderms (Brittle stars) were present to the extent of only nine percent of the total food weight.

East Point and Souris, P. E. I.

The analysis of two hundred and twenty-eight stomachs of which one hundred and thirty contained food, caught on line trawl during November of 1934 and 1935, revealed that haddock in this vicinity were feeding on echinoderms (mostly brittle stars) to the extent of sixty-eight percent. Worms made up eleven percent, mollusks approximately six percent, and crustaceans approximately six percent.

North Point.

Seventy-two stomachs taken from haddock caught by steam trawl. Fifty contained food. Echinoderms (practically all consisting of holothurians) comprised the greater part (35-40 percent) of the total contents. Mollusks, all pelecypods, ranked next. Worms were a relatively poor third. No crustaceans and no fish were present.

Using the above data as a basis the inshore haddock grounds can be combined into three general areas, characterized by a dominant food type. It may be said that the Bay of Fundy is a mollusk feeding ground for the haddock; while the outer coast of Nova Scotia is an echinoderm area, except for a small spot off Ingonish and Port Hood where crustaceans are the dominant group. The Gulf of St. Lawrence in the vicinity of East Point and North Point, P. E. I. is also an echinoderm area. Table VII shows the percentage composition for the three above areas.

SEASONAL VARIATION IN FOOD COMPOSITION

Samples obtained from inshore localities were collected too irregularly, and are too few in number to render them analizable for a seasonal variation in the type of food eaten by the haddock in these areas, except in one locality. In July, 1936, plans were completed for the procuring of monthly samples from Passamaquoddy Bay. Samples collected in the months of July, August, October, November, and January have been analyzed. The vagaries of fishing prevented any collection being made in September and December. In Table VIII is given the percentage composition of the principal stomach contents.

In the July sample the haddock were feeding chiefly on mollusks, Yoldia myalid, and to a lesser degree on echinoderms (Ophi-

ocholis aculeata). In August the mollusk diet was replaced by a crustacean one of shrimps, followed by a return to the Yoldia diet in October and November. Worms entered the food composition in November for the first time, ranking next to the dominant mollusk diet in this month. In the January sample the entire food composition consisted of echinoderms (Brittle stars).

The change from the normal Yoldia diet to one of pelagic shrimps in August probably coincided with a swarm of these large euphausiids, Meganctiphanes norvegica, M. Sars, which, according to Bigelow and Welsh"---regularly appear during the warm months of the year about St. Andrews----". (Bigelow and Welsh p.147, 1924) With the disappearance of the shrimps a return was made to the Yoldia beds until January when the haddock stomachs examined contained only Brittle stars.

Although stomach samples were collected extensively over a period of eighteen months from the Western banks it is hardly possible to draw any general conclusions regarding a change of diet with a change in season, due to the casual manner in which the material was collected. This was unavoidable since the supply of stomachs was limited to samples received from the trawlers, which trawl only on smooth bottom and rarely trawl in the same area consecutively. Therefore systematic collecting on restricted areas, so necessary for information on the above subject, was impossible. Furthermore, such a study must be correlated with quantitative examinations of the bottom fauna in each particular area, in order to yield worthwhile results.

By a study of Table LX a few very general observations on the seasonal occurrence of the major food groups composing the diet of haddock on the Western banks can be made.

Type of Feed in Percentage

Month	<u>Echinoderm</u>			<u>Mollusks</u>			<u>Worms</u>			<u>Crustacea</u>			<u>Fish</u>		
	1934	1935	1936	1934	1935	1936	1934	1935	1936	1934	1935	1936	1934	1935	1936
Sept.	0.4	1.5	-	12.5	1.6	-	2.5	10.3	-	10.7	13.2	-	57.3	72.6	-
Oct.	9.4	12.3	-	4.0	0.8	-	-	9.4	-	15.8	6.8	-	25.1	57.0	-
Nov.	3.8	9.8	-	20.8	19.8	-	10.8	57.4	-	9.1	2.7	-	25.9	3.4	-
Dec.	9.3	9.04	-	15.6	0.02	-	13.5	14.3	-	18.5	2.8	-	7.2	22.5	-
Jan.	-	2.9	0.7	-	10.1	2.2	-	18.9	2.3	-	23.5	9.4	-	4.3	66.0
Feb.	-	18.2	29.2	-	11.7	4.6	-	19.4	7.0	-	4.5	34.5	-	-	5.0
Mar.	-	20.0	-	-	14.1	-	-	22.2	-	-	4.0	-	-	2.5	-
Apr.	-	6.3	-	-	4.8	-	-	16.4	-	-	8.9	-	-	10.9	-
May	-	-	-	-	1.5	-	-	10.3	-	-	0.9	-	-	20.1	-
June	-	31.1	-	-	4.1	-	-	10.5	-	-	6.0	-	-	13.4	-
July	-	0.7	-	-	1.2	-	-	1.6	-	-	2.8	-	-	31.5	-
Aug.	-	26.0	-	-	-	-	-	31.1	-	-	13.1	-	-	2.0	-

