Bulletin of the Fisheries Research Board of Canada

The Capelin *(Mallotus villosus)*

Biology, Distribution, Exploitation, Utilization, and Composition

P. M. Jangaard

BULLETIN 186
Ottawa 1974

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THE CAPELIN (*MALLOTUS VILLOSUS*)

BIOLOGY, DISTRIBUTION, EXPLOITATION, UTILIZATION, AND COMPOSITION

Bulletins are designed to assess and interpret current knowledge in scientific fields pertinent to Canadian fisheries and aquatic environments. Recent numbers in this series are listed at the back of this Bulletin.

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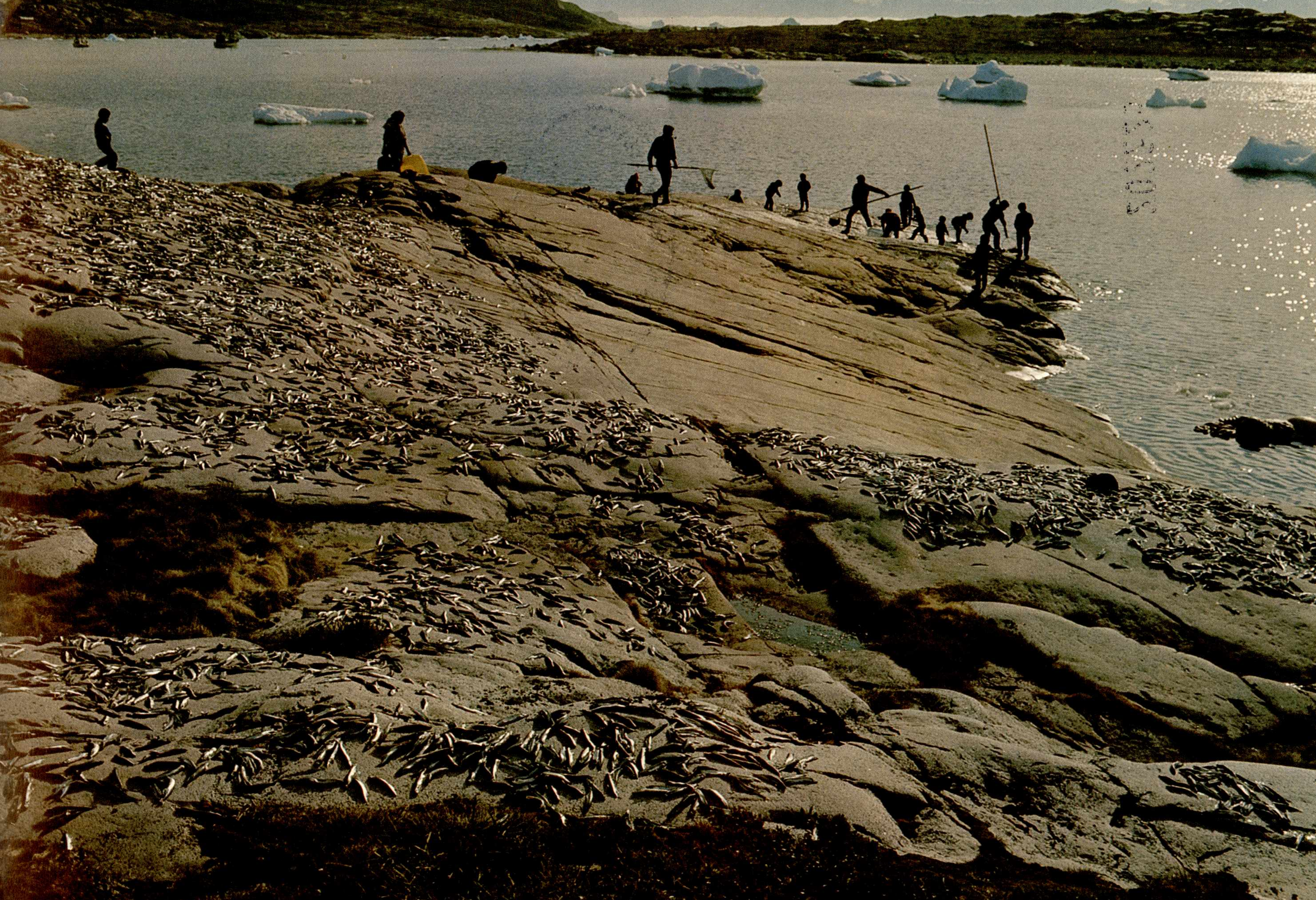

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Exploitation, Utilization, and Composition

P. M. Jangaard

Department of the Environment
Fisheries and Marine Service
Atlantic Regional Office (Research)
Halifax, N.S.

DEPARTMENT OF THE ENVIRONMENT
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Ottawa 1974

Frontispiece: "Capelin time" at Sarqaq, Greenland

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CONTENTS

x ABSTRACT

x RESUME

1 INTRODUCTION

1 LIFE HISTORY

Systematic Position

Common Names

Description

Distinctive Features
Meristic characteristics

Distribution

Reproduction
Spawning
Spawning survival
Hatching

Growth, Food, and Feeding
Age, size, and growth
Food and feeding

Parasites

Predation

12 OCCURRENCE, MIGRATION, ABUNDANCE, AND CATCHES

Eastern Canada
Bay of Fundy and Nova Scotia
The Gulf of St. Lawrence
Grand Bank and St. Pierre Bank
Northern Grand Bank, Newfoundland, and Labrador
The Eastern Arctic

Greenland

Iceland

Barents Sea, Norway, and USSR

Pacific Ocean

CONTENTS (*Continued*)

20 THE FISHERY

VESSELS AND GEAR
Traditional and shore-based gear
Purse seines and seine vessels
Trawls and trawlers
Electronic gear

HANDLING THE CATCH
For human consumption or bait
For reduction to meal and oil

Preservatives
Unloading

30 PROCESSING AND UTILIZATION

FOR HUMAN CONSUMPTION
Fresh and frozen. Traditional use
Fresh and frozen. Current use and future prospects
Cookery
Canned (heat sterilized)
Semi-preserved canned products
Salted, dried, and smoked
Fish protein concentrates

ANIMAL FEED AND BAIT

UTILIZATION AND PROCESSING FOR FISH MEAL AND OIL

Conventional reduction equipment
Basic studies
The low temperature process

OTHER USES

BACTERIAL SPOILAGE

CONTENTS (Concluded)

49 CHEMICAL AND NUTRITIONAL COMPOSITION

FRESH CAPELIN

Seasonal variation

Other analyses

CAPELIN PRODUCTS

Meal and protein concentrate (FPC)

Oils and total lipids

Physical and chemical constants

Fatty acid composition

Other studies

60 SUMMARY AND CONCLUSIONS

60 ACKNOWLEDGMENTS

60 REFERENCES

68 CREDITS FOR ILLUSTRATIONS

69 APPENDIX

Abstract

JANGAARD, P. M. 1974 The capelin (*Mallotus villosus*): biology, distribution, exploitation, utilization, and composition. Bull. Fish. Res. Board Can. 186: 70 p.

The rapidly increasing interest in the use of capelin for human consumption has led to the production of this bulletin. The following topics are examined: life history, including systematic position, common names, general description, distinctive features, meristic characteristics, growth, and feeding; occurrence; fishery procedures, handling, unloading, and use of preservatives; utilization, processing, and equipment; and chemical and nutritional composition of whole capelin, capelin meal, and oil.

The capelin, *Mallotus villosus,* a small, pelagic fish belonging to the family Osmeridae, occurs in large quantities in the cold waters of the northern hemisphere. Distribution is circumpolar with large stocks found in the Barents Sea, around Iceland and Greenland, and in Canadian waters from Nova Scotia to Labrador. Small stocks occur on both sides of the North Pacific.

Spawning occurs in March–April in northern Norway and Iceland, and in June–July in Newfoundland and Labrador. It takes place on beaches in some areas, but also in deeper waters. Spawning stock consists almost exclusively of 3- and 4-year-old fish. Most capelin die after spawning.

The fishery is carried out chiefly with purse seines or midwater trawls; small quantities are taken inshore in traps, seines, etc. Barents Sea stocks are heavily exploited, but there are large underutilized stocks in the northwest Atlantic.

Formerly, small quantities of capelin were used for food in fresh, salted, and dried forms. At present, most capelin catches are used for production of meal and oil. However, various frozen and canned products have recently been developed and test-marketed, Japan being the leading importer and consumer.

The fat and water contents of capelin fluctuate seasonally; the fat content can be as low as 1–2% following spawning, but goes above 20% in the fall. As capelin and capelin products are nutritionally of high quality, the use of capelin for human consumption will no doubt show a rapid increase over the next few years.

Résumé

JANGAARD, P. M. 1974. The capelin (*Mallotus villosus*): biology, distribution, exploitation, utilization, and composition. Bull. Fish. Res. Board Can. 186: 70 p.

L'intérêt sans cesse grandissant que l'on porte au capelan comme source de nourriture humaine est à l'origine de ce Bulletin. On y examine les points suivants: cycle biologique, y compris position systématique, noms vulgaires, diagnose générale, caractères distinctifs, y compris caractères numériques, croissance et alimentation; répartition; méthodes de capture, de manipulation, de déchargement, et usage de préservatifs; utilisation, transformation et équipement; composition chimique et valeur nutritive du capelan entier, de la farine et de l'huile de capelan.

Le capelan, *Mallotus villosus,* un petit poisson pélagique de la famille des Osmeridae, se trouve en grande abondance dans les eaux froides de l'hémisphère nord. Sa distribution est circumpolaire, et il existe des stocks considérables dans la mer de Barentz, autour de l'Islande et du Groenland et dans les eaux canadiennes, depuis la Nouvelle-Écosse jusqu'au Labrador. De petits stocks se trouvent sur les deux côtés du Pacifique Nord.

La fraie a lieu en mars–avril en Norvège septentrionale et en Islande, et en juin–juillet à Terre-Neuve et au Labrador. En certains endroits la fraie se produit sur les plages, mais également en eau plus profonde. Le stock reproducteur est constitué presque exclusivement de poissons âgés de trois et quatre ans. La plupart meurent après la fraie.

On le pêche surtout à la senne à coulisse et au chalut pélagique; on en capture de petites quantités près du rivage, à l'aide de trappes, sennes, etc. Les stocks de la mer de Barentz sont l'objet d'une exploitation intensive, mais il y a plusieurs stocks en Atlantique Nord-Ouest qui sont sous-utilisés.

Dans le passé, de petites quantités de capelan étaient utilisées comme nourriture, à l'état frais, salé et fumé. Maintenant, la plus grande partie des prises est transformée en farine et en huile. Cependant, on a récemment développé, après essais de commercialisation, divers produits congelés et en conserve hermétique, le Japon étant le principal importateur et consommateur.

La teneur en gras et en eau du capelan varie suivant la saison; la teneur en gras peut être aussi basse que 1–2% après la fraie, mais elle atteint 20% en automne. Comme le capelan et ses produits ont une haute valeur nutritive, leur usage dans l'alimentation humaine prendra sans doute rapidement de l'importance au cours des quelques années à venir.

Introduction

Although capelin have been well-known to inhabitants of countries bordering on arctic and subarctic seas since ancient times, the species is largely unknown outside these areas. Due to the current high demand for fish and the resource constrants on traditional food fish species, this situation appears to be changing.

Over the past decade capelin have been heavily exploited by Norwegian and Icelandic fishermen for reduction purposes, with Norwegian landings from the Barents Sea surpassing 1.6 million tons in 1972 (Fig. 1). The Newfoundland–Labrador capelin stocks are also considered to be large, and exploitation with modern purse seiners and midwater trawlers has recently begun off the east coast of Canada.

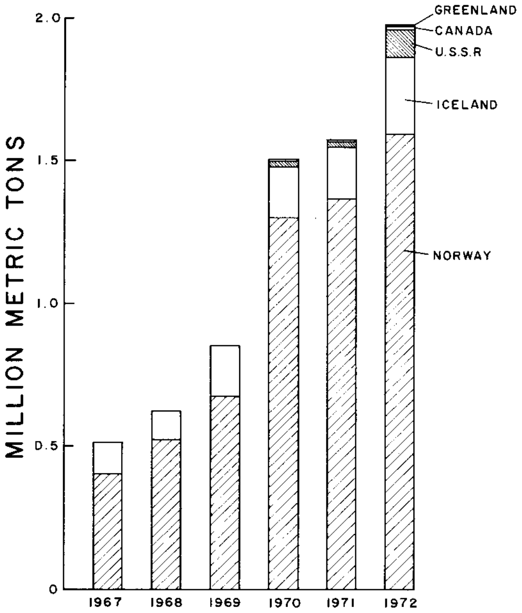


FIG. 1. Recent world catch of capelin.

Research on the biology of capelin has been carried out intermittently for several decades in Newfoundland. Norwegian, Soviet, and Icelandic scientists are also closely studying the stocks in their respective areas as the fishery develops. Hopefully, enough effort can be put into this research to avoid excessive exploitation and the subsequent rapid declines in catches which have occurred in the fishery of some other species.

Technological research and development on capelin has received much less attention, but over the past 5 years a number of studies have been carried out on the composition and utilization of capelin. Fresh capelin is a tasty fish and modern processing, canning, freezing, and marketing technology should make it possible to introduce it to dinner tables across North America and Europe. Lightly salted and dried capelin, especially females with roe, are already known in Japan where the fish are barbecued and eaten as a snack.

Studies on the economics of capelin utilization have been published (Mitchell 1973; Hansen 1971). This bulletin is intended to summarize the current knowledge of the biology, occurrence, exploitation, utilization, and composition of capelin, so that further research can be directed to areas where there are obvious gaps in our knowledge.

Life History

Systematic Position

The capelin, *Mallotus villosus* (Müller), is classified in the suborder Salmonoidea or salmon-like fishes, and with the smelts comprises the family Osmeridae. The suborder Salmonoidea comprises a large number of marine and freshwater species. Canadian Atlantic salmonids are classified in four families: Salmonidae (salmon, trout, whitefishes), Osmeridae (smelts, capelin), Argentinidae (argentines), and Bathylagidae (blacksmelts) which are found primarily in deep water (Leim and Scott 1966).

The Pacific capelin and the Atlantic capelin were at first considered to be two separate species, respectively *Mallotus catervarius* and *Mallotus villosus*. However, further examination showed arctic capelin to be intermediate in meristic and morphometric composition between Atlantic and Pacific capelin. Consequently, *Mallotus villosus* is now regarded as a monotypic species with the Atlantic and Pacific forms being consubspecific (McAllister 1963; Winters 1969).

Jeffers (1931) stated that the genus *Mallotus* was probably established by Cuvier about the year 1829, as it appeared in the second edition of his famous book, "Le Règne Animal, distribué d'après son Organisation", published that year. It is not mentioned in the "Systema Naturae" of Linnaeus, nor in the "Bibliotheca Ichthyologica" of Artedi, published in 1738.

The specific name *villosus* (Latin=hairy) was first noted in the preface of O. F. Müller's "Zoologiae Danica" (1776) under the name *Clupea villosa.* Fabricius (1780) determined the relationship more accurately by placing it in his "Fauna Groenlandica" under the name of *Salmo arcticus.*

Bloch (1793) used the name *Salmo groenlandicus* for Greenland capelin, and specimens from Newfoundland, Greenland, Iceland, and Norway were described as *Salmo lodde* by Lacépède (1804). Hermann (1804) classified Icelandic capelin as *Clupea lodna,* and Pallas (1814) used the name *Salmo socialis* to classify specimens from the North Pacific.

Although the specific name had been given to this fish as early as 1776, its generic position was not definitely fixed until more than 50 years later. Cuvier's predecessors had constantly shifted it from the Salmonidae to the Clupeidae, although the presence of an adipose fin clearly showed its relationship to the former (Jeffers 1931).

Common Names

The earliest obtainable reference to *Mallotus* in North America is contained in "An Account of Two Voyages to New England, a Description of the Country, Natives and Creatures" by John Josselyn, published in 1674. This writer referred to the "capeling" as a small fish, like smelt. Possibly he was referring to the silverside, to which fish the name "capelin" is still incorrectly applied in the vicinity of Boston (Jeffers 1931). In Newfoundland the letter "e" is omitted and the name is spelled and pronounced "caplin". Otherwise, the generally accepted spelling is now capelin.

In Norway the name is "lodde," which is derived from lodden = hairy, i.e. the same meaning as *villosus*. This name has been adopted in a number of languages, such as Danish, German, and Dutch (lodde), Swedish (lodda), and Icelandic (lodna).

In Greenland, capelin are known as "angmagssat" and the name of a village in East Greenland, Angmagssalik, gives an indication of the importance of this fish to native Greenlanders. In Russian the capelin is known as "moiva" or "mojva," although in the Soviet Far East the name is "uyok." In Japanese it is "karafuto-shishamo," and in Finnish "villakuore" (McAllister 1963; Anon. 1968; Jeffers 1931; Prokhorov 1965).

Description

The capelin is a relatively small fish, with mature specimens being generally 13–20 cm (5–8 inches) in length, although fish up to 25.2 cm (10 inches) have been recorded (Winters 1970a). During the first year both the male and the female are the same size, but the male is 1.0–2.5 cm larger than the female at sexual maturity (Winters 1969). Above the lateral line the color is transparent olive to bottle green, and below it the sides are silvery. The belly is silvery white. The scale margins are dotted with minute dusky specks, and the gill covers (opercula) are rough and have numerous black dots.

The body is elongate and slender, but appears angular in breeding males because of enlarged scales on the lateral line (Fig. 2). The mouth extends back below the fairly large eyes and the lower jaw protrudes. There are minute teeth on the jaws and tongue, and on the roof of the mouth. The scales are small and soft and the lateral line is almost straight. There are two fins on the back: a fairly large dorsal fin about the middle of the back, and a small, soft, adipose fin just in front of the tail.

The spawning male appears distinctly different from the female. Fins of the spawning male are larger than those of the female and project out from the body (Pitt 1966). Another obvious feature at spawning time is the appearance on the male of two pairs of spawning ridges: a prominent dorsal pair beginning at the gill cover and extending along the back immediately above the lateral line to the caudal peduncle, and a much smaller ventral pair extending from the pectoral fin back to the pelvic fin. These spawning ridges begin to develop 4–5 weeks before the start of the spawning season and result from

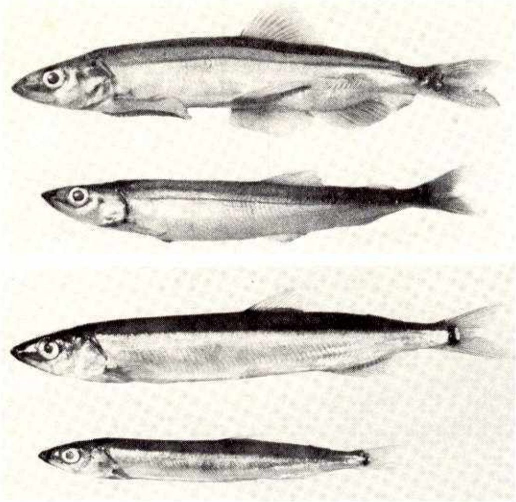


FIG. 2. *Top*, male capelin (upper) and female capelin (lower) as they look during the spawning season. Note the spawning ridges and enlarged fins of the male and the plump belly of the female (Winters 1969); *Bottom*, male capelin (upper) and female capelin (lower) as they look after the spawning season has ended. Note the absence of spawning ridges and regression of the fins of the male, and the slender appearance of the female (Winters 1969).

elongation of scales that project outward to form soft, plush-like ridges (Fig. 2). These ridges are essential to the execution of the spawning act and disappear within a month after spawning has ended (Fig. 2). After this time external identification of the sexes becomes difficult (Winters 1969).

DISTINCTIVE FEATURES

On the Atlantic coast of Canada three other small, slender, silvery fishes of similar appearance may be mistaken for capelin, especially in the young stages (Fig. 3). They are the rainbow smelt, *Osmerus mordax,* the Atlantic silverside, *Menidia menidia,* and the Atlantic argentine, *Argentina silus.* The smelt ranges from Labrador to New Jersey, and the silverside from the Gulf of St. Lawrence to Delaware. *Argentina silus* is a deepwater fish found on both sides of the north Atlantic. The other three species are abundant in the Gulf of St. Lawrence.

The capelin may be distinguished from the smelt by the absence of fang-like teeth on the tongue, by the longer adipose fin, by the projecting lower jaw, by the smaller scales, and, in spawning males, by the two ridges on either side of the body. The argentine may be distinguished from the smelt and capelin by the position of the dorsal fin, in front of the pelvic fins instead of over them (Leim and Scott 1966).

The silverside has a small mouth gaping only halfway to the eye, and the tongue has no fang-like teeth. There is no adipose fin on the back near the tail; instead there is a spiny fin and a large soft fin. Scales are quite large, and along each side is a silver band with a distinct black line on its upper edge (McKenzie and Day 1949).

On the Pacific and arctic coasts of North America the following members of the Osmeridae family occur in the same areas as the capelin: eulachon or candle fish, *Thaleichthys pacificus*; longfin smelt, *Spirinchus thaleichthys*; surf smelt, *Hypomesus pretiosus pretiosus*; and toothed or rainbow smelt, *Osmerus mordax* dentex (Clemens and Wilby 1961; Hart 1973).

Meristic characteristics—There is a correlation between the latitudinal distribution of capelin and its vertebral number, i.e. the further north the fish occur, the greater the number of vertebrae (Winters 1969). Temperature, which generally affects the vertebral number to a marked degree, would seem the obvious explanation; but this is not so. For instance, the spawning temperatures for capelin in the Barents Sea are approximately 2–4°C, which are very near those required by capelin spawning on the Grand Banks of Newfoundland (2.8–4.2°C); yet the capelin from these two areas have vertebral averages differing by about three vertebrae. The British Columbia capelin spawn at temperatures between 10–11°C, yet they have vertebral averages close to those of the Grand Bank area, which lies at the same latitude. Apparently temperature either does not greatly influence the vertebral number of capelin or some other factor has an overriding effect. Furthermore, the regional populations of capelin in the Atlantic, each with its spawning stock, are so widely separated that genetic influences are likely to come into consideration. There is more variation meristically within the Atlantic than between the western Atlantic and the Pacific. In the Atlantic capelin the female vertebral averages exceed those of the male, whereas in the Pacific the opposite is true.