The quantity of fish, Ammodytes americanus, present in the food composition of the haddock varies considerably (from zero to 92 percent) of the total stomach contents at different times of the year. In September of 1934 and of 1935 Ammodytes americanus amounted to fifty-seven and seventy-three percent, respectively. In October, 1935, the amount was fifty-seven percent of the total amount of stomach contents analyzed. This species accounted for a considerable portion of the total stomach contents in December, 1935 (82 percent), and in January, 1936 (66 percent). The greatest percentage of Ammodytes americanus forming the total stomach contents was found in July, 1935, when the stomach contents analyzed was about ninety-two percent Ammodytes americanus. As an illustration of the abundance of these individuals it may be stated that as many as forty-three, ranging in size from twenty-five to one hundred millimetres and weighing altogether about one hundred and seventy-five grams, have been found in a single haddock stomach.

In general it may be said that Ammodytes americanus in large numbers are usually found in haddock stomachs only during the summer and fall months. The occasional occurrence of large numbers of this fish in haddock stomachs during the winter months coincides no doubt with warm water temperatures, and certain pre-spawning conditions of the haddock. (Vladykov and Homans, 1936).

Fish eggs form a very small part of the food of haddock on the Western banks. They occur usually during the spring and early summer months.

It can be stated that worms, as a rule, occur in greatest numbers during the winter and spring months. At this time they comprise from fifteen to twenty-two percent of the total stomach contents. However, the largest quantity of this food occurred in November, 1935 (fifty-seven percent).

The echinoderm group seem to be a seasonal food. It appears that the haddock prefers to feed on them shortly before spawning (February-March) and afterwards (June and August). Echinoderms comprised sixteen percent of the total stomach contents in February, 1935, and twenty percent in March. In February, 1936, they comprised twenty-nine percent of the food diet. The highest quantity for any one month (thirty-one percent) was eaten in June, 1935.

The crustaceans are eaten in largest amounts by haddock during the winter months. The greatest quantities were consumed in December of 1934 (18.5 percent), January of 1935 (23.5 percent), and February of 1936 (34.5 percent).

Mollusks seem to be preferred by haddock during the late fall of the year. In November and December of 1934 and in November of 1935 they comprised twenty percent, sixteen percent, and twenty percent, respectively, of the total stomach contents.

THE FEEDING CYCLE

The number of stomachs containing food and the number of empty ones was determined for each sample, and the results are briefly shown in Figure 1. Some very interesting facts are yielded by a study of this figure and have already been discussed (Vladkov and Komans, 1935). It is seen that the number of fish taking food diminished considerably from September to March. Thus in September eighty percent of the fish examined had food in their stomachs, whereas in March only sixteen percent of those studied had eaten any food. In April and May a very slight increase in the number of fish taking food was indicated. However, in June there was a sudden increase in the number of feeding fish when approximately seventy-two percent of the stomachs examined con-

tained food. A pronounced decrease occurred in July when only about fifty-two percent of the haddock were found to be taking food. This apparent discrepancy coincides with very high water temperatures in the vicinity of Sable Island (where these fish were captured). No doubt the extremely warm water was mainly responsible for the decrease. Thereafter the number of feeding fish increased and amounted to seventy percent in August.

The period under consideration may be divided into four parts. A Fall feeding season, September and October, which is identified with a relatively high number of feeding fish varying from seventy to eighty percent. This is followed by a winter season, November to January, when a large number of haddock (from fifty to sixty-five percent) cease to take food. During the spring months, from February to May, only a very small percentage (10-24 percent) of fish continue to eat. During this period, which may be called the spawning season, haddock belonging to Quereau and Sable Island schools (Vladykov, 1935) are spawning. The greatest number of these haddock usually spawn from the end of March to the middle of April. It must be noted that this period does not necessarily apply to other haddock schools. The remaining part of the year, June to August, can be called the summer feeding season or recovery period during which time the spent haddock feed greedily in order to regain strength lost by the act of spawning.

The changes in the life cycle of the haddock affect the feeding habits of this fish. Therefore, the difference in the number of feeding fish at different periods of the year must be mainly attributed to the causes given above and not to changes in the water temperatures on the banks, which, varying in limits from 3°C. to 8°C. from October to June, are quite favourable for haddock feeding.

Due to the fact that among the fish examined there was a mixture of large spawning haddock with small immature fish, the figures for the percentage of haddock taking food during the spawning season are probably somewhat high, as the immature fish continue to eat.

It is a well-known fact that haddock catches by hook and line during the spring months of the year are almost negligible. This can be explained by the fact that the majority of haddock are in the process of spawning at this time and as a result refuse to take food.

Beginning with September, 1935, the determination of the percentage of feeding fish was undertaken for a second consecutive year, as a check on the period, September, 1934, to August, 1935, just discussed. This information has been prepared to the end of May, 1936. The results are summarized in Figure 1. Unfortunately a shift in the fishing made it impossible to complete observations for a second year.

It is seen that the haddock continued feeding almost at the maximum for a full month longer than they did for the year previous. This high feeding percentage in November was correlated with slightly higher water temperatures for the fall of 1935. After November, 1935, the percentage of feeding fish dropped rapidly and in January and February, 1936, the percentage of feeding fish has fallen to a level slightly below what it was for the same months of 1935.

Thus the curve is repeating practically the same story for a second consecutive year.

Hence the difference in the number of feeding at different seasons of the year can only be attributed to the changes in the ripening cycle of the haddock as shown above. The temperature conditions are favourable for feeding and there is no positive evidence that animals which constitute the haddock diet are less abundant

during the winter and spring months than during the summer and fall.

Vladykov (MS, 1936) determined that haddock cease to take food when they have reached stage four of maturity. His observations show that when haddock approach to maturity these fish cease to take food and therefore cannot be caught by means of baited hooks, therefore haddock catches made in this manner are not possible since successful application of this method depends entirely upon the feeding stimuli of the fish. In this connection the following investigation may be interesting. The sexual stages of one hundred and thirty-four haddock were checked with the number of stomachs containing food. Of the one hundred and thirty-four fish examined one hundred and nineteen or 88.9 percent were in what is known as the near-spawning state, i. e. in the range from stage three to four. Out of the one hundred and thirty-four stomachs examined one hundred and twenty-seven or 95.3 percent were entirely empty. By this basis of comparison it may be said that sexually ripening haddock cease to eat before spawning is begun.

Bigelow and Welsh (1924, p. 436) made an observation on fish breeding at Cape Ann in April, 1924 to the effect that "The haddock fast even more rigorously than cod at spawning time because more than ninety-five percent of the hundreds of fish caught in gill nets were totally empty, and because line trawls set nearby were bringing in very few haddock but were taking hake in fair numbers. In fact it was not until the introduction of the gill net and other-trawl fisheries that any considerable toll was taken of the haddock while spawning."

An additional observation of the same nature is worth recording. Among four hundred and forty-nine spawning haddock taken in mackerel traps during the latter part of May, 1935, at French

Village, St. Margaret Bay, only four fish had food in their stomachs.

Therefore, it can be stated definitely that mature haddock cease to feed during the spawning period. Only when spawning is completed do haddock begin to take food again.

Food variation among fish of different sizes.

With the exception of a few (179) very young haddock (procured through the kindness of Mr. W. C. Herrington of the United States Bureau of Fisheries) ranging in length from one hundred and forty to three hundred millimetres, no samples of the early bottom stages have been available. These fish were captured on Georges bank. As for the pelagic stage not even a single sample has been procurable.

The examination of the stomachs from these young haddock revealed that they had been feeding exclusively upon a single species of molluscan nudibranch (aeolis sp. ?).

Several hundred stomachs from haddock (250-500 mm. in length) caught on hook and line in Halifax Harbour during 1932, examined by Dr. V. D. Vladykov (1932, p. 42) contained primarily pelecypods (cardium etc.). Polychaete worms were next in importance. Crustaceans (amphipods and shizopods) were of little importance. Very few fish were found in the stomachs; and echinoderms (brittle stars and sea urchins) were almost entirely absent. At the same time adult haddock caught in the Halifax Harbour area were found to be feeding mainly on echinoderms (brittle-stars and sea urchins), and among small amounts of other kinds of food, some herring eggs.