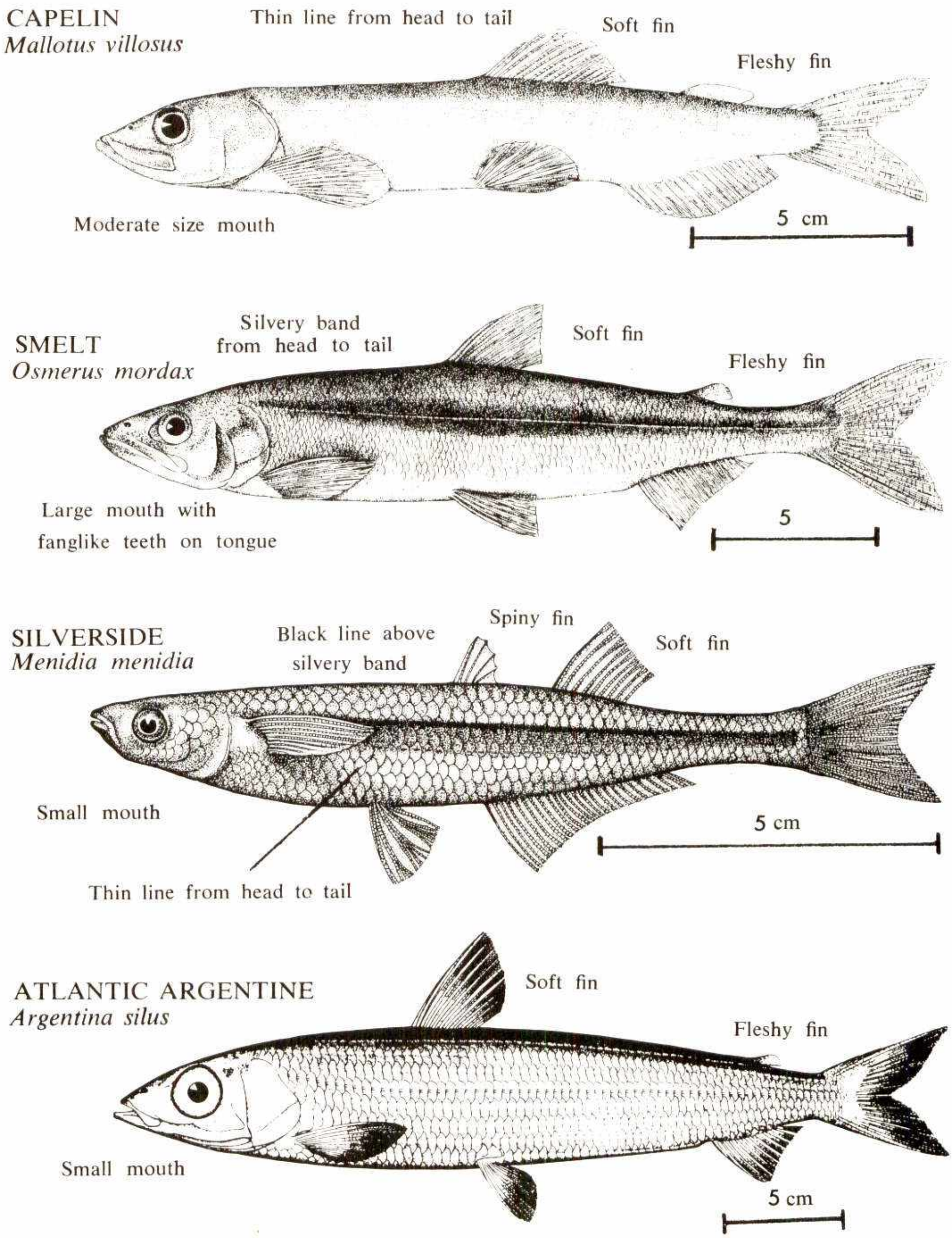


FIG. 3. External characteristics of capelin compared with those of rainbow smelt, Atlantic silverside, and Atlantic argentine. Capelin have a projecting lower jaw, a longer adipose fin, and smaller scales than smelt; the dorsal fin is over the pelvics. Smelt have a short, flap-like adipose fin, and fang-like teeth on the tongue; the dorsal fin is over the pelvics. Argentines have the dorsal fin in front of the pelvics; the jaws lack teeth; the mouth is smaller and the eye larger than in capelin and smelt. Silversides have two dorsal fins, the first being spinous; there is no adipose fin; the anal fin is long; the mouth is very small (Leim and Scott 1966; McKenzie and Day 1949).

Distribution

Capelin has a circumpolar distribution and can be found in the northern regions of the Atlantic and the Pacific (Fig. 4). In the eastern Atlantic the capelin occurs from the Trondheim Fjord region of western Norway northwards to Finnmark and northern Russia. It is widely distributed throughout the Barents Sea from Novaya Zemlya to Spitzbergen and Bear Island, and occurs sporadically in the White and Kara seas. Iceland also has an abundance of capelin around its shores, as does Greenland. On the east coast of North America, capelin occurs from Hudson Bay to Nova Scotia, with occasional reports of appearances as far south as Cape Cod. In this area it is found in greatest abundance off Newfoundland and Labrador.

In the Pacific the distribution of capelin extends from Cape Barrow, Alaska, around the Bering Sea, and south along the Pacific coast of Canada to Juan de Fuca Strait. On the Asiatic coast it extends from the Sea of Chukotsk south to Hokkaido Island, Japan, and Tumen River, Korea (Winters 1969).

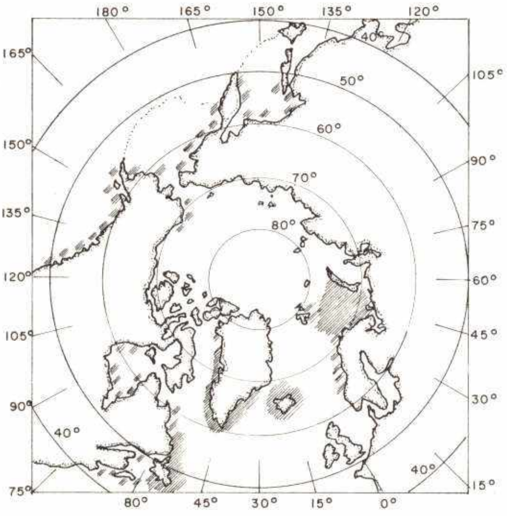


FIG. 4. World distribution of capelin (shaded areas).

Reproduction

Spawning — Capelin spawn on beaches or in deeper water and are highly specific with regard to spawning conditions.

Beach-spawning capelin found along the Newfoundland and Labrador coasts in June and July prefer water temperatures of 5.5–8.5°C, although spawning has been reported in temperatures as high as 10°C. Preferred beaches generally have pebbles of 0.5–2.5 cm size. Tides are important because they determine the size of pebbles that are exposed. Light conditions are also important, with most spawning taking place at night or in dull, cloudy weather.

Spawning begins in Newfoundland around the first of June on the south coast and progressively later further north, in Labrador often not until mid-July or later (Huntsman et al. 1954). On the west coast of Newfoundland, where the cold Labrador current has less effect than on the east coast, water temperatures rise so fast that beach-spawning occurs only sporadically and is usually replaced by deepwater spawning. Beach-spawning lasts from 4 to 6 weeks, but spawning may continue in deeper water near shore for those fish which failed to spawn during the regular period (Winters 1969; Templeman 1948).

The spawning act as observed on the beaches of Newfoundland (Fig. 5, 6) was described by Jeffers (1931) as follows:

"The school swam gracefully back and forth just beyond the crests of the small waves that were breaking on the beach . . . . The males were more active in seeking a mate . . . When a female was found the two became attached side by side and quite often a second male attached itself to the free side of the female, and the three together rushed up the beach . . . They go up the beach as far as they possibly can get in this way and then settle in one spot as the wave recedes, all the time using their fins and tails with great rapidity. In this way they scoop out a slight hollow in the soft sand as if trying to bury the eggs as far as possible, and the vigorous action of the fish in the tiny puddle of water thus formed can be distinctly heard. After separating the capelin lie still on the sand for a second as if exhausted before starting to paddle furiously in an attempt to regain the water, for by this time another wave has rolled up the beach. The writer has tried to pick up a pair that was still in contact, but found it impossible. Timing the spawning act with a stop-watch shows that it is over in less than five seconds."

Beach-spawning has also been observed on the coast of the Gaspé Peninsula, Que. in June and July (Brunel 1960, 1961, 1962, 1964), on the north shore of the Gulf of St. Lawrence, and on the northeast coast of Cape

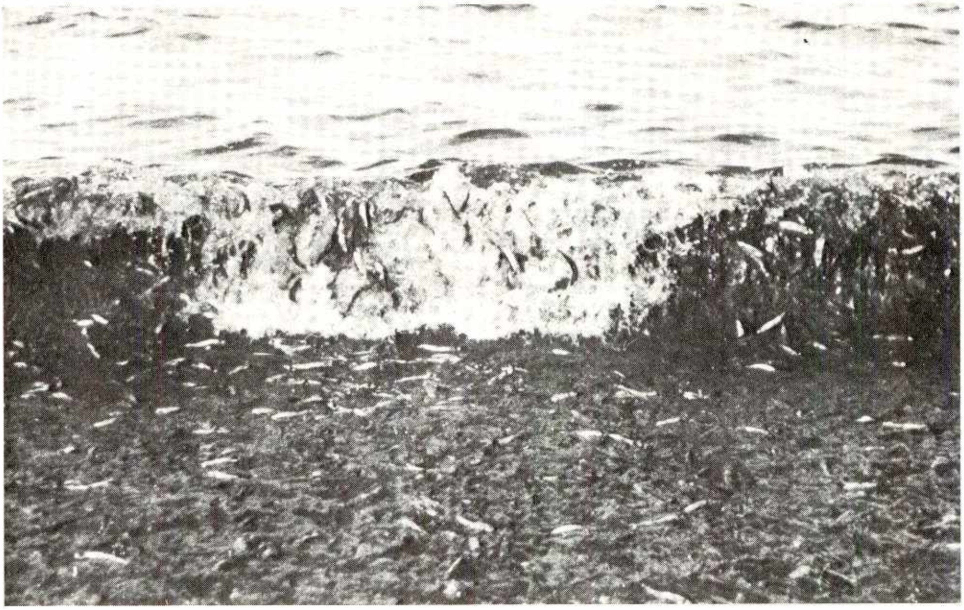


FIG. 5. The onrush (roll) of a wave filled with spawning capelin as it approaches the beach at Conception Bay, Newfoundland (Templeman 1966).

Breton Island, N.S. On the southeast shoal of the Grand Bank, spawning occurs in deeper water (30–50 meters) in June and July (Pitt 1958b).

On the Pacific coast of Canada capelin spawn on gravelly beaches in various localities in the Strait of Georgia during late September or October, usually in the evening at high tide and at the water's edge. The water temperatures are then about 10–12°C (Hart and McHugh 1944).

The Barents Sea capelin spawn off the coast of Norway or the USSR in March and April at depths of 10–70 meters, although quantities of eggs have been found as deep as 175 meters. Observations by divers (Fig. 7) indicate that preferred spawning areas are covered with fine gravel (0.5–1.5 cm) and have strong currents (Bakke and Björke 1971; Björke et al. 1972). The water temperatures are generally about 2–4°C.

In Iceland capelin spawn in deeper water from March to June at water temperatures of 6–7°C. In Greenland the spawning takes place in shallow water in the fjords at temperatures of 2–6°C (Winters 1969).

At the spawning grounds the capelin are segregated into schools of different sexes. The general pattern in Newfoundland seems to be

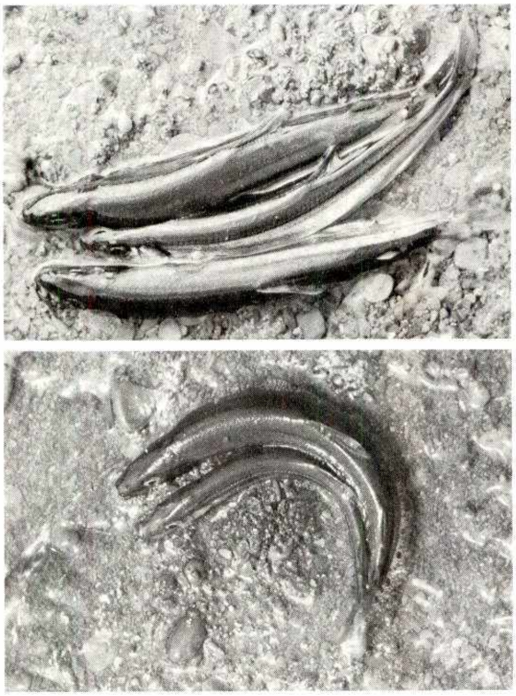


FIG. 6. Beach-spawning capelin photographed during the spawning act: *upper*, female in the middle; *lower*, female on the inside.

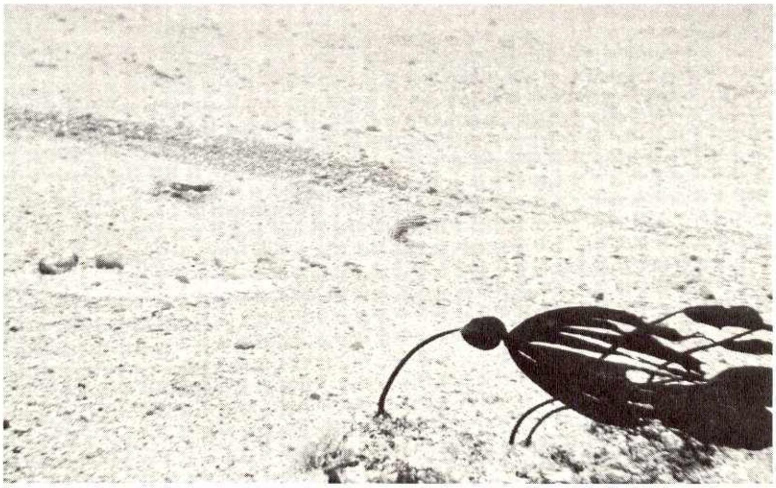


FIG. 7. Spawning grounds of capelin at a depth of 30 meters off northern Norway. The layer of gravel and eggs is about 7 cm thick. The dark line was caused by the dragging of a grapnel along the bottom. Current was about 2 knots (Björke et al. 1972).

that ripe males await opportunities to spawn near the beaches, while large schools, mainly composed of relatively inactive females, remain for several weeks off the beaches in slightly deeper water. As these females ripen, individuals proceed to the beaches to spawn. Thus, most males remain in attendance near the beaches and join successive small groups of females which spawn and depart from the area (Templeman 1948). Divers studying the capelin spawning grounds off northern Norway (Fig. 8) found similar schools of "males in attendance patrolling the area" (Björke et al. 1972).

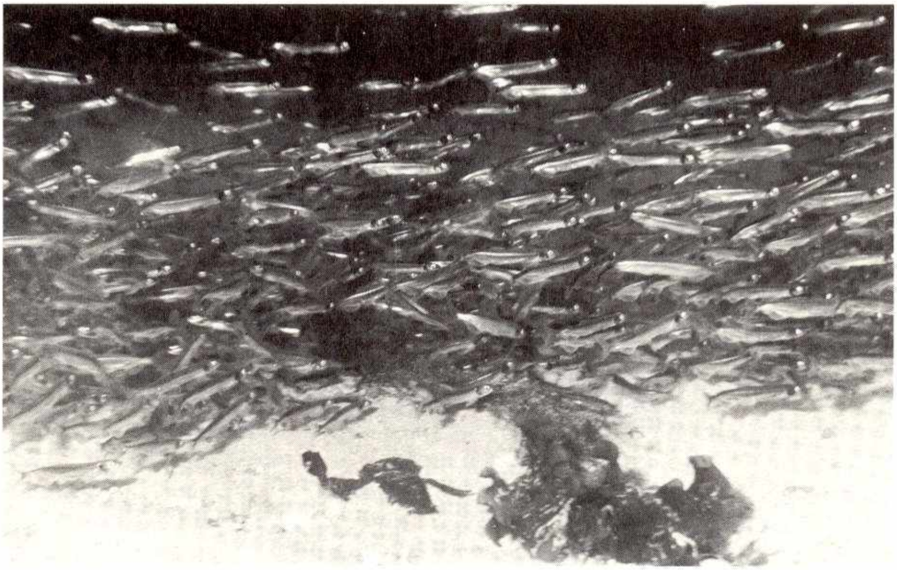


FIG. 8. Male capelin "in attendance" near spawning area off northern Norway at a depth of about 20 m.

Spawning survival — During and following the spawning season large numbers of dead capelin can be observed floating on the surface or stranded on the beach. This has led to the impression that capelin are one-time spawners, but this is not entirely true as spent fish in prime feeding condition have been caught at least a month after spawning (Winters 1969). Some authors believe that the bulk of the first-time spawners survive to spawn a second time, but because of the great predominance of a single age-group (usually 3-year-olds) in the spawning schools, it must be assumed that the overwhelming majority of capelin die after spawning. Most of the dead fish stranded on the beaches are males. Dead males were also observed by divers on the deeper spawning grounds off northern Norway. Since many of the males are in constant attendance at the spawning area throughout the season, most of these are in emaciated condition towards the end of the season and their chances of survival are slim.

Hatching — Capelin eggs are demersal and become attached to the gravel on the beach or on the bottom (Fig. 9). The incubation period varies with the temperature, and hatching has been demonstrated to occur in about 55 days at 0°C, 30 days at 5°C, and 15 days at 10°C (Jeffers 1931). The newly hatched larvae soon assume a pelagic life near the surface. They remain there until the winter cooling sets in, when they move closer to the bottom until the water warms up again in the spring.

FIG. 9. Sampling tube showing layers of eggs and gravel. Sample was taken by divers off northern Norway (Björke et al. 1972).

GROWTH, FOOD, AND FEEDING

Age, size, and growth — Most eggs laid on beaches on the east and south coasts of Newfoundland hatch in July, and recently hatched larvae range in size from 3 to 6 mm. Newly hatched larvae from deepwater hatching may appear in numbers in August (Templeman 1948). Hodder and Winters (1972) found that capelin larvae are widely distributed in the Gulf of St. Lawrence and off the southwest coast of Newfoundland in November. Their length distribution is shown in Fig. 10.

This information and data gathered by Templeman (1948) indicate that most capelin larvae are between 2 and 4 cm long by the beginning of the first winter.

Around Iceland the largest numbers of capelin larvae smaller than 10 mm were found in May or June, with the earliest hatching taking place along the southwest coast. The smallest larvae observed were around 4 mm

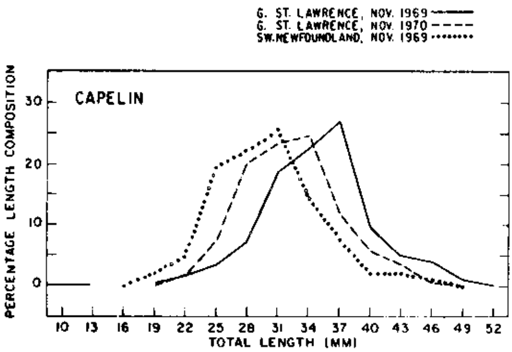


FIG. 10. Length composition of larval capelin sampled in November 1969 and 1970 (Hodder and Winters 1972).

(Magnusson 1968). The rate of growth during this first summer was as follows (mean lengths in mm):

	May	June	July	Aug.	Sept.
1960	–	–	22.54	–	–
1961	10.04	14.68	19.06	25.18	–
1962	9.99	9.80	21.07	22.76	25.15
1963	10.57	17.32	22.67	31.00	38.28
1964	–	17.25	24.34	30.92	42.85
Mean	10.20	14.76	21.94	27.47	35.43

Data on Barents Sea capelin indicate that the length of juveniles entering their first winter is about 5–6 cm (Prokhorov 1965; Monstad 1969).

Templeman (1948) carried out a detailed study of capelin larvae. Fig. 11 shows larvae at three stages of development.

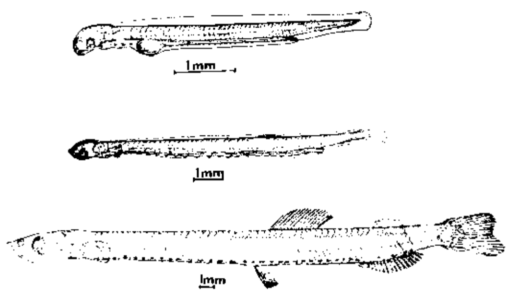


FIG. 11. Capelin larvae 5 mm, 11 mm, and 40 mm long (Templeman 1948).

During the first year the male and the female are the same size, but during the second year a differential growth rate sets in, favoring the male. Since most capelin growth occurs during the second and third years of their lives (I and II age-groups), the availability of food, water temperatures, etc. can have a considerable effect on the size of mature specimens (Pitt 1958b; Prokhorov 1965).

Capelin spawning on the Grand Bank and those spawning inshore in Newfoundland were found by Pitt (1958b) and Templeman (1948) to have similar growth rates (number of samples in parentheses):

Age-group	Total length, inshore July 1940, 1941	
	♂	♀
	cm	cm
II	16.0 (17)	14.2 (40)
III	17.5 (1020)	15.9 (621)

Age-group	Total length, Grand Bank July–Aug. 1948–50	
	♂	♀
	cm	cm
II	15.0 (101)	14.2 (26)
III	17.8 (228)	15.4 (90)

Templeman (1969) found that the age composition and mean lengths of 1547 male and 952 female spawning capelin, sampled in 1944 from southern Labrador and the east and south coasts of Newfoundland, were as follows:

Age-group	Age composition ♂	Age composition ♀	Mean length (*cm*) ♂	Mean length (*cm*) ♀
2	1	4	16.0	14.2
3	66	65	17.5	15.9
4	33	28	19.0	17.7
5	0.3	2.7	19.9	19.0

Dragesund et al. (1973) calculated and plotted the growth rates of Barents Sea capelin on the basis of thousands of measurements and the resultant curves (von Bertalanffy's growth curve) for males and females are shown in Fig. 12.

A few capelin mature and spawn at 2 years of age, but it is not until the third year that

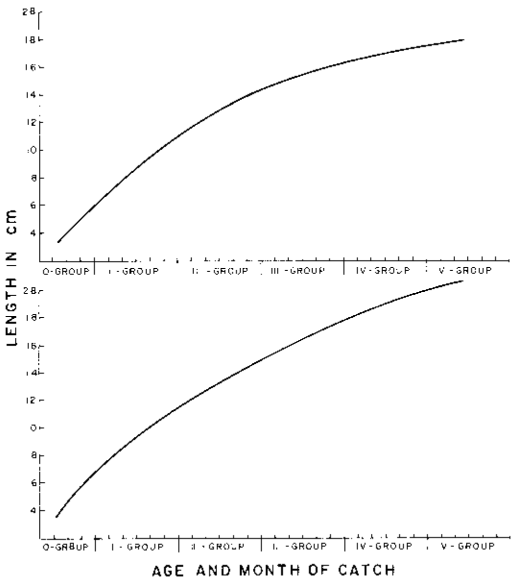


FIG. 12. Growth curves for female (upper) and male (lower) capelin, Barents Sea and the coast of Finmark, 1968–70 (Dragesund et al. 1973).

mass maturation occurs. Three- and four-year-old fish, therefore, dominate the spawning schools of both Newfoundland and Barents Sea capelin, with the ratios between 4-year-olds and 3- and 5-year-olds varying from year to year. The average lengths of capelin on the spawning ground, therefore, varies according to the dominant year-class. There is also a tendency for larger fish to arrive and spawn first. Winters (1967b) measured close to 3900 spawning capelin in Newfoundland in 1966, and found that males averaged 18.5 cm and females 17.75 cm. In some areas averages were as high as 19.56 and 17.86 cm.

The average lengths and percentages of each year-class of spawning capelin off northern Norway over a 5-year period have been tabulated by Olsen (1968) in Table 1; it indicates that the age composition, and thus the average length, of spawning fish vary considerably from year to year.

Capelin weight varies with season as well as with length of the fish. Overwintering capelin from Trinity Bay, Newfoundland, caught in February–April before rapid gonadal development had started, were studied by Winters (1970b). His data are shown in Fig. 13.

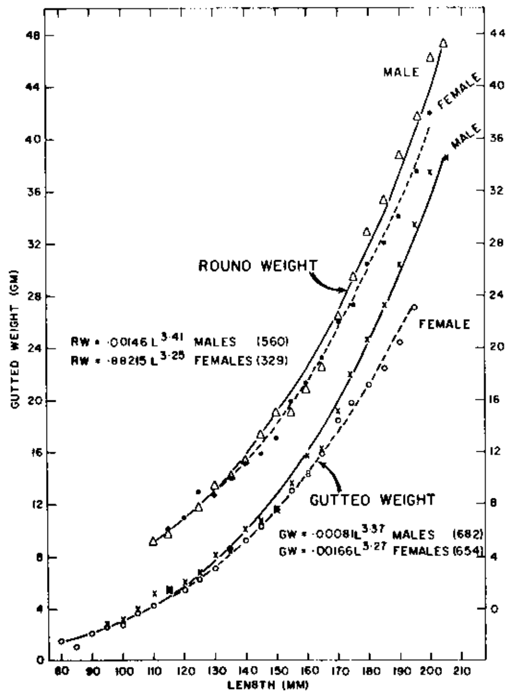


FIG. 13. Length–weight curve of overwintering capelin caught in February–April in Trinity Bay, Newfoundland (Winters 1970b).

Ripe capelin (June–July) were measured and weighed by Templeman (1948) and the relationship between length and weight is shown in Fig. 14.

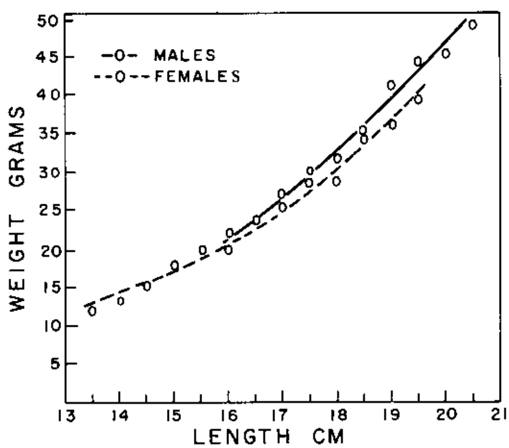


FIG. 14. Average weights of male and female prespawning capelin caught at Holyrood, Newfoundland on June 28, 1941 (Templeman 1948).

TABLE 1. Percentage age distribution and mean length (l) at age (in cm) of the Norwegian capelin (*Mallotus villosus*) spawning stock, 1961–65 (Olsen 1968).

		Age									
		2		3		4		5		6	
Season	Sex	%	l	%	l	%	l	%	l	%	l
1961	♂	–	–	1.2	16.97	94.2	18.76	4.6	19.79	–	–
	♀	–	–	4.7	15.76	94.5	17.12	0.8	18.54	–	–
1962	♂	–	–	2.0	16.22	63.9	17.30	33.9	18.48	0.2	20.40
	♀	–	–	8.4	14.99	66.9	16.06	24.4	17.16	0.2	18.43
1963	♂	0.2	14.42	2.3	15.76	93.5	16.67	4.0	17.95	–	–
	♀	0.1	12.86	7.7	14.50	91.1	15.29	1.1	16.77	–	–
1964	♂	–	–	1.9	15.91	47.2	17.14	50.9	17.60	–	–
	♀	0.3	13.88	6.5	14.85	58.0	15.82	35.2	16.41	–	–
1965	♂	0.7	16.09	89.6	17.60	9.5	18.25	0.2	19.40	–	–
	♀	1.0	14.65	92.4	16.02	6.0	16.85	0.4	17.71	0.2	–

Food and feeding—Feeding activity in capelin is highly seasonal. The feeding intensity increases in the prespawning season in late winter and early spring, but begins to decline with the onset of the spawning migration. Feeding ceases altogether during the spawning season, except for sand and capelin eggs apparently swallowed incidentally. The survivors of spawning resume feeding several weeks after the spawning period, and feeding proceeds at high intensity until early winter when it ceases. The condition of the fish reflects this seasonal feeding pattern: the fat content can be as low as 1% in spent fish and as high as 23% in fish in prime condition (Winters 1969).

Capelin are mainly filter feeders, thriving on planktonic organisms which are filtered out by the gill rakers. Euphausiids compose the highest proportion by weight, although in stomachs examined, copepods, especially *Calanus* sp., occur with most frequency. Amphipods and a variety of other planktonic invertebrates are also generally included in the diet (Prokhorov 1965; Kovalyov and Kudrin 1973; Templeman 1948).

PARASITES

The capelin is parasitized by a larval nematode (*Contracaecum* sp.) 5–30 mm long, usually lying free in the body cavity. Very few have been found in the flesh. Incidence of infection ranges from 26 to 81%, with the highest values usually found in larger fish that have spawned previously (Templeman 1948, 1968). However, since mouth size is directly related to body size, the number of nematodes per fish is probably related also to the feeding rate and the species composition of the capelin diet (Winters 1970b).

PREDATION

Capelin are an extremely important food for other fish, sea mammals, and birds.

Cod (*Gadus morhua*) are the main predators of capelin because of their numbers, size, and feeding habits. During the spawning migration to the coasts of Newfoundland and Labrador, Iceland, Norway, Greenland, and the USSR, schools of capelin are followed by large numbers of cod which, in many cases, have just completed spawning. Studies carried out at St. John's (Templeman 1965b) showed that from June to early August 98% of the food of cod was capelin. This is typical of the east and southeast coasts of Newfoundland. Cod on the offshore banks also feed heavily on capelin.

Haddock (*Melanogrammus aeglefinus*) consumed large quantities of capelin eggs and capelin on the Southeast Shoal of the Grand Bank when haddock were plentiful there (Pitt 1958a; Templeman 1968). Large quantities are eaten by haddock on the spawning grounds off Norway (Dragesund et al. 1971; Björke et al. 1972). Winter flounders (*Pseudopleuronectes americanus*) gather in large numbers off the spawning beaches in Newfoundland. Capelin are the main food item of Atlantic salmon (*Salmo salar*) in the northwest Atlantic (Lear 1972). All large fishes in the area where capelin are present will feed on them to a certain extent. Smaller fishes, including Atlantic herring (*Clupea harengus*), often feed on the larvae and young.

Whales are known to feed heavily on capelin. Sergeant (1963) reported that capelin were found in 85% of the stomachs of minke whales (*Balaenoptera acutorostrata*) caught commercially in Newfoundland. Fin whales (*Balaenoptera physalus*) are also frequently seen feeding on capelin concentrations.

Seals, especially harp seals (*Pagophilus groenlandicus*), eat large quantities of capelin on their migration to and from the breeding grounds off Newfoundland and in the Gulf of St. Lawrence (Sergeant 1973). Various seabirds also consume considerable quantities throughout the year.

Occurrence, Migration, Abundance, and Catches

Eastern Canada

Bay of Fundy and Nova Scotia — Sporadic occurrences of capelin in the Bay of Fundy have been recorded since 1850, although not in commercial quantities (Huntsman 1922). In the spring of 1965 more than 80,000 lb of capelin were caught in herring weirs on the New Brunswick side of the Bay of Fundy (Tibbo and Humphreys 1966). Inquiries made at the time indicated that in previous years capelin had occasionally been found in weirs. In years with below normal water temperatures, capelin are apparently carried by the cold Labrador current from their normal habitats off Newfoundland and northern Nova Scotia into the Bay of Fundy. They were found there again in 1965–1968, with a commercial catch of 187,000 lb being reported in 1967. Since 1968 no occurrences have been reported (Tibbo 1965, 1966, 1968).

On the Atlantic coast of Nova Scotia, occasional isolated schools of capelin have been reported from several areas, such as Halifax Harbor (Jeffers 1931), and some spawning occurs on Cape Breton Island. Pitt (1958a) stated that no capelin have been taken on Banquereau or Sable Island Bank, either from nets or from the stomachs of cod.

The Gulf of St. Lawrence — Capelin are plentiful on the North Shore of the Gulf of St. Lawrence and from the Strait of Belle Isle to the St. Lawrence River below Quebec City. Catches have generally been small, with a total catch of 263,000 lb from local fisheries reported for Quebec Province in 1970. Capelin are abundant around Anticosti Island and can be found off the Gaspé Peninsula and northern Cape Breton (Srivastava 1971). In years with below average temperatures, schools occur occasionally in the southern Gulf, Chaleur Bay, and around Prince Edward Island.

Grand Bank and St. Pierre Bank — Capelin have been found in most areas of the offshore banks, and a sizeable population spawn on the Southeast Shoal of the Grand Bank. Indications are that spawning also occurs in other areas of the Grand Bank and St. Pierre Bank (Pitt 1958a).

Commercial exploitation of Southeast Shoal capelin started in 1971 when the Soviets reported to the International Commission for the Northwest Atlantic Fisheries (ICNAF) that their vessels had caught 750 tons in subarea 3N, i.e. the southeastern part of the Grand Bank. Further studies were carried out by two Soviet research vessels and excerpts from

Kovalyov (1972) are: "Observations on the capelin distribution in the Grand Newfoundland Bank area were started in late May. The St. Pierre and Green banks were investigated. Concentrations suitable for fishery were not registered. . . .

"In the first half of June considerable concentrations of pre-spawning capelin were distributed on the southwest slope of the Grand Bank. The heaviest concentrations occurred over depths of 100–200 m in the area at 44° 30′–45°00′N and 52°30′–54°00′W. Investigations on the southeast slope of Grand Bank were carried out in the second half of June. Data on trawlings in this area showed that spawning concentrations of capelin formed at the end of June, yielding catches from 3 to 10 tons per half hour trawling with bottom trawl. Capelin concentrations were distributed in the area between 43°31′–45°10′N and 49°10′–51°00′W. The heaviest concentrations . . . were observed on the shallows and small banks at depths of 45–55 m where spawning took place. In the north of the area, 97% of the fish were females, with fish that had already spawned dominating."

The Soviet fishery and explorations were greatly expanded in 1972, and over 48,000 tons were taken in subarea 3. A research report by Kovalyov and Kudrin (1973) gives the results of surveys carried out by Soviet research and scouting vessels which may be summarized as follows: "Small schools of capelin were found in February on the northeastern slope of the Grand Bank, and in March concentrations were found in the area bounded by 46°00′ to 48°00′N and 50°00′ to 53°00′W. Considerable capelin concentrations migrated into the Virgin Rocks area by the middle of the month, while dense concentrations remained in the Avalon Peninsula area. By the end of the month, capelin were distributed over a large area from the southern part of the Avalon Peninsula to the southwestern slope of the Grand Bank. In April capelin schools were recorded on the northeastern slope of the Grand Bank, in the Virgin Rocks area, on the southwestern slope of the Grand Bank, and also on St. Pierre and Green banks. In May capelin migrated to the southern and southeastern area of the Grand Bank, with the densest concentrations found on the southwestern slope of the Bank. The first capelin schools migrated to the southeastern slope of the Grand Bank at the end of May and the mature part of the stock . . . concentrated on the southeastern slope in June. Immature capelin were distributed above depths of 100–150 meters over a large area of the northeastern slope of the Bank. . . . Spawning commenced around June 7–10, with intensive spawning occurring on the Southeast Shoal area in the second half of June." Catches by Soviet factory trawlers in ICNAF subarea 3K were 27,313 tons, in 3L — 430 tons, in 3N — 16,628 tons, in 3O — 3970 tons, and in 3Ps — 21 tons.

The Industrial Development Branch of the Canadian Fisheries and Marine Service, Department of the Environment, has carried out experimental fishing for capelin since 1971. In that year the midwater trawlers *Rupert Brand V* and *Foam V* made good catches of up to 40 tons per haul on the Southeast Shoal between June 16 and July 10, by which time the fish had completed spawning and dispersed.

In 1972 they increased investigations to assess possible commercial exploitation of the Grand Bank capelin stocks. During the spawning season (June–July) six vessels were operated under charter for varying periods of time (Hinds 1972), and the total catch was about 4000 tons. In their report they attributed the low production of the purse seiners to lack of experience in seining capelin, to gear and mechanical failures, and to adverse weather. The best purse seine catches were made at night, while midwater trawlers fished best in the daytime when capelin were ascending or descending.

Scientists from the Norwegian Institute of Marine Research, Bergen, conducted research cruises to Newfoundland and Labrador waters from 1970 to 1972. The cruise in 1972 concentrated on the Grand Bank area (Dragesund and Monstad 1972). One seiner took a catch of 900 tons with midwater trawl. Integrating equipment coupled to the echo sounder on the *Johan Hjort* was used, and the Southeast Shoal population was estimated to be 126–170 thousand tons. The scientists estimated concentrations of capelin to the west of 52°20′ from May 27 to June 9 to be about 250,000 tons. In the period June 7–18, these fish had moved, possibly towards the Newfoundland coast to spawn (Fig. 15). According to the authors the behavior of capelin off Newfoundland during the spawning migration is apparently somewhat different from that observed for the Barents Sea capelin. No dense schools were observed during the spawning migration on the Grand Bank towards the Southeast Shoal. Mature capelin were segregated from the immature, and they approached the spawning grounds in rather small schools. The maps in Fig. 16 show seasonal capelin concentrations as reported by various authors. The fishing effort was greatly

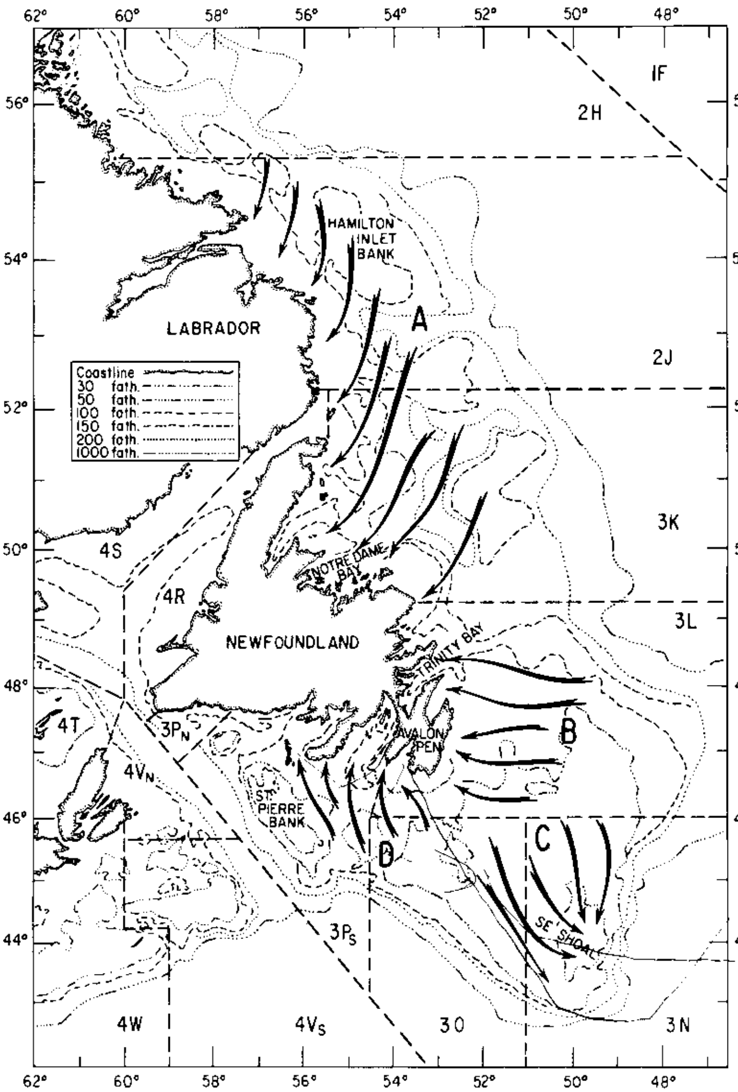


FIG. 15. Possible migration pattern of mature capelin off Newfoundland and Labrador A. Labrador–Northeast Newfoundland stock. B. Northern Grand Bank–Avalon stock. C. South Grand Bank stock. D. St. Pierre-Green Bank Stock (Campbell and Winters 1973).

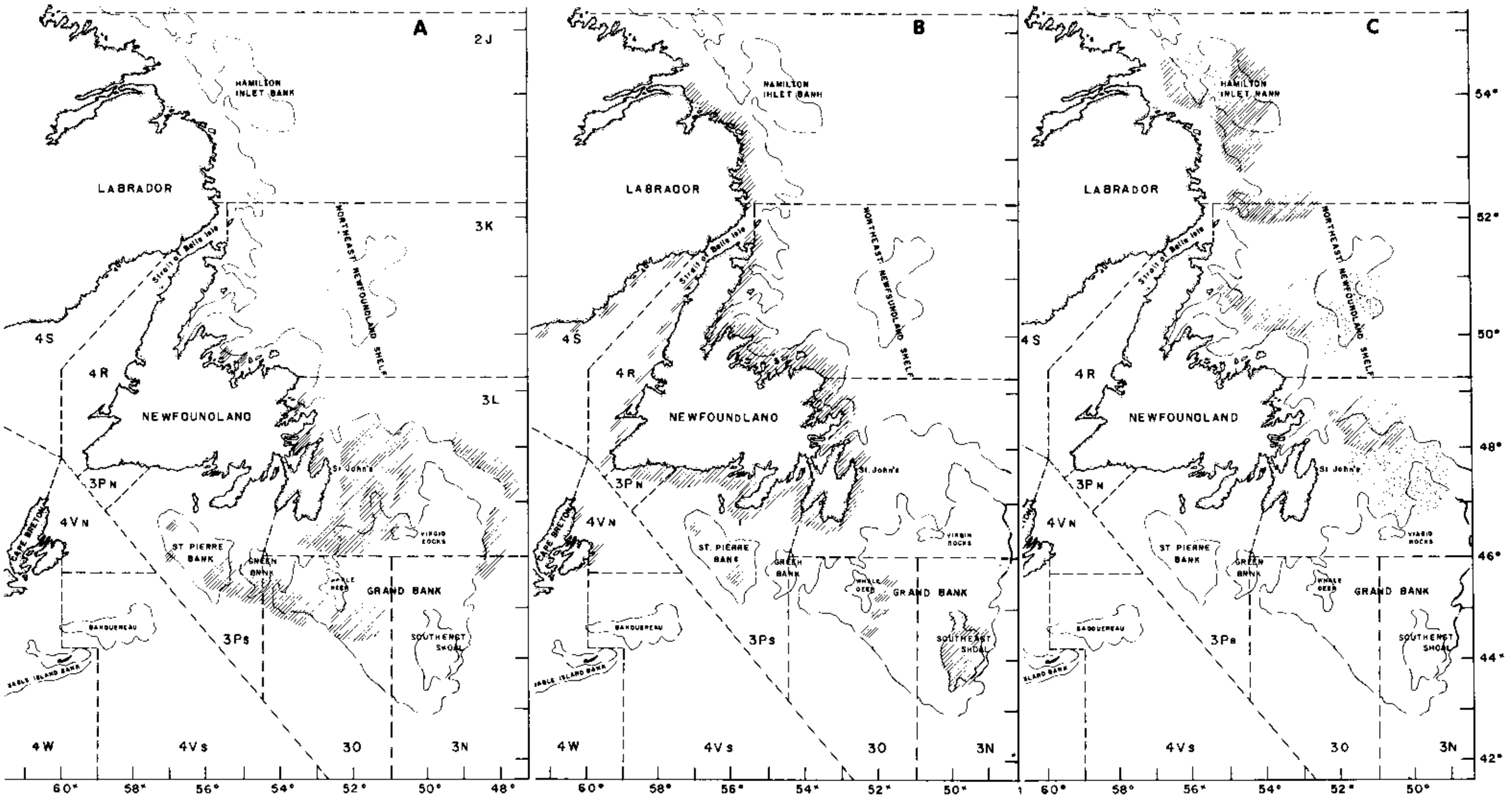


Fig. 16. Areas (shaded) off Newfoundland and Labrador where capelin have been registered and reported by various authors mentioned in the text. The absence of registrations does not indicate that capelin could not be present in these areas. Period: A, February–May; B, June–July; C, August–December.

increased on the Southeast Shoal in 1973. A Norwegian fish meal factory ship with 6–8 catching vessels operated there in addition to a number of Soviet and Canadian vessels.

Northern Grand Bank, Newfoundland, and Labrador — The largest concentrations of capelin in Canadian waters are found around Newfoundland and off the Labrador coast. Capelin spawn on the beaches or inshore in most areas of Newfoundland and Labrador, starting early in June on the south coast and progressively later as one goes northward along the coast; in Labrador it is often mid-July before spawning begins. Capelin have traditionally been caught by local fishermen employing traps, seines, and dipnets. In Newfoundland most capelin are landed on the east and southeast coasts in areas most affected by the cold waters of the Labrador current.

Early in this century, with more than twice as many fishermen and a much greater use of capelin for potato fertilizer and dog food, capelin production in Newfoundland must have been close to 23,000 tons (Templeman 1967). Between 1946 and 1952 capelin were used for the production of fish meal, and about 18,000 tons of capelin were processed in 1950. In the last few years there has been a decline in the use of capelin for bait, due to the increasing use of gillnets for the cod fishery.

The total Newfoundland and Labrador catch and utilization of capelin over the past few years is given in Table 2.

Exactly where the survivors of spawning go to feed and winter is not completely known. Mass mortalities of capelin inshore in winter (Templeman 1965a), vessel catches, and the presence of capelin in stomachs of Greenland turbot (*Reinhardtius hippoglossoides*), cod, and seabirds indicate that some beach-spawning capelin spend their winters locally in the deeper waters of the bays. These so-called "whitefish" are often taken by local residents for food in late winter and early spring. Winters (1970b) studied the overwintering capelin in Trinity Bay and suggested that commercial exploitation would be possible, especially since fish were then in excellent condition, with relatively high fat content. Two experimental fishing trials in February and March 1971 (d'Entremont 1971a,h) resulted

TABLE 2. Total landings (metric tons) and utilization of capelin (percent of landings) for Newfoundland. (Source: Economics Branch, Fisheries and Marine Service, St. John's, Nfld.)