The present author examined a number (289) of stomachs taken from young haddock (225-420 mm. in length) captured by hook and line in Bedford Basin during the summer of 1932 and found them to contain

mostly pelecypods (cardium) (see Table VI) and considerable amounts of mud (the bottom of Bedford Basin is of muddy nature). Polychaete worms were the next food of any importance. Echinoderms, holothurians, were eaten to a limited extent and crustaceans, amphipods, formed a negligible part of the food composition; Fish were entirely absent. This analysis agrees with Vladykov's findings. However, an examination of the stomachs from one hundred and thirty-nine haddock caught near Eastern Passage (230-380 mm. in length) during 1932, showed them to be feeding considerably (see Table VI) on echinoderms, (brittle stars and sea-urchins). Bivalve mollusks (cardium) were of definite importance in the dietary, but less so than echinoderms. Crustaceans and fish were completely absent from the food composition. In the vicinity of Eastern Passage the bottom is broken ground.

Large adult haddock taken off the harbour mouth were found to be feeding on echinoderms (brittle stars). No other groups were present. (see Table VI).

The above data indicates the possibility of a variation in the diet according to age and size. However, further investigation is needed to settle this point satisfactorily.

Comparison between weight and sizes of the food organisms

A series of graphs designed to show the relation between the percentage weights (calculated from the total food weights) and the percentage occurrences (calculated by taking the total number of occurrences, all groups together, and deriving the percentage occurrences for each group from the total) of major food groups has been drawn up. These graphs comprise Figure 2. Unfortunately figures on the percentage occurrence of the food organisms are available only from July, 1935, to February, 1936.

It is noticed that on the whole there is a relationship between the two factors. In the case of fish this relationship is very striking. A high or low percentage weight of this species is correlated very distinctly with a similar condition in the percentage occurrence curve. The percentage weights for fish rank higher than the figures for the percentage occurrence due to the relatively great weight of this species, whereas the organisms comprising the remaining groups have as a rule a weight which is much less in proportion to their numbers.

The worms, while not showing as striking a similarity as the fish, have a general conformity on the whole. The remaining three groups, echinoderms, crustaceans, and mollusks, show a lesser degree of conformity which may be explained by the fact that many types of organisms are included under a systematic group, such as either of the above, and consequently the variation in size, weight, etc. is large.

FACTORS INFLUENCING FEEDING:

The haddock, as is the case with all living forms, lives in a finely adjusted state of balance with its surroundings. The slightest change in this state of balance may produce far-reaching results. In this way it is to be expected that a variation in certain factors of the haddock's habitat will have an effect upon the feeding of this fish. These factors may be conveniently divided in two groups, (a) physical and (b) biological.

(a) Physical factors

One of the most important physical factors is that of temperature. Several authors (Mathaway, 1927. Bull, 1928, 1930 Thompson, 1926, McEnzie 1935) have shown that feeding is directly

influenced by temperature changes. Sudden rises and falls in temperature tend to bring about a decrease in food consumption. It is known that the haddock will not feed in water temperatures above and below certain limits (Vladykov, 1933). Therefore, it is probable that haddock will not remain in areas where the water temperature is excessively cold, or warm, and it is known that haddock prefer certain temperatures for spawning purposes (Vladykov, 1935). Therefore, it is quite possible that haddock will migrate from a feeding ground on which the water temperature has become unsuitable to one which has a suitable temperature.

The nature of the bottom obviously exerts a certain amount of influence on the feeding habits of the haddock. The organisms eaten by the haddock include groups widely diversified in habits and habitats. The type of bottom preferred by one group, may possibly be detrimental to the successful existence of another group. Therefore the characteristic type of animals on a certain bottom will in turn probably be characteristic of the food eaten by haddock feeding on those grounds. For example, the sand-lance has the habit of burrowing itself in the sand, and so presumably the distribution of this species, (chief food of the haddock on Western banks), depends upon its location of areas with a sandy bottom, consequently if the haddock is to make the sand-lance a regular part of its diet it must frequent an area where there is sandy bottom. With respect to the type of bottom preferred by the haddock, Bigelow and Welsh (1924, p. 435) write: "Haddock are less catholic than cod in their choice of the type of bottom being hardly ever caught over ledges, rocks, kelp, etc., on the one hand where the cod are so plentiful, or on the other, on the soft oozy mud to which hake resort, but chiefly on broken ground, gravel, pebbles, clay, smooth hard sand. etc."

sand of gritty consistency, or where there are broken shells. They are especially partial to the smooth spots between rocky patches."