Year	Landings	Frozen, round	Fresh, round	Dried and smoked	Fresh bait and fertilizer	Frozen, bait	Meal	Canned
1956	13,800	–	0.78	0.48	98.74	–	–	–
1957	11,950	–	1.05	2.15	96.80	–	–	–
1958	9,920	0.32	1.14	3.62	93.24	1.68	–	–
1959	6,240	1.27	1.45	8.82	78.49	6.99	–	2.98
1960	7,010	0.49	1.62	5.79	78.67	10.58	–	2.85
1961	5,100	0.89	2.28	9.91	72.05	11.59	–	3.28
1962	4,450	0.28	2.62	9.36	76.92	10.82	–	–
1963	5,350	0.37	2.17	5.58	71.98	19.90	–	–
1964	4,870	0.18	2.39	5.98	77.07	14.38	–	–
1965	4,780	3.59	–	4.96	54.41	12.19	24.85	–
1966	4,845	0.66	–	4.83	63.51	12.28	18.72	–
1967	3,503	2.10	–	5.14	55.60	8.68	28.48	–
1968	3,313	2.45	–	4.82	63.17	18.63	10.93	–
1969	3,442	3.60	–	6.05	53.27	14.89	22.19	–
1970	3,340	3.31	–	4.75	62.50	16.40	13.04	–
1971	2,518	4.37	–	6.31	38.96	14.02	36.34	–
1972	4,367	1.36	1.27	4.57	12.83	6.20	73.77	–

in small catches of both juvenile and mature capelin in Trinity and Conception Bays.

Some shore-spawning capelin undoubtedly feed offshore on the banks. Dragesund and Monstad (1972) suggested that dense concentrations of capelin migrate towards Newfoundland to spawn. Several authors have suggested that the northern part of the Grand Bank is a major nursery area for immature and prerecruiting capelin (Templeman 1967; Kovalyov and Kudrin 1973).

Large concentrations of capelin have been recorded off northern Newfoundland and Labrador. Two Norwegian research cruises, from July to September, found feeding capelin over a large area from the Avalon Peninsula to Hamilton Bank (Devold 1970; Devold et al. 1972). The authors found that midwater trawling would yield higher catches than purse seining, because while the immature capelin (I–group) stayed in the upper, warmer layer both day and night, the older and more valuable fish penetrated the extremely cold intermediate layer twice in 24 hours. In the daytime the schools stayed close to the bottom and as the light decreased in late afternoon they moved to the surface layer, dispersing after sunset. In the morning they again formed schools, but soon afterwards they descended to the bottom. Therefore, it was only during a short time of the day that substantial catches could be made with a purse seine in the Labrador area. The same authors also found that the older, maturing capelin were feeding further to the east than the juveniles.

The *Foam V* made catches of mature capelin with high fat content in the Hamilton Bank area in the fall of 1972 (Hinds 1973).

Soviet vessels also exploited the Labrador capelin in 1972, taking 17,777 tons from subarea 2J. Kovalyov and Kudrin (1973) reported: "In September and October dense capelin concentrations were found on Hamilton Bank . . . In November the capelin were distributed more to the southeast . . . "

The Eastern Arctic — Capelin are usually rare in northern Labrador but have appeared occasionally in Ungava Bay in large numbers (Dunbar 1970; Dunbar and Hildebrand 1952). They are common in James Bay and southern Hudson Bay, especially in the Belcher Islands, but are not fished to any extent in these areas.

Greenland

Capelin (angmagssat) are abundant in Greenland from Angmagssalik on the east coast to Upernavik on the west coast. Spawning takes place in May and June in the southern area near Godthaab and in June and July further north (Kanneworff 1968) (Fig. 17).

During the most recent warming trend, in the 1930s and 1940s, spawning capelin no longer appeared regularly on the beaches but presumably spawned in deeper waters, and the northern limit for capelin moved northward from Vaigat to Umanak Fjord and Kraulshavn. A few individuals were also caught as far north as Thule (Hansen and Hermann 1953).

In summer and fall, schools of juvenile capelin can occasionally be seen near shore, and the stocks are considered to be rather stationary. Large schools of feeding capelin, often pursued by whales, are also frequently recorded on fish-finding equipment off the east coast of Greenland.

In the southern region, spawning capelin are followed by schools of cod; the Greenlanders carry out a fishery for both species. Capelin have always been important to the native people of Greenland, and quantities are caught with beach seines or dipnets and dried as an important source of winter food for people and animals. The recorded annual catches have

FIG. 17. Map of Greenland showing the place names discussed in the text.

been somewhat variable (they are shown in metric tons): 1967, 3700; 1968, 200; 1969, 200; 1970, 3100; 1971, 2500; 1972, 1920 (Source: FAO Yearbook of Fishery Statistics. ICNAF, Dartmouth, N.S.).

ICELAND

Capelin are extremely abundant in Icelandic waters, but are found close to shore only when they appear along the south and west coasts to spawn. Limited spawning also occurs on the east and north coasts.

The schools arrive in the shallow waters along the south and southwest coasts in February or March, depending on oceanic and weather conditions, and spawning is generally completed by late June (Vilhjalmsson 1968). The larvae are carried by currents to the west and north of Iceland where they frequently account for more than one-half of all fish larvae caught in this area. Survivors of the spawning population and immature capelin are distributed at or near the warm–cold boundary off the north and northeast coasts during the greater part of the year. Large schools are frequently observed in the area between 67° and 68°N from 13° to 27°W in summer and fall (Fig. 18).

A large-scale fishery for capelin has been carried out only since 1963, and was begun chiefly because of the drastic reduction in the abundance of herring stocks in Icelandic waters. The largest catches are landed in February and March, and are taken exclusively by purse seiners. Only a few thousand tons are used for human consumption or bait and the rest go for fish meal and oil. No fishery is presently being carried out on schools of feeding capelin in summer or fall. The catches in recent years, shown in metric tons, were: 1963, 1077; 1964, 8600; 1965, 49,600; 1966, 124,000; 1967, 97,200; 1968, 78,200; 1969, 171,000; 1970, 188,600; 1971, 182,900; 1972, 270,000 (Source, FAO Yearbook of Fishery Statistics; personal communication, P. Olafsson, Reykjavik).

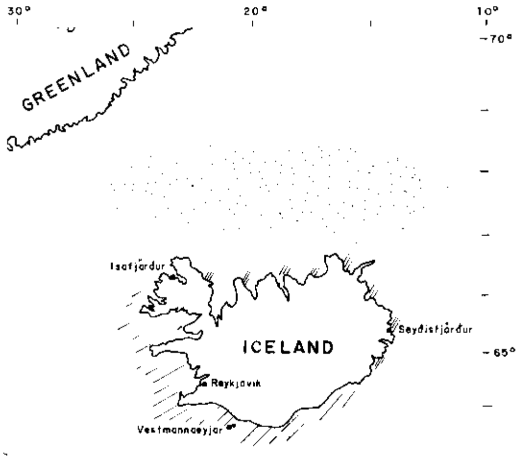


FIG. 18. Spawning and important feeding areas of Icelandic capelin. Most spawning takes place along the west or southwest coast.

BARENTS SEA, NORWAY, AND USSR

Capelin are abundant in the Barents Sea, and stocks there have been heavily exploited recently by Norwegian and Soviet fishermen. Capelin are a very important link in the food chain in this area; for instance, the large cod fishery in Finnmark exploits the cod which follow the capelin on their annual spawning migration.

The life cycle of the Barents Sea capelin has been studied extensively by Norwegian and Soviet scientists (Prokhorov 1965; Møller and Olsen 1962; Olsen 1968; Dragesund et al. 1971; Jakupsstovu et al. 1972).

Spawning occurs in March and April on the northern shores of Russia and Norway. The capelin move toward the coast from the north and east, and usually appear first on the Norwegian coast near the Varanger Peninsula (Blindheim and Monstad 1972). Several factors, such as water temperature, appear to determine the exact route and timing of the spawning migration. Indications are that in years of high temperatures capelin spawn mainly on the Russian coast, and in years of low temperatures on the Norwegian coast. (Olsen 1968). Routes of the spawning migration to northern Norway and the USSR are shown in Fig. 19.

After hatching, the larvae drift north and eastward with the surface water, and the year-by-year distribution is quite variable (Hognestad 1973). The 1-, 2-, and 3-year-old capelin are generally found along the boundary of the cold arctic water and the warmer Atlantic water in summer and fall (Corlett 1968; Gjösæter et al. 1972; Hylen et al. 1972). They are feeding heavily at this time and can have a fat content above 20%. A fishery for these large, feeding capelin has been carried out

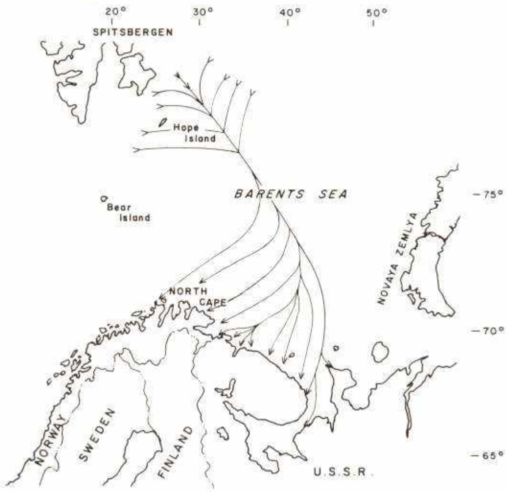


FIG. 19. Spawning migration of Barents Sea capelin (from Prokhorov 1968).

during the past few years by Norwegian purse seine vessels, and a record catch of 360,000 tons was recorded in 1972. Most of the catches were taken in the vicinity of Hope Island and were transported to reduction plants as far south as Bergen.

Although 1972 and 1973 were years of high abundance and catches of Barents Sea capelin (Jakupsstovu et al. 1972; Monstad and Kovalyov 1973), records show that both abundance and migration routes can be extremely variable. Norwegian and USSR catches in the Barents Sea for the past 15 years are shown in metric tons. (Source: FAO Yearbook of Fishery Statistics; ICNAF, Dartmouth, N.S.; International Council for the Exploration of the Seas, Charlottenlund, Denmark.)

	Norway	USSR
1958	91,700	1400
1959	79,000	3000
1960	92,800	4500
1961	217,200	1800
1962	400	3300
1963	28,300	6400
1964	19,600	400
1965	217,200	7300
1966	391,300	9700
1967	402,800	5700
1968	522,200	19,100
1969	678,900	900
1970	1,301,000	15,400
1971	1,371,100	20,800
1972	1,600,000	37,000[a]

[a]The USSR also took 66,200 tons off Newfoundland.

The most noticeable item in this table is the Norwegian catch for 1962. No commercial catches were taken near shore that year and only a few schools of capelin, in poor condition, were registered off the Kola Peninsula, about 150 miles east of Vardö. Therefore, it was assumed that spawning took place offshore much farther east than usual, even though oceanographic conditions were similar to those of 1961.

Large fluctuations in abundance can also occur due to the success or failure of the one or two year-classes which dominate the spawning stock.

Barents Sea capelin have been exploited by many generations of fishermen living along the coast of Finnmark. Since the schools often come close to shore, good catches could then be taken by seines or traps.

Norwegian catches have been recorded since 1914, when 23 tons were taken. That year must have been a complete failure since annual catches were later generally from 3000 to 8000 tons (Nitter–Egenaes 1967a, b). Towards the end of the 1950s, when the great winter herring fishery on the west coast started to decline, purse seiners switched to fishing capelin. Except for the 3 years from 1962 to 1964, when abundance was very low, catches have steadily increased. The size of purse seine vessels has also increased, and modern equipment such as power blocks has greatly increased efficiency, making it possible to fish further and further offshore. Since 1960 the Institute of Marine Research in Bergen has operated an extensive program of capelin investigations, and research cruises are carried out at least twice a year in order to evaluate the abundance and migratory pattern of the stocks.

A fishery for capelin has also existed on the Murmansk coast for centuries. As a rule the fishery lasted from March to July, with a peak in April (Prokhorov 1965). Until recently most of the catch was taken with fixed nets, and in 1953–55, 98–99% of the catch was made with this gear. In 1957–60 the capelin did not come to the Murmansk shore but migrated to the Norwegian coast, and most land-based gear was abandoned. Purse seiners and midwater trawls are now generally used.

Pacific Ocean

Little is known about the Pacific capelin. It can be found from Juan de Fuca Strait on the American side to Tumen River, Korea. It has been exploited by the Japanese, but catches have been diminishing in recent years. Soviet scientists have studied the stocks in the North Okhotsk Sea (Malkin and Chuzikov 1972; Shilin 1970).

In British Columbia, spawning has been recorded at several isolated areas along the coast from the Strait of Georgia north to the Queen Charlotte Islands. The species is not sufficiently numerous to be of economic importance (Hart and McHugh 1944; Hart 1973). Small quantities are used for food by local residents during the spawning period, when capelin are caught on the beaches with dipnets or buckets. Some species of salmon have been shown to feed on capelin, but no migration of larger fish preying on spawning capelin has been demonstrated.

Fig. 20. Capelin (angmagssat) dipnets and four east Greenlanders, Angmagssalik district, June 3, 1885.

The Fishery

Vessels and Gear

Traditional and shore-based gear — The peculiar spawning habits of the capelin have made it possible to catch considerable quantities with simple dipnets, buckets, and even bare hands. This is particularly true in areas where capelin spawn on the beaches, as shown in Figs. 20, 21, and 22. Small castnets are also commonly used in Newfoundland (Fig. 23).

Trapnets of various types have also been utilized in Norway and Newfoundland. A diagram of a trap currently being used in Newfoundland is shown in Fig. 24. The leader is set out from shore as shown in Fig. 25, and the capelin follow this into the trap. The net can be lifted to concentrate or dry up the fish so they can be transferred to the carrying vessels (Figs. 25, 26).

Clarke (1967) mentions that traps were used extensively in the 1940s and early 1950s in Newfoundland to supply capelin to a reduction plant in the western part of the province. Fish were pumped directly out of the trap into the carrier vessel, thereby eliminating most of the labor involved in the traditional methods of castnet and beach seining. Two fixed traps of 60 fathoms in the round and 7 fathoms

Fig. 21. Dipnet used for catching capelin in west Greenland about 1920.

FIG. 22. Beach-spawning capelin being caught in a simple dipnet in Newfoundland.

FIG. 23. Castnetting for capelin in Newfoundland. When capelin are not actively spawning on the beach, catches can be made with castnets or beach (bar) seines.

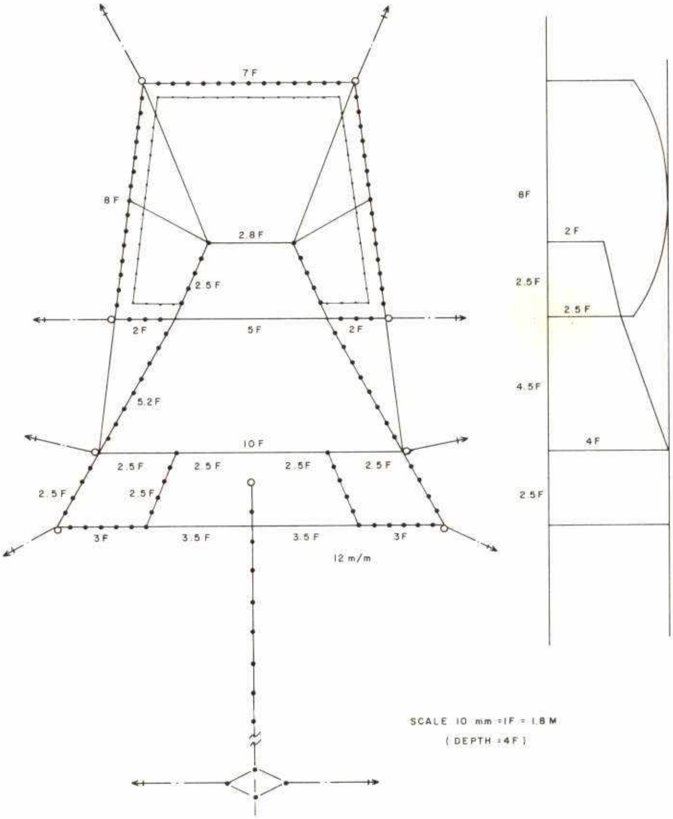


FIG. 24. Diagram of a capelin trap (Japanese type) used in Newfoundland.

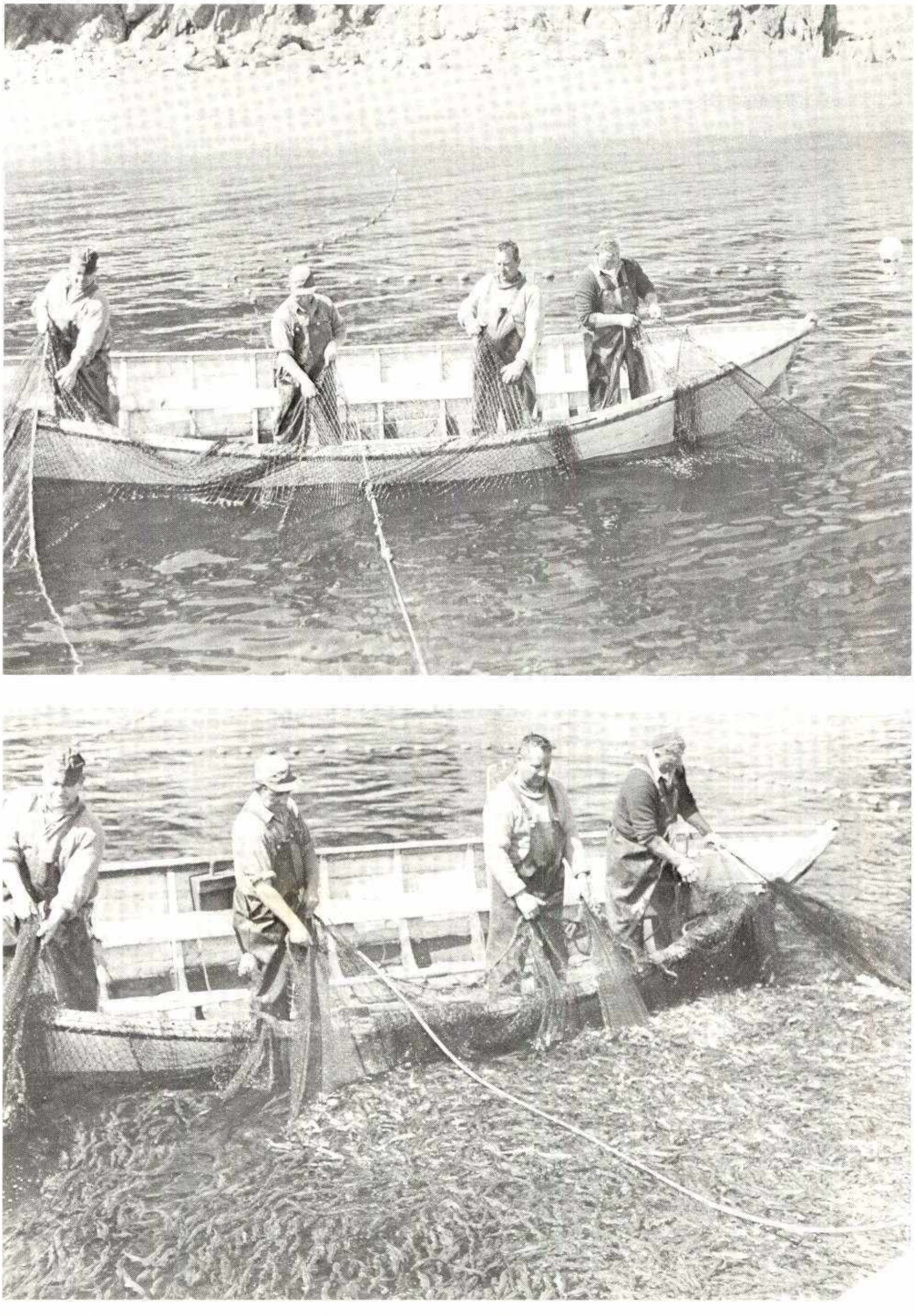


FIG. 25. *Upper*, starting to haul a Newfoundland capelin trap; the leader fastened to shore can be seen in the background. *Lower*, capelin trap being "dried up."

FIG. 26. Fish being brailed out of Newfoundland capelin trap.

deep were fairly successful, although capelin tended to get caught in the $1\frac{1}{4}$-inch mesh. A new trap with $\frac{3}{4}$-inch mesh in the bunt section was then constructed. However, later experiments with traps in Conception Bay yielded good catches of squid, and outside St. John's the trap filled with cod in pursuit of the capelin.

Beach bar or shore seines have also been used extensively. One end is run out from shore in a semicircle and the two ends are then hauled in from shore. Other types of nets that have been used successfully in Newfoundland are ringnets (Fig. 27), lamparanets, and "tuck" seines (Anon. 1973a).

Purse seines and seine vessels—By far the largest quantities of capelin are taken with purse seines. In the Icelandic capelin fishery, all of the catch is taken with this gear, and in Norway probably more than 90%.

Purse seining was first attempted in Newfoundland in 1946. Although herring was the principal species sought, a number of sets were made on capelin with a small purse seine, 150 fathoms (82 meters) in diameter and 12 fathoms (6.5 meters) deep. However, capelin were caught in the mesh until a finer bunt was added. About 1500 tons of capelin were taken by purse seines and traps from Placentia Bay in one season (Clarke 1967). In the period 1952–72 there was no capelin purse seining in Newfoundland.

Experimental purse seining for capelin was attempted on the Grand Bank spawning stock in 1972, with limited success. According to Hinds (1972), the low production experienced by the purse seiners could be attributed to lack of experience in seining capelin, gear and mechanical failures, adverse weather conditions, and lack of dense capelin schools.

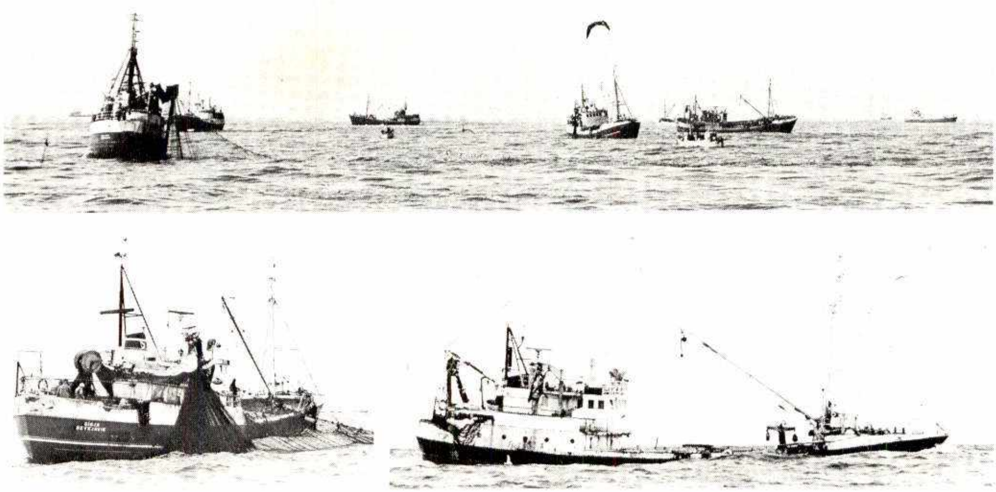
FIG. 27. Trapnet longliner adapted for ringnetting. This technique has proved effective for harvesting capelin and is now being used in Newfoundland waters.

The tremendous increase in landings of capelin in Norway and Iceland since the early 1960s has been due, to a large extent, to the rapid development of modern purse seine techniques and larger vessels. In the 1940s and 1950s, Norwegian herring and capelin seining was carried out close to shore with relatively small seiners capable of carrying 100–200 tons of fish. The seine was set from two dories or seine skiffs and hauled by hand. The introduction of hydraulic power blocks and ring-nets in the 1960s meant that the seine could be set and hauled mechanically and set under adverse weather conditions; also, fewer crew members were required. Calcium carbide pellets, dropped in the water from the skiff, helped to herd fish into the net. Larger vessels were built and several Norwegian seiners can now carry 1000 tons or more, and can operate several hundred miles from shore. Icelandic vessels are largely built in Norway and are, therefore, similar in construction. Figures 28, 29, and 30 show typical purse seiners from Norway and Iceland during fishing operations and underway with a full load.

The purse seines are constructed differently than those used for herring. Since capelin will die quickly and sink to the bottom of the net during pursing, smaller and shallower seines are usually used. A typical Norwegian capelin purse seine is shown in Fig. 31. It measures 210 meters/115 fathoms hung-length × 94 meters/51 fathoms stretched depth, whereas mackerel or herring seines are 549 meters/300 fathoms × 165 meters/90 fathoms.

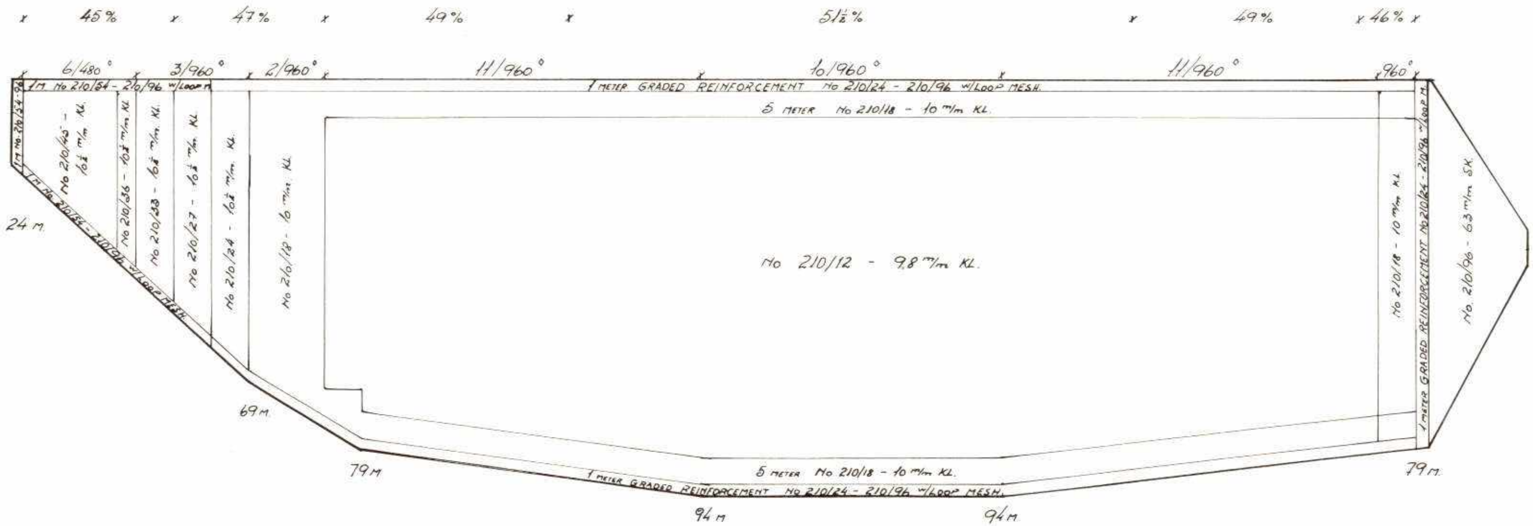
Trawls and trawlers — Capelin can at times be caught by bottom trawl, especially on the Grand Banks of Newfoundland, and they have frequently been taken there during cruises by Fisheries Research Board of Canada research vessels. However, capelin are pelagic during most of their life cycle, and midwater trawls have been demonstrated to be a most efficient gear for commercial exploitation, particularly when fish concentrations are not dense enough for purse seining.

A midwater trawl used by the *Foam V* in the experimental fishing trials off Newfoundland was a Canadian "Diamond VII" trawl,



FIGURES 28–30

FIG. 28. *Top*, purse seiners on the capelin fishing grounds off Iceland. FIG. 29. *Left bottom*, hauling the purse seine with the power block. FIG. 30. *Right bottom*, typical Norwegian or Icelandic purse seiner with a capacity load of capelin.



Type: PURSE SEINE (CAPELIN)

Hung length along corkline: 210 Fms.
Hung length along leadline: 237 Fms.
Stretched length:

Stretched depth: 24 - 69 - 79 - 94 - 79 METRES.
Nos. of panels: 6/480 MESH. 38/960 MESH.
Meshsize in bunt: 10½ m/m.
Meshsize in body: 9.8 m/m.
Meshsize in choke: 63 m/m.

Float rope: 14 m/m braided multiflex
Corkline rope: 2 parts 16 m/m terylene over bunt, 2 parts 18 m/m terylene.
Leadline rope: 1 part 16 m/m terylene, 1 part 14 m/m terylene.
Bridles: Nylon rope 18 m/m.
Sinkers: 1.700 kilos
Floats: 1540 pcs. reinforced 6" x 7½"
Purserings: 28 pcs. stainless steel - 6 kgs ea.
Breast rings: 10 pcs. 7.05

Ref.:
Treatment of netting:
Treatment of ropes:
s.k. = single knot k.l. = **knotless (Raschel).**

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BERGEN, NORWAY, MARS 1973
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FIG. 31. Typical capelin purse seine.

designed by Mr W. W. Johnson, Industrial Development Branch, Fisheries and Marine Service, Environment Canada, Ottawa. A diagram of this midwater trawl is shown in Fig. 32. A series of "Diamond" trawls is available to match various sizes of engines.

In Norway a number of small vessels (60-100 feet) fish for capelin with midwater trawls when the schools of spawning fish are close to shore. A sketch of a commonly used Norwegian midwater trawl is shown in Fig. 33. This type of midwater trawl is towed with four doors in relatively shallow water. The 12 × 12 fathom trawl is normally used by vessels 80–100 feet long having 250–400 hp engines, the 14 × 14 fathom trawl by vessels 100–120 feet and having 400–700 hp engines, and the 16 × 16 fathom trawl by 120-foot or larger vessels having 700–1200 hp engines and a loading capacity of 250–400 tons.

The flexibility of the midwater trawl could possibly be used to economic advantage when fishing on or near capelin spawning grounds. At the present time there is a certain demand for female capelin for the Japanese market. Since male and female capelin are often in separate schools on the spawning grounds, a high proportion of female fish could be caught by adjusting the depth of the trawl once the distribution of the two sexes had been determined by trial fishing.

Electronic gear — The tremendous increase in world-wide capelin catches in the past decade would not have been possible without the electronic fish-finding gear now available and in use by the fishing fleets.

The vertical echo sounder was first used to register fish concentrations in 1934, but improved equipment in use today is sensitive and powerful enough to register single fish at great depths. Several types of integrators and computers which can count fish registrations, add them up, and print them out are in use on research vessels from several countries (Midttun and Nakken 1971). The equipment has to be calibrated for each fish species by means of fishing trials. The results are most reliable on scattered schools of fish.

The development of sonar over the past 2 decades has revolutionized the ocean fishery for pelagic fish such as capelin. Instead of only being able to spot fish schools directly under the vessel, as with vertical echo sounders, fishermen can scan an area at least 1000 meters (3000 feet) on each side while the vessel is underway. Newer, more powerful sonar units have a calculated range, under ideal conditions, of 4000 meters (13,000 feet) in any direction. Sonar is skillfully used by fishing skippers while setting seines or trawls (Fig. 34). The small seine skiffs used in Norway also have echo sounders to assist in the final catch phase.

Sophisticated electronic gear is sometimes used on midwater trawls to record the depth at which the net is travelling, the effective opening of the trawl, and the location of fish schools. These net recorders make it possible

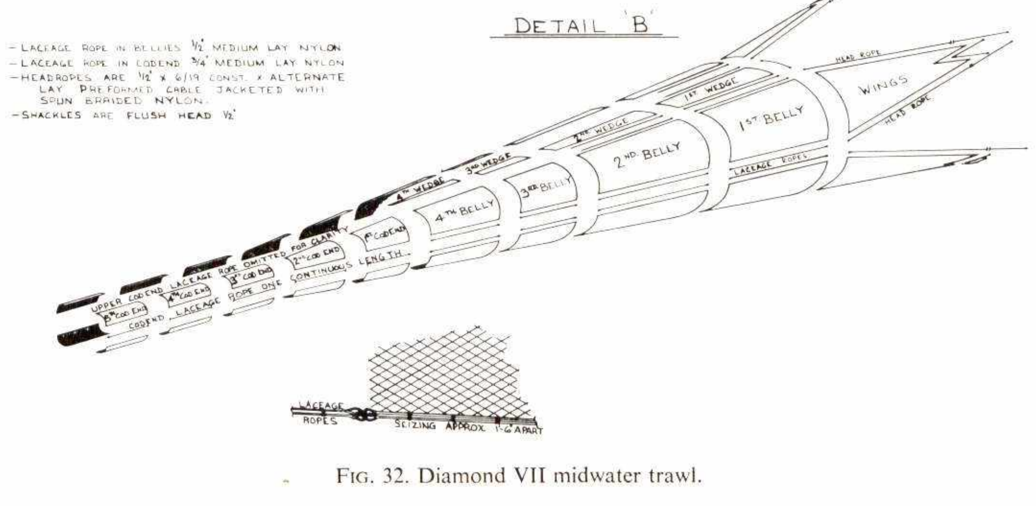


FIG. 32. Diamond VII midwater trawl.

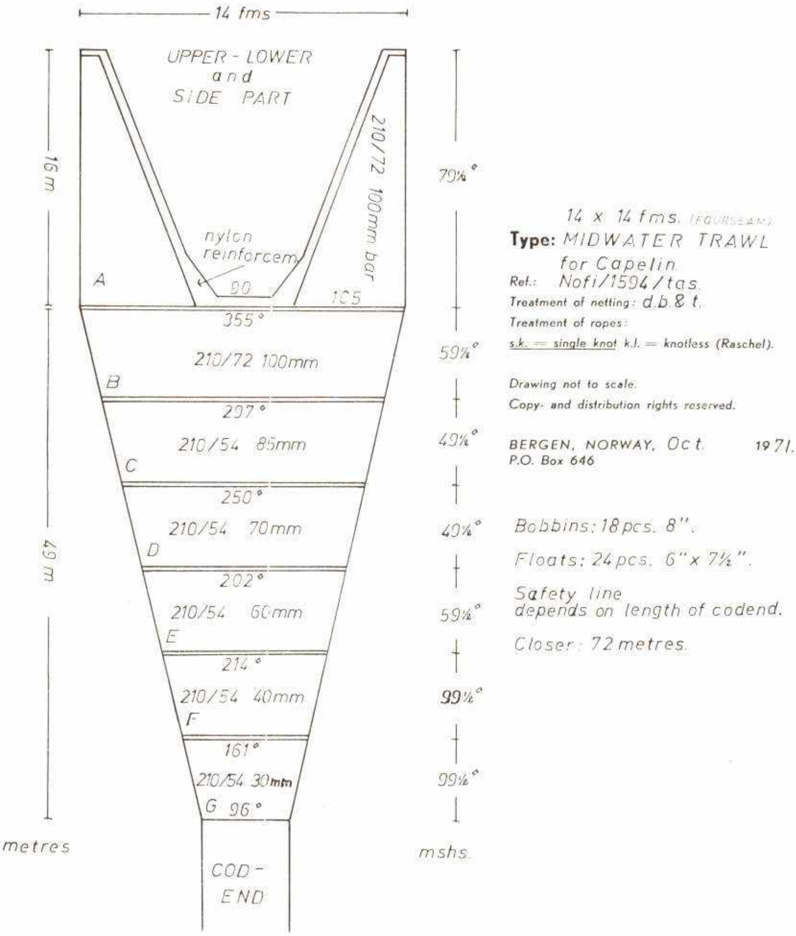


FIG. 33. Midwater trawl used in the northern Norway capelin fishery.

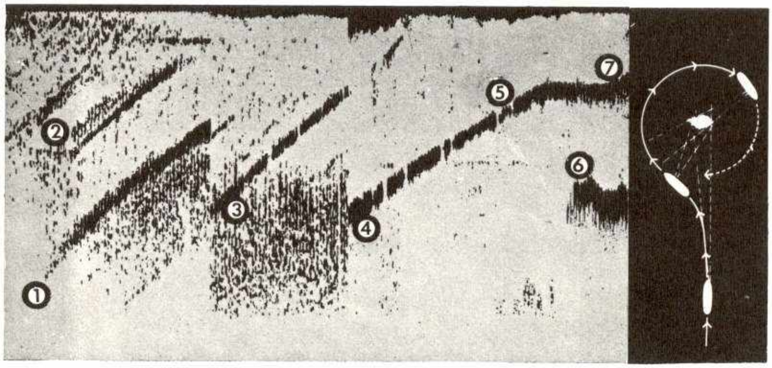


FIG. 34. Use of sonar in purse seining capelin. 1, range 0–1500 meters, contact with school 1400 meters away. The vessel changes course towards the school and the distance decreases; 2, smaller schools closer to the vessel; 3, range 0–750 meters, school 500 meters away; 4, range 0–250 meters, school 150 meters away. The skipper trains the sonar beam to the sides of the school and estimates its width and the direction it is moving; 5, purse seine set; 6, net set halfway around the school; 7, purse seine set.

for the skipper to quickly raise or lower gear to take advantage of available fish concentrations.

Handling the Catch

For human consumption or bait — Capelin intended for uses other than reduction must be handled with care while being removed from the net, transported on the vessel, and unloaded ashore. The methods employed depend, of course, on the fishing method and the size of the catch.

Trap-caught fish are taken from the nets with dipnets and brought to shore immediately in small boats. If the air temperature is not too high, fish handled in this way should be of excellent quality, although ice should be used whenever possible. Walking on the fish must always be avoided.

Capelin caught in midwater trawls are usually dumped into the hold directly from the cod end. To avoid crushing the fish, hauls should be of shorter duration than when the catch is destined for the fish meal plant. Use of boxes or refrigerated sea water is recommended if a high percentage of the catch is destined for human consumption. As much water as possible must be drained from the fish before transfer to the hold, and the cod end must be handled carefully.

Fish caught in purse seines are almost always pumped on board the vessel, although until quite recently brailing was used extensively in Norway. Pumps should have a large diameter and be operated at slow speed. It is important that the vessels have screens and drains so that the fish are as dry as possible when placed in the hold (Fig. 35).

Capelin for human consumption must be handled on board the vessel in the manner customary for all food-grade fish. Norwegian guidelines (Anon. 1972c) specify that the raw material be transported on fishing vessels: a) "In boxes of wood, plastic, or aluminum"; b) "Chilled in tanks according to the usual guidelines, under the conditions that fish carried in tanks are suitable raw material for the intended product"; or at c) "The top of bulk cargoes."

A number of purse seiners now have tanks that can be chilled mechanically or with ice. Tank temperature is usually kept at –1 to –3°C (30–26°F), and the ratio of fish to water at about 4:1. Since capelin do not have large scales like herring, there are reportedly less difficulties with water circulation due to clogging of screens, although the roe may clog fine mesh screens. Pressure on fish at the bottom is much less than when carried in bulk because of the buoyancy of fish in water. Low

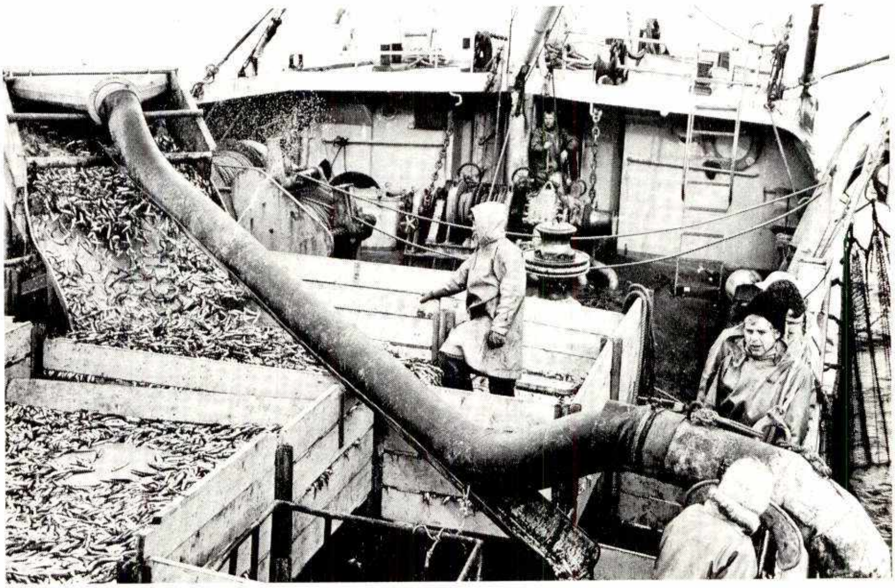


Fig. 35. Capelin being pumped from purse seine into vessel. Note screens used to drain water from fish.

temperatures greatly retard bacterial and enzymatic deterioration of quality. Capelin carried in refrigerated sea water, and later frozen and shipped to Japan, were judged to be of excellent quality by the Japanese buyers.

If carried on top of bulk cargoes, it is essential that no preservatives, often used in Norway on fish for reduction purposes, be permitted on board at all. Pumping or brailing of fish must be carried out carefully and slowly in order to drain the fish thoroughly.

Fish must be unloaded carefully to avoid damage. Various types of conveyors can be used (Fig. 36) and at this stage pumping should be avoided. Grabs are used extensively in Norway (Fig. 37). These should be equipped so that they do not close completely and crush the fish.

For reduction to meal and oil—Practically all capelin purse-seined for reduction are pumped into the hold of the vessel. It is extremely important for good storage that the fish be well drained and dried completely before entering the hold. Capelin have a high water content near spawning time and a quantity of "bloodwater" will be pressed from the fish. If excess sea water enters the hold with the fish it will greatly increase the amount of bloodwater and decrease the keeping time.

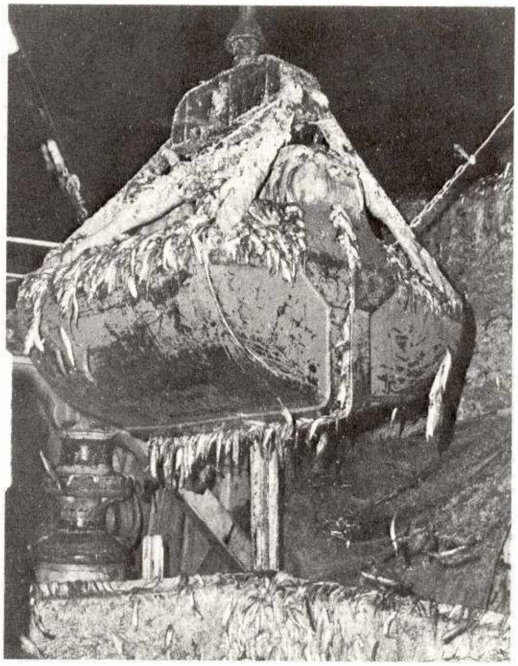


FIG. 37. Unloading capelin with a grab at a reduction plant in Norway.

FIG. 36. Trap-caught capelin being unloaded with conveyor, Cape Broyle, Newfoundland.

Preservatives — Since the capelin fishery in Norway is often carried out several hundred miles from the coast, and since the fish sometimes have to be stored for several weeks before being processed, preservatives are used at certain times of the year. Intensive research into various types of preservatives, their effectiveness, quantities to be used, residue levels, toxicities, etc. has been carried out for a number of years at the Research Institute of the Norwegian Herring Meal and Oil Institute. A good summary has been published by Sand (1966).

About 1950 the Norwegian fish meal industry started to produce "whole meal" by evaporating the stickwater and adding the solubles back to the meal. Common salt could then no longer be used as a preservative since it would make the salt content of the meal too high. Following experimentation, regulations for the use of sodium nitrite as a preservative were issued in 1953. Later it was found that small amounts of nitrite used with formalin effectively prevented both bacterial spoilage and a high free fatty acid content in the oil produced. The preservative used by the Norwegian fishing fleet since 1965 is the so-called V65, which contains 500 ml formalin and 125 grams of sodium nitrite per liter. This solution must be added to the fish with accurate metering devices to make sure that excessive amounts are not used. Regulations are issued each year regarding the quantities of V65 that can be used, and for the summer and fall capelin fishery in 1972 the quantities were 150 ml or 350 ml V65 per hl (1.5 or 3.5 liter per ton), depending on the distance fish had to be transported. Since the fishery was carried out near Hope Island, south of Spitzbergen, and the catches were carried as far south as Bergen, some vessels travelled more than 1000 miles to unload. The Norwegian pricing system includes a mileage allowance in addition to the price paid for the fish.

Keeping time can be extended considerably by using V65. Experiments carried out during the winter capelin fishery (Lohne 1968) showed that fish could be kept for about 60 days at 0–4°C, compared to 5 days for the unpreserved control.

Research has continued in order to find preservatives that are less toxic than sodium nitrite. Under normal conditions, nitrite decomposes at a fairly steady rate. The fish must not be processed until the concentration has dropped below 150 ppm (Urdahl and Halvorsen 1968). The resultant meal should then have a nitrite content well below permissible limits (Lohne 1967, 1968; Lohne and Utvik 1967). If fish containing high concentrations of nitrite — 2000 ppm (0.2%), for example — are processed, dimethylnitrosamine (DMNA), a toxic and carcinogenic substance, might be produced and carry over into the meal (Ender et al. 1964, 1967; Ender 1966; Sakshaug et al. 1965; Aas-Hansen 1964; Koppang 1964). Therefore, analytical control of the raw material is essential.