Another factor in considering the results of stomach analysis is the limitations of trawling. Trawlers are able to operate only on a fairly smooth bottom. They cannot successfully trawl on a rocky bottom since severe damage to the gear usually results. All samples of stomachs examined from the Western banks were brought in by trawlers. Therefore, the food composition of haddock for this region has been determined on the examination of stomachs taken from haddock mainly caught on smooth bottom and will be characterized by animals living on such types of bottom. If haddock gather in quantities on rough bottom it may be that their average food composition is somewhat different than that determined for haddock caught on smooth bottom. However, according to Bigelow and Welsh (1924, p. 435; quotation above) haddock normally are not found over rough bottom in quantities so that the food composition determined is probably the normal one for this region.

Depth of water also exerts an influence on haddock feeding, although probably not to any great extent in the normal course of events. Haddock will not enter as shallow water as the cod. Bigelow and Welsh (1924, p.435) state that, "Probably the lower limit of depth is about the same for the haddock as for the cod in the Gulf of Maine few being caught much below one hundred fathoms, but on the average haddock live deeper than cod, few being caught in less than five to ten fathoms and most of them in twenty-five to sixty fathoms.

Haddock, large or small, so seldom come into the very shoal waters along rocky shores and over ledges where young cod are plentiful that the found nets of Massachusetts reported only about five thousand pounds of haddock in 1919 as compared with almost three million pounds of cod."

Thus the haddock would not be expected to feed extensively on the animals inhabiting the littoral zone and in fact does not do so.

(b) Biological factors.

The habits of the haddock--as of all fishes--are inextricably bound up with structures and structure with habit. Structure is a very important factor, influencing to a marked extent the type of organism upon which a fish will normally feed. The prey which a fish can catch depends in a large degree upon its foraging methods. These vary greatly in different fishes and there is always a resultant difference in the type of animals which form their staple food.

The haddock is apparently not the most active of swimming forms and as a result we do not find a large proportion of animals which might require considerable chasing before they are caught, such as fishes, squids, etc., making up the dietary of the haddock. True, on the Western banks, a fish--the sand-launce--forms the most important part of its food composition, but this fish has the habit of burrowing into the sandy bottom and is probably captured by the haddock under such circumstances.

The haddock has its upper jaw protruding out beyond the lower one and the lips are somewhat prehensile, forming an organ which is ideally adapted for feeding off the bottom itself. In addition the heaviest built portion of the haddock is the anterior part of the body and it may be that this helps it to remain more easily in a forwardly tilted position while feeding. It is then not surprising to find the haddock subsisting to a great extent upon those animals whose natural habitat is near the bottom, on the bottom, or buried in the bottom. The majority of these animals are somewhat slow-moving but it must be borne in mind that some animals which

TABLE X

List of the identified species taken from the stomachs of haddock

Brachiopod: identified by the author.

Terebratulina septentrionalis Couthuoy.

Crustaceans: identified by members of the United States National
Museum.

Cumacean: * Diaetylia bispinosus Stimpson.

Amphipods: Mr. Clarence R. Shoemaker.

Aegina longicornis Kroyer.

Anonyx nugax Fhippe

Rhachotropis oculata Hansen

Syrrhoe crenulata Goes

Unciola irrorata Say

Hyproche medusarum Kroyer

Leptocheirus pinguis Stimpson

Monoculodes edwardsi Holmes

Themisto compressa Goes forma compressa Goes

Tmetonyx nobilis Stimpson

Hyperia galba Montagu

Melita dentata Kröyer

Pleustes panoplus Kröyer

Maera loveni Bruzelius

Neohela monstrosa Boeck

Hyperia (prob. H. medusarum Müller)

Stenopleustes (prob. S. galba Boeck)

* Identified by the author.

TABLE X

- Crabs: identified by Dr. Mary J. Rathburn
Planca minutus Linnaeus.
Hyas coarctatus Leach
Cancer irroratus Say
- Isopod: identified by Mr. J. O. Maloney
Asca psora Linnaeus.
- Other Crustaceans: identified by Dr. Waldo L. Schmitt
Megalops (sp.?)
Pagurus Krøyeri Stimpson
Pagurus acadianus Benedict
Pandalus noronhai G. O. Sars.
Pandalus montagu Leach
Dichelerandalus leptocerus Smith
Spirontocaris polaris Sabine
Spirontocaris spina Sowerby
Spirontocaris musiola Krøyer
Crago septemspinosa Say
Sclerocrangon boreas Phipps
Meganyctiphanes norvegica M. Sars
Thysanoessa (sp.?) inermis Krøyer?
Erythrope erythrophthalmus Goëse
- Molluscans: identified by the author
- Amphineura: Tonicella marmorea Fabricius.
Trachydermon albus Linnaeus
- Gastropods: Nassa trivittata Say
Nassa obsolata Say
Bulla solitaria Say
Polynices heros

TABLE X

Fucus ventricosus Gray
Margarita obscura Gould
Scala groenlandica Chemn.
Bela cancellata Stimpson
Cyclichna alba Stimpson
Tuttitela erosa Couthuoy
Lamellaria perapicua Stimpson
Crucibulum stiratum Stimpson
Margarita cinerea Gould
Eupleura caudata Verrill
Fasciolaria ligata Mighels
Bela turricula Stimpson
Buccinum undatum Linnaeus
Sipho pygmaeus
Aeolis (sp.?)
Pelecypods: Leda tenuisulcata Couthuoy
Nucula tenuis Mighels
Astarte elliptica Brown
Cardium pinnatulum Conrad
Leda minuta Müller
Glycimerus siligua
Yoldia myalis
Modiola plicatula Lamarck
Siliqua costata Say
Solecurtis gibbus Blainville
Macoma fusca Gould
Cardita borealis Conrad
Macoma calcarea Gmelin

- Pelecypods: Saxicava rugosa Linnaeus
 Cephalopods: Illex illecebrosus
 Echinoderms: Identified by Mr. Austin H. Clark of the Smithsonian Institution.
 Asteroidea: Ctenodiscus crispatus Retzius
 * Asterias vulgaris Verrill
 Ophiuroidea: Ophiopholis aculeata Linnaeus
 Ophiura saraii Lütken
 Ophiura robusta Ayres
 Stegophiura nodosa
 Echinoidea: Strongylocentrotus drobachiensis O. F. Muller
 * Echinarachnius parvus Lesark
 Holothuroidea: Cucumaria calcigera Blainville
 Thyone briareus Leseur
 Thyone unisemita
 Ebalus phantapus Struelsenfeldt
 Molradia politica
 Tunicates: Identified by Willard G. Van Name of the American Museum of Natural History
 Ascidiacea: Boltentia ovifera Linnaeus
 Bostrichelbrachus pilularis Verrill
 Felonina corrugata Goodair and Forbes
 Thaliacea: Salpan(iasia) zozaria Pallas
 Pisces: identified by the author.
 Amodytes americanus DeKay
 Sebastes marinus Linnaeus
 Hippoglossoides platessoides Fabricius
 Triglone pinxelli Fabricius
 Merluccius bilineatus Mitchill
 Argentina silus Ascanius * identified by the author
 Menidia notata Linnaeus
 Clupea harengus Mitchill

are commonly found in haddock stomachs are very fast-moving forms, for example, the shrimps. That the haddock does, however, root around in the sea-bottom much like a pig in a pig-sty is shown by the occurrence of considerable amounts of mud, sand, and gravel, etc. found in its stomach quite frequently.

Although the haddock feeds on a tremendous variety of organisms only the smaller specimens are eaten, as a rule. With reference to the large number of specimens eaten, Richie (1932, p. 17) states that one hundred and eighty-eight recognized species have been enumerated as occurring in haddock stomachs and Clapp (1912) found haddock from Georges bank feeding on no less than sixty-eight species of mollusks (bivalves and gastropods), while Needler (MS. 1928) identified fifty-three species of mollusks in the stomachs of haddock caught in the coastal waters of the Maritime Provinces.

In Table X there is given a list of the identified specimens collected from the present investigation. Unfortunately the list is not complete as a considerable collection of marine worms sent away for identification have not yet been reported upon. The echinoderms, crustaceans, and tunicates have been identified by several authorities in the United States; the mollusks and fishes have been identified by the author.

With respect to the size of the specimens eaten, sand-lance up to two hundred and fifty millimetres in length have been found. On one occasion a total of forty-three specimens of this species, ranging in length from twenty-five to one hundred millimetres, and weighing about one hundred and seventy-two grams were found in a single stomach. A herring (p. 14) with a length of two hundred millimetres was found on one occasion. On the whole no worms longer than two hundred millimetres were found. The majority were very much less in length.

Echinoderms with a diameter greater than twenty-five millimetres were unusual. A few holothuroideans with a length of thirty-five millimetres were encountered. Crustaceans were on the average much less than fifty millimetres in length; and the largest mollusks found were a bank clam (Glycymeris siliqua) measuring fifty-six millimetres in length, and a small squid (Illex illecebrosus) about seventy-five millimetres long (without tentacles). This specimen was the only cephalopod found in the total number of stomachs examined. The members of this group are probably too agile to render them easy prey. A pebble measuring about thirty-five by twenty-five millimetres and weighing twenty-nine grams was found in a stomach taken from a fish caught near Digby.