A preservative that has shown some promise, if used on strictly fresh raw material, is sodium benzoate and formalin (Ström 1969; Lie and Ström 1970; Lie 1971). Capelin could be kept for 3–4 weeks at 2–4°C as compared to less than 1 week for unpreserved raw material.

Unloading — In Iceland, all unloading of capelin to be used for meal and oil is carried out with pumps since the fish are usually fresh due to the short distance from the fishing grounds to the reduction plants (Fig. 38). Pumping is also carried out in Newfoundland (Fig. 39).

In Norway pumps are not used at all because quantities of bloodwater containing soluble protein often collect in the hold of the vessel; this would be lost during pumping because the fish are drained before entering the weighing scales. In the summer, when capelin are fat, considerable quantities of oil are also liberated and would be lost. Thus, vessel owners and crew could be paid for 20–30% less fish than they actually took on board. In addition, a serious pollution problem would occur in the harbors. As a result, all unloading in Norway is carried out with grabs or bucket elevators so that little liquid is lost (Fig. 39). The bloodwater remaining in the hold of the vessel after the fish have been unloaded is pumped into tanks on shore.

Processing and Utilization

For Human Consumption

Fresh and frozen. Traditional use — Fresh capelin have traditionally been used for food by people living in areas where the fish spawn annually close to shore. Jeffers (1931) quotes several authors to the effect that capelin have been known as an excellent food fish for centuries. For instance, Jensen (1925) wrote that the Greenlanders boil and eat large quantities during the spawning run, in addition to drying large numbers for winter provisions. Fraser (1916) states that it is considered a delicacy, and Bigelow and Welsh (1924) write that it is a delicious little fish on the table. Cuvier and Valenciennes (1848) remark that "it is as splendid as a sardine . . . its flesh is very delicate comparing perhaps with that of the gudgeon, but it has a very particular and characteristic taste." Prokhorov (1965) states that when large capelin catches are being made, there is hardly a family in Murmansk that does not use fried capelin.

Most capelin eaten fresh are caught during the spawning migration, when the fat content is low and the fish are in relatively poor physical condition. Many reports indicate that fat capelin taken in summer or fall, or during the overwintering period, have superior flavor and eating quality (Winters 1960; Prokhorov 1965).

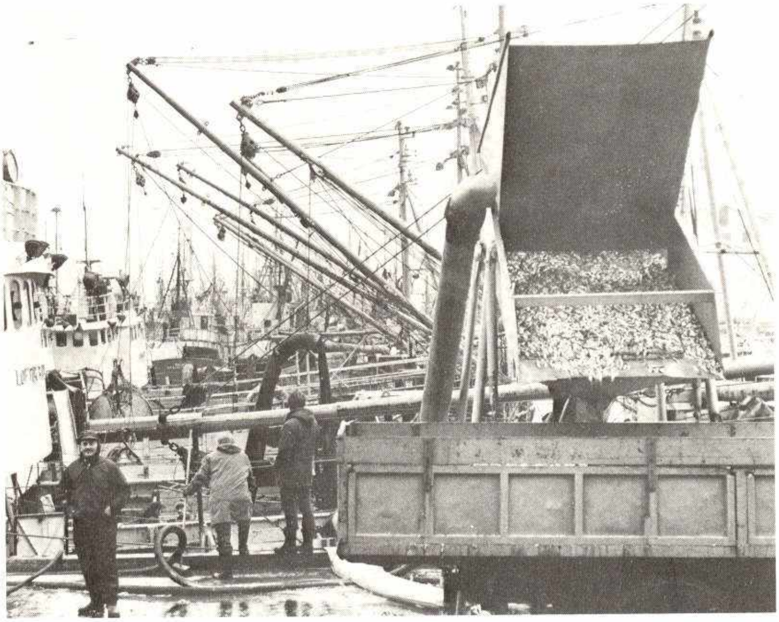


FIG. 38. Capelin being unloaded by pumps from seiners in Vestmannaeyjar, Iceland. Before the catastrophic volcanic eruption in 1973, which destroyed a large part of the city, this was the center for the Icelandic capelin fishery.

FIG. 39. Fishpump being used to unload a dory, Harbour Breton, Newfoundland.

People living along the northeast coast of Newfoundland and the Labrador coast as far north as Nain have been reported to catch capelin for use as food through cracks in the ice in winter when the fish are in good condition (Templeman 1948).

Fresh and frozen. Current use and future prospects — The utilization of fresh capelin is limited to the area immediately adjacent to where the fish are landed. Increased utilization must be based on frozen raw material. Comparatively lean capelin (1–8% fat), caught while the fish are on their spawning migration, have been shown to stand up well in frozen storage; they can often be stored for at least a year without any objectionable deterioration in eating quality. Few, if any, controlled studies have been carried out on the storage stability of fat capelin caught in the summer or fall.

Although the reason for the good frozen storage stability of capelin has not been studied, it could be partly due to the low iodine value of the depot fat. Herring, however, are susceptible to rancidity in frozen storage, even though the iodine value of herring oil in some cases is as low as that of capelin oil (100–110). The distribution of depot fat globules in capelin muscle tissues is probably different from that found in herring, since it is often difficult to press enough oil from capelin following normal cooking in a fish meal plant. Cooking at lower temperatures (60°C) seems to assist in liberating the oil globules (Lohne and Utvik 1971). It is also possible that the natural antioxidants, such as tocopherol, may be concentrated in capelin fat as this is depleted during the spawning migration. The absence of a subdermal fat layer may improve keeping ability compared to other similar types of fish.

The difference in size between female and male capelin during the spawning migration makes it possible to a certain extent to separate them in commercial grading machines based on the thickness of the fish. The roe-containing females have been frozen whole in recent years and exported to Japan, where they are further processed by drying after a short dip in salt brine (see p. 40). Norway, Iceland, and the USSR supplied most of this product (7000–8000 tons in 1972 and about 45,000 tons in 1973).

The grading machines that have been used in attempts to separate female fish from males are essentially herring-grading machines, which separate on the basis of thickness across the back. However, since there is always more than one year-class present in the spawning schools, and since the growth rates of fish of similar ages are different, some small male capelin are invariably mixed in with the females. Over 70% female fish can be obtained, but even so a high labor content in the grading and packaging of this product is required (Fig. 40).

Japanese buyers usually negotiate directly with the producer regarding the percentage of female fish and the degree of ripeness of fish required in a shipment. A generally accepted guide is that the weight of the roe should be 15–20% of fish weight, although higher or lower values might be acceptable.

The Norwegian Directorate of Fisheries has issued guidelines for the handling and freezing of capelin for Japan (Anon. 1972c). Recommendations regarding treatment on board the vessel are given, and under "Quality Requirements at Freezing" the following points are listed:

> The fish must be as dry as possible.
>
> The fish must still be completely or partly in rigor.
>
> Fresh odor and natural, fresh appearance (color). Capelin with blood in the jaws or which are red around the eyes cannot be used for freezing and must be graded out.
>
> The fish must be whole with head and skin intact and must not be damaged. Fish that have been damaged during unloading or by pressure from having been walked on are not suitable for this purpose and must be removed.
>
> The fish must be clean when frozen. Freezing must be carried out immediately after the produce has been packed.
>
> When freezing in a tunnel (blast) freezer, the produce shall be frozen through to a temperature of –20°C (–4°F) or colder within 24 hours after being placed in the freezer. When contact freezing (plate freezing) is used, the produce must be frozen through to a temperature of –15°C (+5°F) in a period of hours which does not exceed the thickness of the block measured in centimeters.
>
> After freezing, the blocks can either be glazed with water or be protected by wraps of a suitable type and/or packaged in waxed cartons, all according to agreement reached with the buyer.
>
> The product shall be placed in frozen storage immediately after being frozen and stored there at a temperature of –20°C (–4°F) or colder.

The larger male capelin left after grading should also be marketed frozen in order to fully utilize the raw material. Since there is already a market for eviscerated frozen smelts in North America, this appears to be the most promising outlet for these fish.

For smaller operations, and while the market potential is being tested, the gutting of capelin and the removal of the head can be carried out manually with scissors, knives, or shears. The largest sardine cannery in Canada still finds this type of processing economical, especially since herring of various sizes are encountered. However, the sardine packing operations do not include gutting.

The few studies carried out on frozen capelin indicate that the fish should be completely eviscerated and the stomach cavity thoroughly cleaned before packaging and freezing. However, these operations could be carried out on frozen and thawed capelin, and the product packed in consumer packs and refrozen. If this product met with approval in the market place, more or less continuous processing could be carried out using frozen capelin as raw material.

In Newfoundland, knives have traditionally been used for heading and gutting capelin. Sepic and MacCallum (1969) studied the use

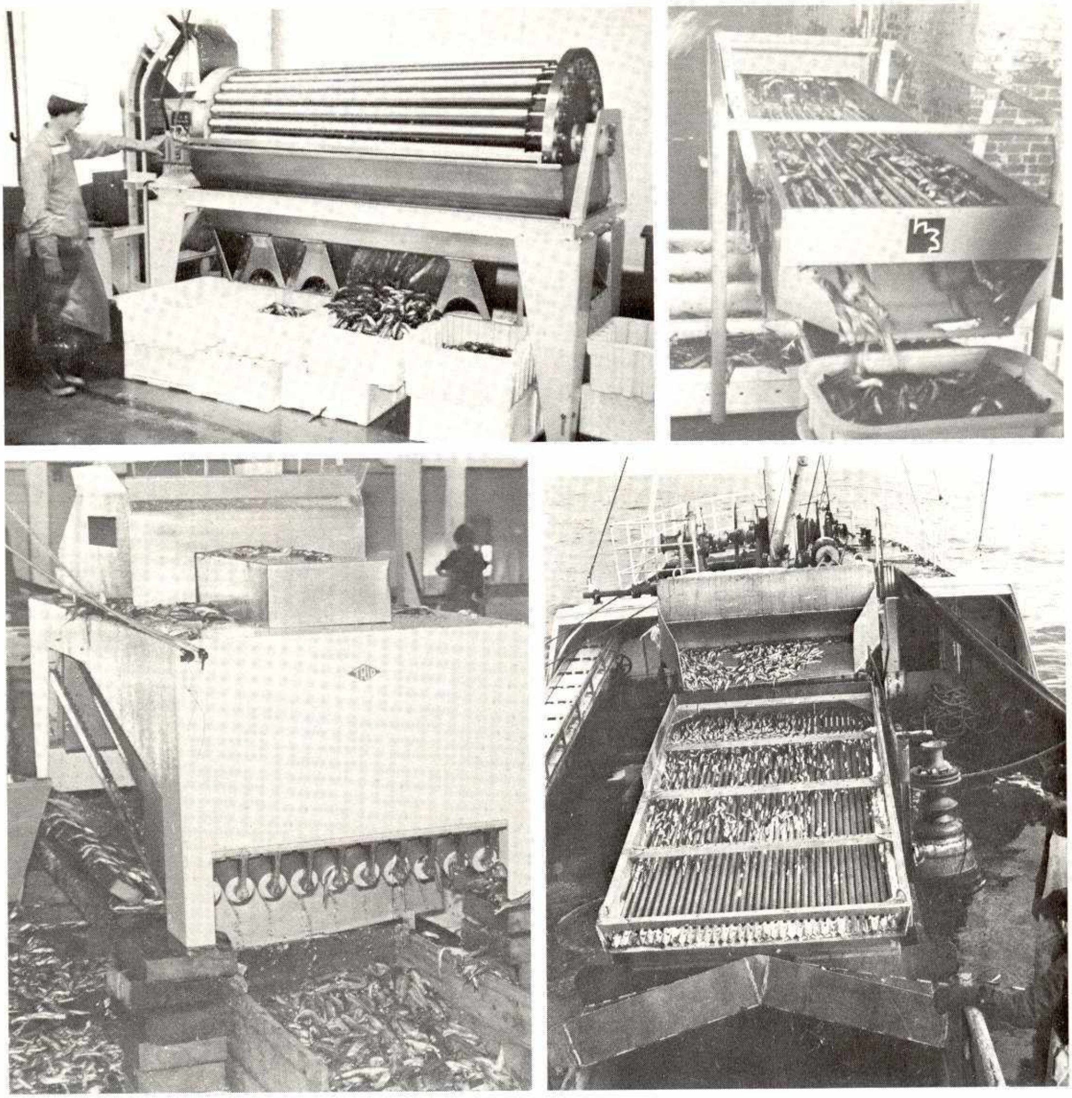


FIG. 40. Various makes of grading machines being used to separate female capelin from the males by size difference.

of a type of hand shears which is used successfully in Mediterranean countries for heading and gutting small fish prior to canning. Two experiments were carried out in St. John's, with the persons participating having had no previous experience in using the shears. The capelin numbered 12–14 per pound, and the operators headed and gutted an average of 120–130 pounds of capelin per hour. This is about four times as many as were processed in Newfoundland plants with knives. The appearance of the cut was satisfactory for both males and females.

If markets are developed for headed and gutted capelin, large operators might want to investigate the use of machinery. Relatively simple "home-made" but patented gutting machines for smelts have been in use in eastern Canada for some time and could be adapted to process capelin. One company in Ontario uses modified commercial machines to head and gut smelts from Lake Erie; it has a total processing capacity of 150,000 pounds a day.

Two major firms currently manufacturing a complete line of fish processing machines (the Swedish company, Arenco, and the German company, Baader) have carried out trials with capelin and have shown that with certain adjustments several of their machines, originally designed for herring, can be used for capelin. The following operations were performed: removal of tail fin; removal of head; removal of pelvic fins with a narrow strip of belly towards the vent, thus opening the belly; removal of entrails; and cleaning of belly cavity and blood vein along the main bone. Single fillets and butterfly fillets can also be produced with existing machines after slight modifications (Fig. 41, 42).

FIG. 41. Capelin being fed into a dressing machine.

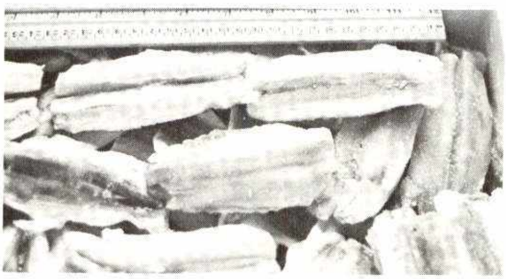


FIG. 42. Frozen machine-processed butterfly fillets from male capelin.

In herring processing, "nobbing" refers to the operation of cutting off the head and pulling out the intestines of the fish, leaving behind any roe or milt. These nobbed herring are then pickled in salt or various spice and salt–sugar mixtures. Capelin have been run through these nobbing machines with satisfactory results. However, even if the remaining roe or milt might be acceptable or even sought after in some markets, it is doubtful it would be acceptable in North America. Off-flavors have been known to develop in the gut cavity region in both frozen and canned capelin. It is not known if these are due to development of rancidity in fatty tissues such as the liver, or to other types of off-flavors occurring in the milt or roe. Therefore, for capelin to be frozen and marketed in North America, it appears that a complete gutting cut with brushing and thorough washing of the gut cavity, including perhaps the removal of the black gut lining, would be preferable.

Although not much work appears to have been carried out on the processing of fat, fall-caught capelin, reports indicate the eating quality is excellent. A Soviet author (Prokhorov 1965) points out that capelin caught at this time would be better raw material for frozen and canned products than fish caught during the spawning migration in spring and summer. Recent reports indicate that Soviet factory vessels are catching considerable quantities of fat capelin off Newfoundland and Labrador (Kovalyov and Kudrin 1973). There are only slight external differences between males and females at this time of the year.

Cookery — Recipes for cooking capelin have been prepared by the Canadian Fisheries and Marine Service and were supplied by Miss C. O'Brien, the Consumer Consultant in St. John's, Newfoundland. (See appendix)

Canned: (heat sterilized) — Acceptable canned products have been produced from capelin in several countries, although only minor quantities have so far been marketed in North America and Western Europe.

In 1925 the Department of Marine and Fisheries of Newfoundland employed an expert from the British Columbia salmon canning industry to conduct experiments on the preparation of capelin (Jeffers 1931). He reported that capelin can be successfully canned after a simple method of dehydration has first been adopted. In 1932 a series of canning experiments were carried out at the Fisheries Research Laboratory in St. John's (Sleggs 1933).

The fish were brined and then canned with a small quantity of sauce; the product was rated successful as regards firmness and flavor.

The most successful canned capelin packs tested have generally been lightly smoked products packed in vegetable oil. A businessman in St. John's, W. J. Bursey, packed several thousand cans of this type and reported a favorable response from test marketing.

Horne (1961) reported on experiments carried out at the Fish Inspection Laboratory in Halifax with both fresh and frozen male capelin as raw materials. The following unsmoked packs were investigated: (a) steamed raw on wire racks, guts in, heads on; (b) steamed raw on wire racks, guts out, heads off; (c) brined, steamed on wire racks, guts in, heads off; (d) brined, steamed on wire racks, guts out, heads off; (e) packed raw in cans, guts in, heads off, steamed, then inverted to drain.

Following precooking, in the first four types of packs, the fish were trimmed, all fins were removed, and the fish were cut for packing in 3½-ounce sardine cans. Following packing and steaming, the cans were processed for 65 minutes at 110°C (230°F).

All six packs were considered unsatisfactory, either because the fish stuck to the wire mesh and the texture of the fish became such that they would not withstand the handling necessary for packing in cans, or because when the raw fish were packed in cans and then precooked a mushy broken-up product resulted.

Smoking was carried out in a smoker dryer unit for 120 minutes, the temperature of the smoke being 54–66°C (130–150°F).

The following eight types of smoked products were investigated: (a) smoked on wire racks, guts in, heads on; (b) smoked on wire racks, guts out, heads on; (c) brined, then smoked on wire racks, guts in, heads on; (d) brined, then smoked on wire racks, guts out, heads on; (e) threaded on wire spindles, smoked, guts in, heads on; (f) threaded on wire spindles, smoked, guts out, heads on; (g) brined, threaded on wire spindles, smoked, guts in, heads on; (h) brined, threaded on wire spindles, smoked, guts out, heads on.

Although all eight types of smoked capelin were considered satisfactory, it was found that when the raw fish were smoked on wire racks, the fish stuck to the wire mesh. Brining the fish prior to smoking greatly improved this condition. When "guts in" fish were smoked, the fish remained softer, due to the non-drying of the inner part of the fish. By threading the fish on wire spindles (through the head), better drying resulted.

In effect, two main types of smoked capelin were investigated: smoked capelin guts in and smoked capelin guts out.

When the cans were opened the fish had a pleasing appearance, arrangement had been maintained, and the texture was good, with no noticeable flaking or breaking having occurred. However, those fish in which the guts had been left in had slightly poorer odors and flavors than did the gutted fish. It was generally agreed that by packing "guts out" a good product resulted, somewhat similar to smoked sprats and undoubtedly with the same consumer acceptance.

It was shown in this study that frozen capelin stored at –24°C (–12°F) for periods of 2, 4, and 6 months could be utilized in the production of a pack measuring up to these standards. Capelin which had been frozen at –24°C (–12°F) for over 2 months were defrosted in running tap water and gutted. They were threaded through the head with spindle wires and smoked at 54–66°C (130–150°F) for about 2 hours. At the end of this time the surfaces were dry and had a golden brown sheen. After they were trimmed and packed into 3½-ounce oblong sardine cans, olive oil and about a teaspoon of salt were added. The cans were autoclaved for 1 hour at 110°C (230°F) and immediately cooled in running tap water.

This canned product was rated acceptable by fish inspection grading. The general appearance was excellent. The fish were whole, the texture firm, the flavor good, and the degree of smoking was just right to impart the proper flavor. There was a minimum of liquid to drain from the product.

Experiments with canned prespawning male Newfoundland capelin were also carried out by Lantz (1966) and his procedure, slightly modified by D. G. Iredale, Fisheries Research Board of Canada, Winnipeg (personal communication), was as follows:

The headed and gutted capelin were washed, immersed in 80° salinity brine at 16°C (60°F) for 1 minute, drained on screens for 1 minute, and placed in the smokehouse. Smoking was carried out for 20 minutes, with a kiln temperature of 38°C (100°F) rising to 68°C (155°F), followed by drying for 75 minutes in 60% relative humidity air flowing at 60 feet per minute. The capelin were then trimmed, the tails were removed, and they were packed in 4-ounce oblong cans (can size 405 × 301 × 014), with 20 ml or ½ ounce vegetable oil added per can. The cans were sealed under a 20-inch vacuum. Retorting was carried out for 50 minutes at 116°C (240°F) and cooling at 10 psi for 15 minutes in cold water at 4°C (40°F).

An alternate method was suggested by Iredale. Capelin were headed, dressed, washed, brined, and drained, as above. The fish were then packed in cans and given a steam precook for 35 minutes at 99°C (210°F). The cans were inverted and allowed to drain for 5 minutes. 20 ml soybean oil plus 2.5% smoke oil flavoring were added, and the cans were sealed and processed as above (Fig. 43).

The Research Laboratory of the Norwegian Canning Industry in Stavanger has carried out numerous experiments with capelin over the past few years (A. Olsen, K. H. Skramstad and R. Ragård personal communication) with the following results:

Prespawning capelin caught in January and February north of Vadsö were canned in different combinations for comparison: small or large fish; headed and guts pulled out, or whole; smoked or not smoked; packed in brine or oil. The results were variable, but the quality was generally judged to be better in smoked fish than in non-smoked fish. The gut contents had a strong detrimental effect on the quality of the products. Headed, gutted, and smoked capelin resulted in the most attractive product.

Capelin steamed in cans showed a weight loss of about 20% for large capelin and about 10% for smaller fish.

Smoked capelin were packed in oil on several occasions and the conclusion was reached that the "undesirable capelin smell/taste" was least noticeable if the gut content was completely removed and the fish subjected to a lengthy smoking and drying period before canning.

They recommended that the stomach must first be completely removed with a "cross-cut" and that it was important that none of the black membrane remain. The capelin were then immersed in a 20% brine for 2 minutes, a special brine containing 0.2% metabisulfite producing the best results. The fish were then threaded on rods and smoked for 30 minutes at 70°C; then the head, tail, and preferably the large anal fin were removed. The finished

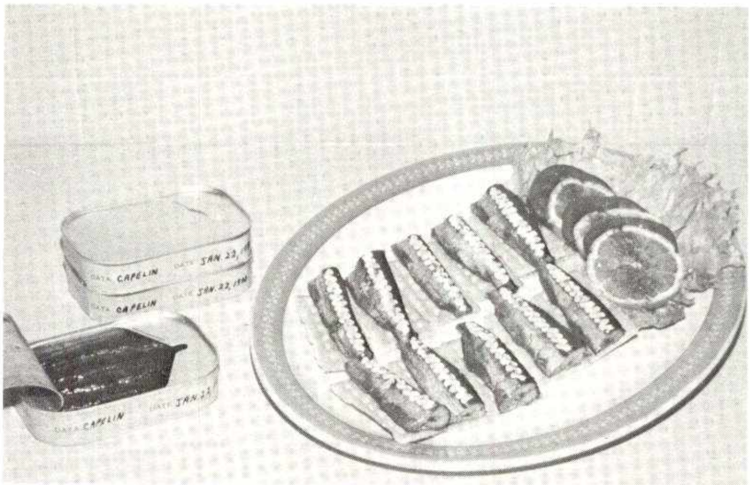


FIG. 43. Smoked capelin canned in oil.

product was similar to smoked herring, but did not have as attractive an appearance as sprats or sardine herring.

A number of other canned products have been prepared from capelin at the Research Laboratory of the Norwegian Canning Industry. Very few of these were considered acceptable, at least for the Norwegian market. According to reports from the laboratory, the flavor of canned capelin tended to be "bitter" or "sharp," and on storage the fish took on the flavor of old, poor quality herring. This was considered to be due to the high content of trimethylamine (TMA) and trimethylamine oxide (TMAO) in capelin (personal communication, R. Ragård, Research Laboratory of the Norwegian Canning Industry). Addition of a reducing agent, such as metabisulfite, tended to remove this off-flavor. The high content of TMA also tended to discolor the tomato sauce in packs of this type. However, one of the most promising products developed was a capelin paste containing tomato paste and spices; it retained an appetizing appearance and flavor on storage. Since the fat content in Norwegian prespawning capelin drops from 10–12% in January to 1–2% in April, the quality of the raw material used could be somewhat variable.

In a Soviet publication, Zaitsev et al. (1969) indicated that capelin are being used as a raw material for several canned products in that country. They described the processes for packing (a) fried capelin in oil, (b) fried capelin in vegetable garnish and marinade, and (c) lightly smoked capelin in oil:

a) Capelin, either fresh or frozen, are gutted, headed, thoroughly washed, drained, floured, and fried in vegetable oil at a temperature of 150–160°C (300–320°F) until golden brown. This procedure also dehydrates the fish; the weight loss is about 10% after 4 minutes frying and 18% after 10 minutes. The capelin are then packed in cans and topped up with hot oil (75% sunflower oil and 25% mustard oil) at a temperature of 80–90°C (176–194°F). The tins are sterilized at 112°C (235°F) for 55 minutes and rapidly cooled.

b) Fried capelin are cooled and packed in lacquered tins. One black peppercorn, one peppercorn of pimento, and a clove are added to each tin. After the tins have been topped up with sauce, a quarter or half a bayleaf is added to each. Tins are sealed, sterilized at 112°C, and rapidly cooled. The sauce consists of sugar, tomato puree, vegetable oil, and spices (pepper, pimento, bayleaf, clove, and cinnamon). The mixture is cooked in an enamel pan for 10–15 minutes, and cooled to between 35 and 45°C (95–113°F). Raw grated carrot and fried onion are added.

c) The fish are thoroughly washed and immersed in brine with a density of 1.14–1.16 g/cm^3 to give a salt content in the flesh of 1.3–1.5% (after drying and smoking the salt content goes up to 2.0–2.5%). The fish are threaded on spits, which are fixed to a frame, and sprayed with water to wash off the brine and prevent the fish surface from forming a salt crust and being patchy in color. After rinsing, the fish are dried and lightly smoked (20–40 minutes) at 70–75°C (158–167°F). They are then headed, gutted, and packed in tins. Hot oil is added, and the cans are sealed and sterilized.

In describing these canning procedures Zaitsev et al. do not indicate if the raw material is the lean, prespawning or the fat, fall-caught capelin. The fat capelin would undoubtedly result in a higher quality pack similar to sardines. Since the Soviet fleet has recently been catching and freezing at sea large quantities of fat capelin off Labrador, quantities of these have undoubtedly been canned in that country.

Over the past 2 years a number of capelin canning experiments have been carried out by students and instructors of the Newfoundland College of Fisheries, St. John's (R. E. Bearns personal communication). The best results were again obtained if the fish were smoked and dried before canning.

Research and development was intensified in Canada in 1973 with the formation of the 1973–1974 Newfoundland Inshore Capelin Development Program, which was supported by federal and provincial governments and the fishing industry. A number of canned capelin products were packed in 3¼-ounce aluminum cans and were consumer-tested in several areas. The following products were packed: dressed, smoked capelin in soya oil and brine; smoked fillets in soya oil and brine; and dressed, slightly smoked capelin with vegetables and soya oil, in tomato sauce and in mustard sauce (Anon. 1973a).

Semi-preserved canned products — Various cured products made from herring and sprats are very popular in Europe. These include such canned delicacies as anchovy type products, herring tidbits, spiced herring, etc. The Research Laboratory of the Norwegian Canning Industry has attempted to process capelin in order to duplicate some of these often high-priced products. To develop the desirable "cured" or "ripe" flavors, the fish would have to mature in barrels or in the can. The mechanism of this curing process is not well known, but is thought to be chiefly enzymatic. The bacterial flora would most certainly also affect the final flavor. Fish that have been feeding heavily and have a high fat content will cure easily; conversely, lean, starving fish in most cases will not cure at all.

The Norwegians found that prespawning capelin packed in barrels with 18–24% salt did not develop the texture and flavor required for Portuguese type anchovies; the fish remained "salt fish." However, fillets from these fish packed in refined olive oil and kept under refrigeration showed good keeping qualities.

Spice-cured capelin packed as Scandinavian type anchovies were somewhat more successful in that capelin caught in fall and winter and packed in 100-kg barrels with 14 kg salt, 6 kg sugar, and 1.2 kg spice mixture developed a satisfactory flavor. However, consistency was a little too soft for a top quality product for the Scandinavian market.

Salted, dried, and smoked — Capelin have traditionally been preserved by salting and/or drying to some extent in Newfoundland as well as in Japan, Iceland, Norway, and Russia. Greenland is the only country where dried capelin could be classified as a staple food of some importance.

When capelin came close to shore to spawn, the Greenlanders travelled to the spawning areas in the fjords, where they lived in tents as long as the fishery lasted. The whole family participated in scooping up capelin in primitive dipnets and spreading them on the rocks to dry. They turned them frequently for even drying (Fig. 44). When thoroughly dry, the fish were packed in sacks made of sealskin and tied with rope. A couple of dried cod or arctic cod were placed on top to cover and protect the capelin (Fig. 45) (Hansen and Hermann 1953; Kanneworf 1967).

Capelin have been called the "Greenlander's daily bread" as they were used daily in winter and were the only food reserve in lean times. If a period of wet weather coincided with the fishing season the catch could be ruined, which would cause great difficulties the following winter.

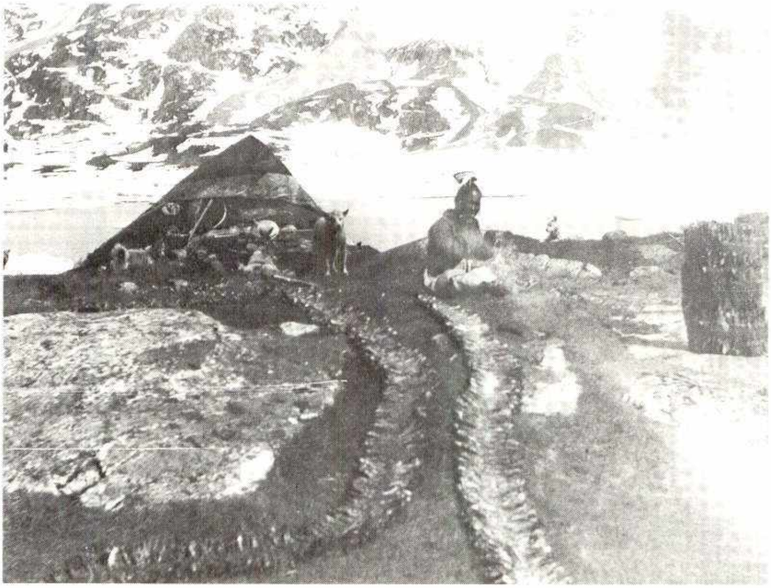


FIG. 44. Capelin drying at Qingaq, Angmagssalik district, East Greenland about 1906.

FIG. 45. Dried capelin packed in sealskin sack for winter provision, East Greenland. Dried cod are used as a "lid" on top.

A thorough study of the artificial drying process of fresh and thawed capelin was carried out by Fougère (1948). He studied the effect of air velocity, relative humidity, and size of capelin on the drying process and the final moisture content of the product.

Salted and/or dried capelin are still produced on a small scale in Newfoundland and Quebec (Fig. 46), but production used to be much higher. This product was exported to England, and statistics show that as many as 1000 barrels were shipped in some years (Jeffers 1931).

A much larger quantity was produced and exported from the French island of St. Pierre. Male capelin were lightly salted, washed, and spread out to dry. Heads and entrails were discarded after the first day. After lying in the sun for 3 or 4 days they were barrelled. According to Bronkhorst (1927), exports of dried capelin from St. Pierre in 1924 were 130,000 pounds.

FIG. 46. Salted capelin being dried on wharf, Long Harbour, Placentia Bay, Newfoundland.

The use of salted and dried roe capelin in Japan was originally confined to the island of Hokkaido, but modern refrigeration techniques have made it possible to distribute this product across Japan throughout the year. Since Japanese capelin landings have been declining, and only amounted to about 1000 tons in 1972, increasing quantities of frozen, female capelin are being imported from Norway, Iceland, USSR, and Canada. The product is prepared as follows (Skilbrei 1972):

Blocks of frozen capelin are thawed in air for 12–24 hours, and the fish are then brined for about 2 hours (6–8% salt). (The thawing can also be carried out in brine if the salt content of the fish is accurately controlled.) The capelin are then washed, graded, and threaded on bamboo sticks (spits). (These sticks are 60–70 cm long and hold 20–25 fish. They pass through the mouth of the fish, not through the eyes.) The spitted capelin are then placed in a drying rack and dried in rapidly moving air at approximately 22°C for 15–30 hours. The moisture content is thereby reduced by about 20–30%. The skin of the fish should have a silvery sheen. The capelin are then taken off the bamboo sticks; plastic sticks are inserted and the fish are packed in consumer packages of, for instance, 10 female fish or 50% of each sex. These packs have a shelf life of about a week under refrigeration, but quantities are also deep frozen for later distribution.

These salted, dried capelin are barbecued or broiled and served hot as a snack, often together with the Japanese rice liquor "sake."

Smoked capelin are also considered a tasty product, and small quantities of both lightly and heavily smoked capelin are produced annually in Canada.

Salted or spice-cured capelin will "ripen" to a certain extent when produced from feeding, fat capelin caught in the fall, as discussed earlier under "canning." Lean, spawning capelin have not shown any of the changes associated with "curing" or "ripening" and remain "salt fish."

Fish protein concentrates — Capelin are well suited as raw material for fish protein concentrates (FPC). Batches were prepared by the Halifax isopropanol process (Power 1962) and evaluated nutritionally. In this process the prespawning capelin were ground and sufficient 99% isopropanol was added to give a 70:30 isopropanol:water mixture. Sufficient polyphosphoric acid was added to bring the pH to 5.5 after which the mass was heated at 81–82°C (178–180°F) in a kettle under reflux. The mass was centrifuged, fresh alcohol added, and the extraction repeated twice. The cake from the centrifuge was dried at 38–43°C (100–110°F) and the nearly odorless, grayish product was finely ground.

Analyses carried out on the FPC showed that the content was: protein, 84%; ash, 11.2%; moisture, 4.2%; and fat, 0.1%. Feeding tests with rats indicated that the Protein Efficiency Ratio (PER) was equal to the casein reference protein. The fluoride content was 50–90 ppm, which is well below the maximum (200 ppm) specified by the Canadian Food and Drug Directorate (Department of Industry, Trade and Commerce, undated).

This type of FPC is nonfunctional in that it will not swell in water and "set" on cooking. It has been successfully used in bakery products such as crackers and bread, in dry cereals, and in other staple foods to increase the protein content. A new functional fish protein (FFP) has recently been developed at the Halifax Laboratory of the Fisheries Research Board of Canada; it blends better with other foodstuffs and could be used as a builder and emulsifier in products such as sausages. In laboratory studies, capelin have been shown to be a suitable raw material for this product.

A non-extracted protein concentrate has been produced from capelin on a commercial scale in Norway. It is essentially a steam-dried fish meal produced under sanitary conditions and has been test-marketed in African and Asian countries under the name "Norse Fish Powder." The chemical composition and nutritional properties of this product are essentially the same as for fish meal from Norway (see Tables 9 and 11). The test marketing indicated that most people preferred the fish flavor in this non-extracted protein concentrate, as the powder was often used as a flavoring agent with bland foods, such as rice. The dried fish normally eaten in these countries often have a strong, rancid flavor.

Animal Feed and Bait

Fresh capelin have traditionally been considered an important bait in the cod fishery in Newfoundland as well as in Greenland, Iceland, and Norway. Jeffers (1931) mentions that such importance was attached to capelin as a bait in Newfoundland that enactments were passed in the 19th century prohibiting its use as fertilizer. It was estimated that in 1871 French fishermen alone used from 60,000 to 70,000 hogsheads annually for bait on the banks off Newfoundland, and similar quantities were used by fishermen in the Province of Quebec. Frozen capelin are not considered to be nearly as good as fresh, since the thawed fish are quite soft and tend to fall off the hooks (Templeman and Fleming 1956, 1963). Even so, considerable quantities are still used in Newfoundland (Table 2).

Since fresh capelin are considered to be most effective as bait at the beginning of the cod fishing season, fishermen in Iceland have been known to transport fresh capelin by aircraft to areas where the capelin schools have not yet arrived.

Fresh, salted, or dried capelin have been an important food for dogs in Newfoundland and Greenland, and some have also been fed to sheep, pigs, and cattle. Due to the low fat content of spawning capelin and the low iodine value of the fat, it is unlikely that the meat or fat of these animals would develop any off-flavors, except if fed at high levels for a long period of time.

Capelin have also been used as mink food, although it has been shown that capelin contain thiaminase (Ceh et al. 1964), an enzyme that destroys the B-vitamin thiamine. When fish containing thiaminase are fed raw at high levels to mink, the animals develop a vitamin deficiency and eventually die. If the capelin are cooked, the thiaminase is destroyed and the mink remain healthy.

Capelin meal can be used in dry pet food, and fresh or frozen capelin in canned products for cats and dogs. The composition and nutritional qualities of capelin are discussed below.

Fresh or frozen capelin have been shown to be an excellent food for salmon and trout and are used extensively in fish farms in Norway. Only fish with a fat content below 5% are used and, therefore, only capelin caught just before spawning are frozen for this purpose.

The production of Atlantic salmon and trout reared in captivity in Norway was about 1500 tons in 1972. Salmonids can be fed whole or chopped capelin for short periods, but the addition of a supplement containing vitamins, minerals, and a binder is recommended for favorable long-term results. Salmon and trout farms are increasing rapidly in Norway, and the quantity of capelin used for feeding is also increasing (Fig. 47, 48).

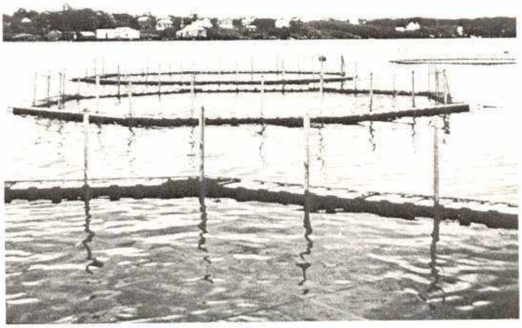


Fig. 47. Seawater salmon and trout farm at Hitra, Norway, where capelin is the chief food used.

Utilization and Processing for Fish Meal and Oil

Conventional reduction equipment — Most of the capelin landed worldwide are processed into meal and oil. Out of the combined Norwegian and Icelandic catch of about 1,870,000 metric tons in 1972, more than 1.8 million tons were used for reduction. Although many plants have had difficulties in producing capelin meal with a fat content (ether extract) below 10–12%, most meals marketed today are lower and are comparable to herring meals in that respect. In the following section some of the difficulties that have been experienced will be discussed together with corrective measures taken by the industry.

A schematic diagram of a fairly typical conventional fish meal plant is shown in Fig. 49. There are a number of makes and designs for each piece of equipment, so the discussion in that regard will have to be quite general. For instance, there are indirect and direct cookers,

FIG. 48. Frozen blocks of capelin being chopped up before being fed to the salmon and trout. Often a supplement containing minerals, vitamins, a binder, and perhaps also shrimp waste is added to the capelin.

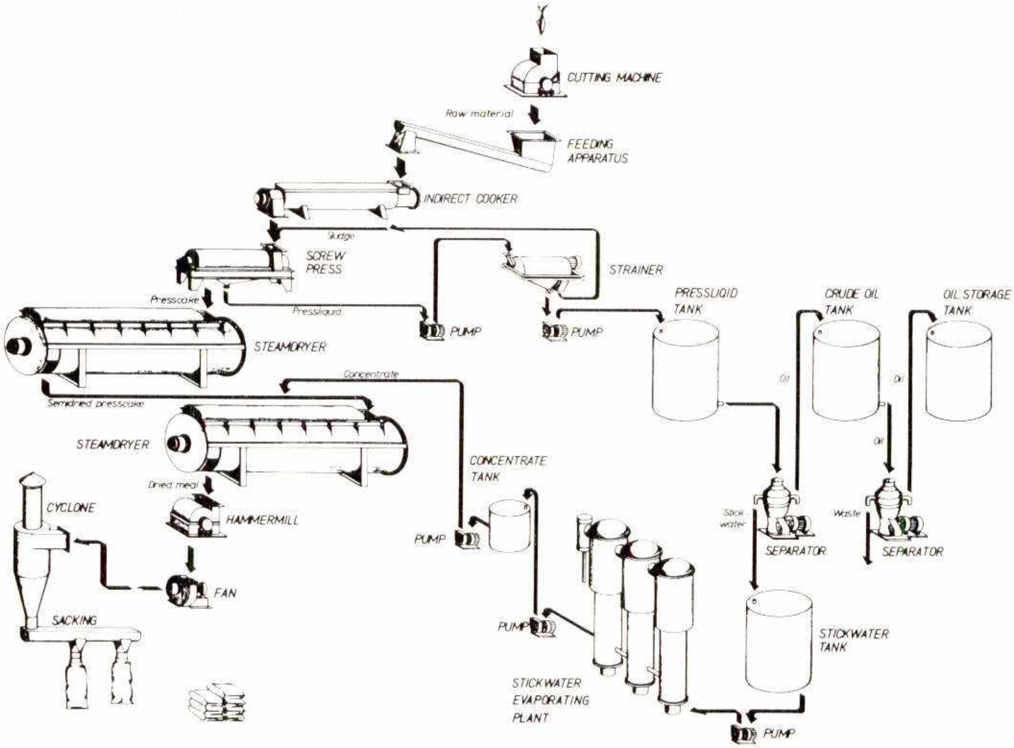


FIG. 49. Simplified diagram of conventional fish meal and oil processing plant.

single and double screw presses, steam and flame dryers, and different types of evaporators.

Another basic type of reduction plant that has had limited use with capelin is the centrifuge process, in which a large decanter centrifuge is used instead of a press (personal communication, E. Gloppestad, Alfa-Laval).

The most serious problems encountered in processing fresh capelin are the difficulties in pressing oil from cooked fish, and the high moisture content found in prespawning and spawning capelin.

A number of studies have been carried out in an attempt to solve the problem of high fat content in the meal and these are discussed below. Icelandic experiments were discussed by Thorbjarnarson (1958). In Norway and Iceland, prespawning capelin having a fat content of 3–10% are stored in winter and early spring for 7–12 days at temperatures around 0°C so that the fish can "ripen." This seems to release the fat globules in the tissues; only then is it possible to produce a meal with sufficiently low fat content in conventional processing equipment. The disadvantages of this ripening process are that the free fatty acid content of the oil produced is high and that extensive fish storage facilities must be constructed.

The ripening process is probably a combination of bacterial and enzymatic action on the fish tissue. This should proceed at a much faster rate at higher temperatures. Sola and Anthonsen (1958) found that the ripening period could be shortened to 7.5, 5.5, and 3 days at 5°, 10°, and 20°C, respectively. For instance, capelin caught in summer and fall in the Barents Sea are actively feeding, and therefore enzymatic and bacterial decomposition is rapid. When the fish are landed in Norway, processing can commence immediately. Norwegian operators indicate that they have few problems processing these capelin and that the meal has a fairly low fat content (ether extract 8–10%) in spite of the fact that the fish may have up to 20% fat at this time.

Similar findings have been reported from Newfoundland, where air temperatures during the fishing season in June and July often go above 20°C (68°F). Clarke (1967) mentions that in earlier attempts to carry on a capelin fishery for reduction in Newfoundland, the fish deteriorated rapidly and were often in poor shape when delivered to the plant. Even so, standard fish meal presses had few problems in handling the fish. Yields averaged 1 ton of meal from 7 tons of capelin, with oil recovery reported at about 4 imperial gallons from 1 ton of fish (14.3% meal, 2% oil). The solubles were not added back to the meal but were collected separately, and yielded 11 imperial gallons of 50% solids per ton fish (solids = approximately 2.8% of raw material). Fish caught later, during the spawning or post-spawning period, yielded about 1 ton of meal to 9 tons of fish, with oil recovery about 2 imperial gallons per ton of fish (11.1% meal, 1% oil).

The high water content of capelin at spawning time has presented some problems to reduction plants, especially in Norway. The fish are usually pumped from the seines to the hold of the vessel over screens, in order to remove as much water as possible. Unloading is carried out with grabs or bucket elevators and all "bloodwater" that has collected in the hold is pumped ashore. The fish are stored ashore in tanks or watertight concrete bins, and if the capelin have to ripen for 7–10 days, additional quantities of bloodwater will separate (Thorbjarnarson 1958). At some specially designed capelin reduction plants this bloodwater, which may contain 2–9% dry matter, is collected in tanks and cooked in a separate cooker (personal communication, E. Hetland, Brödr. Hetland Ltd., Bryne).

Capelin are usually cooked with indirect steam to avoid adding more water to the fish. The drainage screens (vibrating screens) between the cooker and press should have a larger capacity than normal in order to remove as much liquid as possible at this stage. It is important that some of the roe be removed with the liquid at this point, since it tends to clog the screens in the press.

To get a good press, the press is usually run more slowly than it is with herring. No direct comparisons regarding efficiency have been made between the double screw press and the single screw press in handling capelin, and both types are used. The large Norwegian manufacturers of processing equipment have supplied double screw presses to most capelin plants.