The amount of food present in the stomachs varies at times. In figure three is given the figures in grams for monthly averages (calculated by dividing the total number of stomachs containing food into the total food weight found to be present). A study of the graph shows that the average food weight per stomach falls from approximately ten grams in September to a value of two grams in February; from March onward a gradual rise is seen culminating in a maximum of twenty-eight grams in July. Except for the July figure the average amount of food consumed by haddock is not great, probably not more than a maintenance ration. Since the haddock spawns from January to June, with a maximum during February and April, the small amounts of food consumed during February and March might conceivably be an indication of a fast at spawning time; if this be true the sudden burst of feeding activity in July could be explained by saying that the haddock were gorging themselves following the spawning act. However, there is no means of knowing that the fish examined in February and April were of the same school as those examined in July.

A scarcity of food organisms at any particular locality will, in all probability, cause haddock to migrate to other areas in search of better feeding conditions. As a corollary of food scarcity it may be mentioned that at such times the haddock apparently eats a greater variety of organisms than when food is abundant. When there is an abundance of food the haddock will usually confine its feeding to one or two species.

Comparison between haddock food in American and European Waters.

Table XII shows a comparison of the food eaten by haddock on the two sides of the North Atlantic Ocean. The table is unavoidably made up of results computed by three different methods. Most of the European workers expressed their results in percentages calculated from the relative occurrences of particular groups, whereas the results of the present study have been in percentages calculated from the relative weights of particular groups in proportion to the total weight of the stomach contents. Some workers did not express their results mathematically and in such cases descriptive words have been used.

However, in spite of the different methods used it is seen that in broad outlines the food of the haddock is similar on both sides of the Atlantic.

A glance at the table shows that on Spitzbergen bank (correctly speaking Spitzbergen bank and the Barents Sea are part of the Southern Arctic Ocean, but for the purposes of this report the distinction is not necessary) the food of the haddock is mainly composed of echinoderms, mollusks, and crustaceans, in the order given. In the Barents Sea Idelson (1929) found a distinct difference between the food of inshore and offshore haddock, fish and mollusk constituting a much larger proportion of the food of inshore haddock than offshore haddock. With respect to the occurrence of fish in

TABLE XI

A comparison of the chief food groups eaten by haddock
in European and North American Waters

Locality	Description	Fish	Worms	Schin- oderms	Crust- aceans	Mollusks	Misc.	Authority
Spitzbergen Bank	offshore	rare	occasional	abundant	common	abundant	-	Idelson, 1929
Barents Sea	"	30	44	47	38	38	-	" "
Barents Sea	Inshore	61	46	54	30	69	-	" "
Belt Sea	"	2	22	33	20	36	-	Fouleson, 1926
North Sea	Offshore	5	49	44	36	64	-	Todd, 1907
N. Sea (Firth of Forth)	Inshore	3-4	20-26	24-46	56-60	23-45	-	Smith, 1892
N. Sea N.E. Scottish coast	"	rare	occasional	abundant	common	common	-	Brook, 1896
Iceland (N.W. coast)	"	"	common	"	"	occasional	-	Mitchie, 1926
Iceland (South)	"	abundant	rare	rare	occasional	rare	-	" "
Faroø Bank	Offshore	"	occasional	occasional	common	"	-	" "
Grand Bank	"	3.3	24.6	-	59.5	16.4	-	Romans
St. Pierre Bank	"	-	-	100.0	-	-	-	"
Western Bank	"	94.1	11.7	6.3	6.5	4.2	12.2	"
Gulf St. Lawrence	Inshore	-	12.6	47.6	7.3	12.9	16.4	"
Oster Coast N. S.	"	4.4	2.7	57.6	3.6	23.8	7.9	"
Bay of Fundy	"	6.8	1.0	11.6	16.6	60.9	14.9	"

TABLE XI

-2-

Locality	Description	Fish	Worms	Lehio- derms	Crust- aceans	Mollusks	Misc.	Authority
Gulf of Maine	Inshore	0.8		common	common	abundant	-	Rigglew & Welsh, 1924.
Georges Bank	Offshore	occasional	common			*		Clapp, 1913.

the diet of inshore and offshore haddock, the exact opposite was found on the Western side of the Atlantic.

In the Belt Sea mollusks and echinoderms are the main food groups, worms and crustaceans are eaten in small quantities; fish form a negligible portion of the diet.

Todd (1905 and 1907) found that the offshore haddock in the North Sea were feeding mostly on mollusks, worms and echinoderms, and crustaceans in the order named. Fish were of no importance in the dietary.

Inshore North Sea haddock were found by Smith (1892) to be feeding mainly on crustaceans, mollusks, and echinoderms. Worms were eaten to a lesser extent and fish were comparatively unimportant. Smith reaches the conclusion, "The haddock would appear to be the most indiscriminate feeder of all fish. It would appear to eat anything that came its way and show no particular preference."

Brook (1886) for the same area concluded from his examinations that echinoderms were the chief food eaten, followed by mollusks and crustaceans. Worms were eaten sparingly and fish very rarely. Brook observed that the starfishes were very seldom eaten by the haddock. The present writer has also noticed the same peculiarity. Among the thousands of stomachs examined, starfishes were found in less than one dozen instances. Aside from the fact that the commoner starfishes are mainly littoral in their habit, there must be some other objection on the part of the haddock to the use of these animals as food, possibly chemical in its nature, since they are known to occur plentifully in regions frequented by the haddock.

Brook also noticed that haddock caught in the vicinity of the island of May in the spring of the year often had their stomachs filled with herring spawn. Bowman (1923) observed the same fact and states that every year at this time large schools of haddock,

concentrate on the herring spawning grounds for the express purpose of gorging on this seasonal delicacy. A number of haddock with herring eggs in their stomachs were taken in Halifax Harbour in 1932 (see p.14) and in 1936 many haddock caught on St. Pierre bank had their stomachs crammed with herring eggs.

While studying the food of haddock around the coast of Iceland, Richie (1928) found that on the North and Northwest Coasts echinoderms, worms, and crustaceans comprised the chief portions of the food, in the order given, whereas on the south coast the haddock were feeding almost exclusively upon a fish, the sand-eel, Ammodytes tobianus. Richie(1928) found the haddock on Faro bank to be feeding chiefly on the sand-eel, and on crustaceans to a much lesser degree. Other groups were unimportant. Richie (1932) states that although fish do not form a regular diet of the haddock they form an important part of it at certain times. The analysis of a single sample of stomachs from the Grand banks (whole deep) of Newfoundland indicates that crustaceans and worms comprise the greatest part of the haddock's diet in this region. Haddock on St. Pierre bank apparently feed on brittle stars. The chief food of haddock taken on Western banks is the sand-lance, as already stated, while on Georges bank Clapp (1912) found the haddock to be feeding mainly on worms and mollusks. The outer coast of Nova Scotia and the Gulf of St. Lawrence are characterized by the large amounts of echinoderms (mostly brittle-stars) eaten by the haddock in these areas. Haddock caught in the Bay of Fundy feed mainly on mollusks (mostly pelecynods). Bigelow and Welsh (1924) state that haddock in the Gulf feed mainly on mollusks, crustaceans and echinoderms.

It is a pleasure to acknowledge my indebtedness to Dr. A. H. Leim, under whose direction the work was carried out, and to Dr. V. D. Vladykov, for his friendly interest and cooperation.

SUMMARY

The examination of the stomach contents from over fourteen thousand haddock has yielded the following information relative to the food and feeding habits of this important commercial fish.

Samples have been collected from inshore areas over the period, 1932 to 1937 (January) and from the offshore banks during the period, 1934 to 1936.

A detailed description of the method of analysis is given.

Analysis of more than ten thousand stomachs taken from haddock captured on the offshore banks show that in this region the haddock's diet is composed primarily (54%) of the sand-lance, Ammodytes americanus DeKay. Worms (11%), echinoderms (8%), crustaceans (8%), mollusks (4%), and others including sand (12%) make up the remainder. The diet of inshore haddock based on the examination of over three thousand stomachs taken from haddock caught in various localities along the coast of the Maritime Provinces is mainly composed of brittlestars (45%) and mollusks (30%), chiefly Yoldia myalis. Crustaceans (4%), worms (3.5%), and others including mud and sand (10%) constitutes the remainder.

Consistent local differences appear within each of the two above areas, forming distinct sub-areas.

It appears that young haddock feed on a somewhat different diet than do the adult fish. However, this deduction is of a preliminary nature since the amount of material examined was quite small.

Examination on monthly collections of stomachs from one locality showed that the haddock may change its diet from time to time.

A correlation between the feeding activity of the haddock and its spawning period was discovered. The evidence showed that the haddock undergoes a fast immediately before and during spawning. This observation was made on trawler-caught fish.

Ninety-eight species of organisms were identified from collections made of the material eaten by the haddock. Some twenty-five species of marine worms are as yet unidentified.

A comparison is made between the food eaten by haddock on the European and North American side of the Atlantic Ocean.

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