To handle the added quantity of liquids from the cooker, the press, and the bloodwater cooker, the sludge centrifuges (super decanters) should have a higher capacity than usual. The roe again causes problems, as it follows the liquid phase and not the suspended solids (sludge). As a result some roe goes to the separator, which then has to be cleaned occasionally. One apparent advantage of the low temperature process is that roe separates in the decanters.

The evaporators should also have extra capacity to handle the larger than normal quantities of stickwater. It is difficult to concentrate capelin stickwater much above 30–35% solids before it starts to gel. Some factories run the concentrated solubles through a centrifuge before they are added to the dryer in order to remove additional oil. Oil recovered in this step is dark and of poor quality, and must be handled separately. One plant handles the stickwater and solubles under pressure; this facilitates oil separation and minimizes gelling (personal communication, H. Skorpen and J. Teigland, Stord Bartz Industri A/S, Bergen).

It is difficult to add the concentrated stickwater (solubles) to the presscake in the dryer because it tends to be sticky and form balls. Therefore it is important to have thorough mixing to break up the mass in the dryer at this point. The capacity of the dryer should also be higher than that needed to process the same quantity of meal from herring.

The yields from Norwegian capelin plants for the winter season average 16.7% meal (1:6), with specially constructed capelin plants being able to average 17.2% (1:5.8).

Plants using decanters only instead of presses (for instance, the "Centrifish" process) have also been used experimentally to process fresh winter capelin in Norway. They have reportedly been able to produce meals with fat contents of 10–12%. This is somewhat lower than the results obtained in standard plants from non-ripened fish. A Centrifish plant was operated experimentally at lower cooking temperatures with recirculation of stickwater to the cooker; meals with fat contents below 10% were produced (see p. 45).

Basic studies — The Norwegian capelin fishery for reduction began in the mid-1950s. It was soon apparent that research was necessary, because the fat content of the meal produced was generally too high.

In northern Norway, Sola and Anthonsen (1958) used a hydraulic press to measure the ability of the cooked capelin to "take" the press. They found that the maximum pressure (in kg/cm^2) that could be applied to cooked fish after being stored at 0°C increased gradually up to 15 days' storage, and was accompanied by a gradual lowering of the fat content in the presscake. This storage period was called "modningsperioden" or the "ripening period." They also found that ripening was more rapid at higher temperatures, and that the ripening period could be shortened to 7.5, 5.5, and 3 days at 5, 10, and 20°C, respectively.

The effect of various additives on the press was also explored, but none of the chemicals tested gave any significant lowering of the fat content, although the maximum pressure the fish was able to take did increase in some instances. The substances tested were formalin, sulfuric acid, and calcium monophosphate at various concentrations.

Aldal et al. (1961) continued these studies in the laboratory and at reduction plants. They attempted to hasten the ripening process by the use of proteolytic enzymes but did not succeed. Of the various substances added during cooking, the only chemical found to cause a small lowering of the fat content in the meal was calcium monophosphate at levels of 0.4% or higher. The authors found that roe fat was fairly easy to press out and was, therefore, not the chief cause of the high fat content in the meals.

Later experiments failed to find simple solutions to the processing problem. Lohne (1969) attempted to cook under pressure and then press, and Utvik and Lohne (1967) studied the use of a decanter centrifuge ahead of the press without much success. It was obvious from these studies that the fat globules in capelin are much more difficult to release than those, for instance, in herring.

Mohr (1972) and Mohr et al. (1973) reviewed the current basic knowledge of the lipid distribution in fish tissues and pointed out that in some cases extended cooking at high temperatures might actually seal the fat globules in a capsule of denatured protein. Lohne et al. (1971) had shown this, and their applied work resulted in a new reduction process for fresh capelin based on cooking at low temperatures.

The low temperature process — Systematic studies on separation of fat from ground fish with a laboratory centrifuge, at various

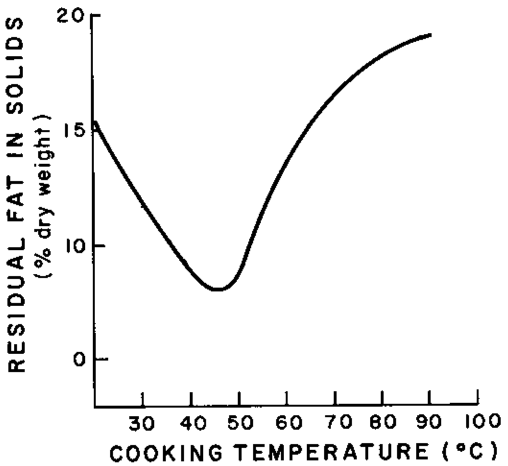


FIG. 50. The effect of cooking temperatures on residua fat content in solids (presscake) following centrifugation (Lohne et al. 1971).

temperatures and speeds (Lohne et al. 1971), showed that more oil could be removed at temperatures lower than those normally used in reduction plant cookers. Figure 50 indicates that a cooking temperature of about 50°C (122°F) would be optimum for maximum removal of fat from fresh capelin.

Studies were continued in a pilot plant and also under actual plant conditions in northern Norway (Lohne et al. 1971; Lohne et al. 1972). They confirmed the earlier findings; low temperature cooking of fresh capelin results in a reduction of the fat content in meal of about 3% (from about 13% to less than 10%).

Two basic reduction processes were studied: the conventional process utilizing a press and centrifuge, and a process using only centrifuges. To obtain a uniform temperature and to avoid overheating in the cooker, or more correctly the coagulator, a certain quantity of stickwater was returned to the cooker in each case. Schematic diagrams of the two processes are given in Fig. 51. It should be pointed out that due to the recycling of large volumes of stickwater in the low temperature process, the capital cost of sufficiently large decanters could be quite high. No reduction plant has changed over to this low temperature process yet, but equipment manufacturers participated in the experiments and are studying modifications to adapt the process to commercial use (Anon. 1972d). The process has been patented (Lohne and Utvik 1971).

Other Uses

In parts of Quebec and in Newfoundland large quantities of capelin have been used as fertilizer (Fig. 52). This fact is responsible perhaps for prejudice against capelin as a food fish (Jeffers 1931). The Report of the Dominion Commissioner for 1875 shows 15,431 barrels used as fertilizer; the following year 34,714 barrels were used. In the same report the fish are termed a "real God-send" for fishermen and farmers as fertilizer.

Due to a decrease in the number of farmer–fishermen and the availability of chemical fertilizers, only small quantities of capelin are now used as fertilizer there. However, some recent books and articles perpetuate the prejudice, reporting that this is the only use for capelin.

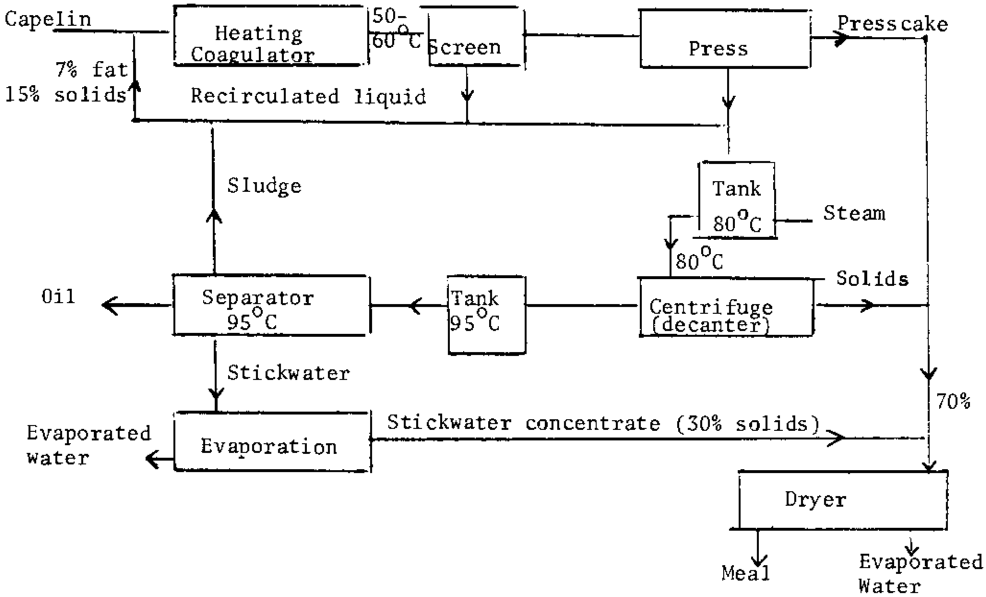
Capelin were also used to a small extent for the production of oil in northern Norway in the 19th century and earlier. The first capelin that arrived on the coast in February and March were still quite fat. When these were placed in barrels to decompose, the oil would float to the top and could be skimmed off (personal communication, A. Kremmervik, Trondheim).

Bacterial Spoilage

Due to the limited use of fresh or iced capelin for human consumption, few studies have been carried out on the rate and pattern of bacterial spoilage.

Hanneson and Dagbjartsson (1969) studied the effect of irradiation on fresh capelin and the subsequent changes which take place during storage at 0–1°C. Samples packed in plastic bags were irradiated at three dose levels (1, 3, and 5×10^5 rad). The highest level was found to cause a pronounced irradiation off-odor and rancidity, and the product was considered unacceptable.

The other samples were stored at 0–1°C, and the nonirradiated controls were judged to be spoiled and inedible after 3 days. The samples irradiated with 1×10^5 rad were rejected after 13 days, and those with 3×10^5 rad after 20 days. These organoleptic ratings were in fairly good agreement with the rise in trimethylamine (TMA) values for all the samples.



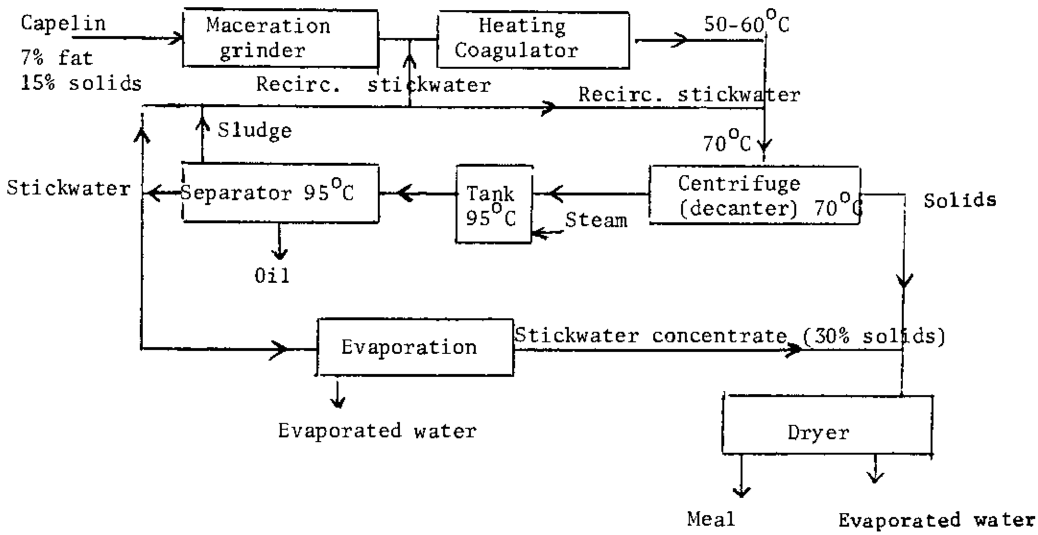


FIG. 51. Suggested flow sheets for future use of low-temperature process: *upper*, press process; *lower*, centrifugal process (Lohne et al. 1972).

FIG. 52. Capelin being used as fertilizer. This was a common practice in Newfoundland and Quebec.

The initial TMA content of capelin is significantly higher than that of whitefish and crustaceans (Kjosbakken 1970), but the rise in the TMA values follows a similar pattern and seems to be a useful quality index also for capelin. The values found for TMA, volatile acids, peroxide, pH, and total bacterial count are shown in Table 3.

In Norway large catches are made over a relatively short period, and capelin delivered to meal processing plants often have to be stored in large tanks or bins for several weeks. Anaerobic conditions exist in these fish and the spoilage pattern has been studied by several authors (Ström 1968, 1969b, 1970, 1971a, 1971b, 1971c, 1971d; Refsnes and Larsen 1972; Kjosbakken 1970; Olafsen et al. 1971). It was shown by Ström (1970) that bacterial growth reaches a stationary phase after about 3 days at 4–6°C, with certain types of bacteria dominating (enterobacter and pseudomonads). These bacteria utilize sugar components and lactic acid as a source of energy, and in the process trimethylamine oxide (TMAO) is reduced to TMA. As soon as the supply of TMAO is exhausted, the growth of these bacteria is inhibited (Refsnes and Larsen 1972). Acetic acid and TMA were found to be the most important end products.

Other substances that were quantitatively converted during the period of active bacterial growth included inosine-5′-phosphate, inosine, serine, arginine, aspartic acid, and tyrosine (Kjosbakken 1970). The ammonia content was relatively low at the start of the storage period and changed little during the first 3 days. Thereafter, however, the ammonia increased rapidly and reached values as high as 90 μmoles per ml filtrate of the capelin mass after 12 days. The acetic acid content also continued to increase after the first 3–4 days, and after a few days there was an accumulation of butyric and propionic acids. The authors (Refsnes and Larsen 1972) speculated that *Clostridium* bacteria were growing actively in the capelin mass, even though their presence could not be demonstrated. The free fatty acid content of the capelin oil reached 5% after 6 days in these experiments, as compared to 23 days in fish preserved with sodium benzoate and formalin (Lie 1971).

TABLE 3. Chemical and bacteriological changes in capelin stored at 0–1°C following irradiation (Hanneson and Dagbjartsson 1969).

Days of storage	Control 0 rad					1×10^5 rad					3×10^5 rad				
	TMA[a]	VAV[b]	PV[c]	pH	TBC[d]	TMA	VAV	PV	pH	TBC	TMA	VAV	PV	pH	TBC
0	10.2	14.8	3.5	6.9	1.9×10^5										
1						11.6	12.0	6.3	7.0	1.3×10^4	11.2	13.2	12.6	6.9	6.0×10^1
2	31.3	28.0	6.1	7.0											
3	70.0	69.2	5.5	7.0	1.8×10^9	9.8	14.8	7.0	6.8	9.1×10^5					
6						12.4	15.2	(31.0)	6.6	2.4×10^5	11.1	15.6	(34.2)	6.8	1.1×10^2
8						19.4	26.0	10.3	6.8						
9											15.1	20.4	13.6	6.8	
10						29.0	30.0	8.0	6.9						
13						65.9	31.2			6.1×10^7	15.8	18.4			4.3×10^5
16											16.0	21.2	13.7	6.9	4.5×10^6
20											31.4	18.2	17.6	6.9	6.5×10^7

[a]TMA = trimethylamine.
[b]VAV = volatile acid value.
[c]PV = peroxide value.
[d]TBC = total bacterial count.

Chemical and Nutritional Composition

Fresh Capelin

Seasonal variation — As in many other fish species, especially pelagic fish like herring and mackerel, the composition of capelin varies considerably throughout the year. The fat content usually reaches a minimum just after spawning in spring or early summer, and a maximum at the end of feeding in the fall. Due to differences in the spawning times among capelin from various areas, these minima and maxima are reached at slightly different times.

Different analytical methods available for fat or total lipid determination give slightly different results, especially when the fat content is low. The chloroform-methanol method of Bligh and Dyer (1959) (abbreviated C-M in the following) extracts all lipid material including phospholipids, but the ether extraction or soxhlet method (abbr. E) and the benzene method (abbr. B) extract mainly triglycerides. Therefore, the C-M method gives higher values than the others, especially when total lipid content is low, as the phospholipid content in fish muscle is fairly constant at 0.5–1.0%.

Winters (1970a) studied overwintering capelin from Trinity Bay, Newfoundland and found that the fat content of mature capelin was as high as 14% in February and March and declined gradually towards the spawning season in June (E). Immature fish had much lower fat contents.

Andrews (1954) and MacCallum et al. (1969) reviewed analyses of capelin caught on or near the shore in Newfoundland in June and July just before or during spawning. The fat content ranged from 2 to 6%, with the majority of samples grouped around 3% (E, C-M). Other analyses were carried out and the range of values and averages for proximate composition are listed in Table 4.

The protein content of the fillets was slightly higher than that of the whole fish, while the fat content was slightly lower. Ackman et al. (1969) reported that the fat content of gonads and viscera of some of the same capelin was the same as or only slightly higher than it was in muscle.

Samples of fish which spawn on the Southeast Shoal of the Grand Bank in June and July have also been analyzed. Fish caught between May 20 and June 18 (Dragesund and Monstad 1972) had fat contents of up to 6.0% at the beginning and 3% (B) at the conclusion. The average fat-free solids content was 16.9%. Fish caught in July in the same area had fat contents as low as 1% (E) (Hinds 1972).

When spawning is completed, the surviving fish feed vigorously and fat content increases rapidly. The same applies to maturing fish which will spawn the following spring. Devold (1970) analyzed fish that were caught off Labrador in August and September and found that large, mature fish had fat contents up to 23.4% (B). Fish caught during experimental fishing cruises off Labrador in October and November were found to have up to 21.3% fat (E). In both cases the smaller, immature fish found in the area had much lower fat contents. The moisture contents in these fish were as low as 65%, compared to 80–84% during spawning; fat-free solids contents were 12.3 to 15%. In Fig. 53 the seasonal variation in the fat content of mature fish is shown.

Few studies have been carried out on Greenland capelin, but scattered analyses indicate that fat contents are similar to those found off Newfoundland and Labrador: approximately 13% in January, 10% in February, declining to 3% at spawning time in May. The proximate composition of capelin caught in Icelandic waters has been reported in the annual reports from the Icelandic Fisheries Laboratories (Anon. 1970; Anon. 1972a) and representative averages are given in Table 5. Females generally have a higher fat content than males. As there has not been a fishery on the fat, feeding capelin off Iceland, compositional data on them are scarce.

An intensive fishery on Barents Sea capelin has been carried out for a number of years, and extensive analytical data on fat and solids content are available. Figure 54 shows the seasonal variation of these values over a 5-year-period. As the Barents Sea capelin migrate a considerable distance from the Hope Island area to Finnmark in northern Norway to spawn, the condition of the fish varies from year to year.

The Norwegian Fisheries Research Institute in Bergen has carried out thousands of analyses of representative samples of capelin taken from all catches landed at Norwegian fish meal plants. The values for fat and fat-free solids in Table 6 for 1972 represent the weighted monthly averages of 5131 individual analyses,

TABLE 4. Composition of prespawning or spawning Newfoundland capelin (MacCallum et al. 1969).

			Fat content (%)		Crude protein (%)		True protein (%)		Ash (%)		Salt (%)	
Dates caught	Total no. of fish	Part of fish	Range	Avg	Range	Avg	Range	Avg	Range	Avg	Range	Avg
June 15–July 5	330	Whole	1.8–8.1	4.1	12.9–15.3	13.94	10.4–12.6	11.25	1.8–2.2	2.0	0.11–0.36	0.28
June 22	30	Fillets	–	2.6	–	14.96	–	12.87	–	–	–	–

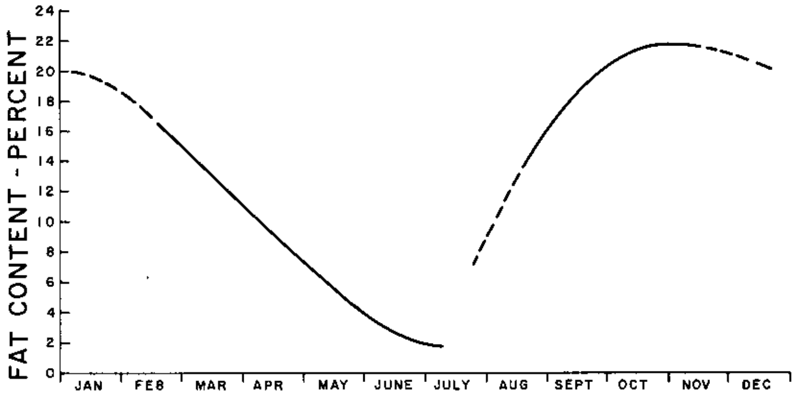


FIG. 53. Newfoundland–Labrador capelin seasonal variation in fat content.

TABLE 5. Analyses of Icelandic capelin caught in 1970. (Source: Anon. 1970, 1972a.)

Date caught	Sex ratio (%)		Fat (%)		Avg	Fat-free solids (%)		Avg
	♀	♂	♀	♂		♀	♂	
Jan. 18	67	33	13.0	11.5	12.4	15.5	15.3	15.4
Feb. 11	56	44	–	–	10.2	–	–	16.0
Feb. 12	47	53	12.6	10.4	11.2	16.7	16.4	16.5
Feb. 12	49	51	12.0	8.8	10.1	16.0	16.7	16.4
Feb. 24	40	60	9.4	7.8	8.3	17.1	15.5	16.0
Feb. 26	58	42	9.3	8.4	8.8	15.7	15.8	15.8
Feb. 28	56	44	9.4	7.5	8.4	16.0	15.5	15.8
Mar. 5	41	59	9.8	7.3	8.1	16.9	16.8	16.9
Mar. 9	56	44	8.4	6.3	7.3	16.8	15.7	16.2
Mar. 10	44	56	6.4	6.0	6.1	16.9	15.5	16.0
Mar. 14	39	61	7.2	5.5	6.0	16.3	16.1	16.2
Mar. 17	28	72	6.6	5.6	5.8	16.5	15.0	15.3
Mar. 22	19	81	6.0	3.0	3.4	15.9	15.0	15.1
Apr. 1	50	50	3.0	2.5	2.7	17.6	16.2	16.7
Apr. 2	74	26	5.6	4.8	5.3	18.1	16.7	17.6
Apr. 2	69	31	7.0	7.0	7.0	17.5	15.4	16.7
Apr. 3	79	21	3.2	3.8	3.4	16.5	15.6	16.2
Apr. 7	42	58	6.4	5.7	5.9	17.1	15.2	15.9
Apr. 13	55	45	6.5	5.9	6.2	17.1	15.7	16.3
Aug. 7	–	–	–	–	13.8	–	–	16.0

ranging from 6 in April to 1909 in both February and March.

As the fish approach the Norwegian coast in January, the fat content is generally 10–15%; it declines rapidly to about 2–3% near spawning time in April. In the fattening period from July onwards, when the fishery is carried out as far north as Spitzbergen, the fat content increases and in some fish reaches 20–23%.

The solids content shows less variation, but indications are that it is at a minimum at spawning time and also when the fish are very fat in September and October. The moisture content reaches a maximum at spawning time and can be as high as 82–84%.

Soviet analytical data are similar to those of the Norwegian workers. In Table 7 Prokhorov (1965) lists the analytical data for capelin caught on Soviet research cruises.

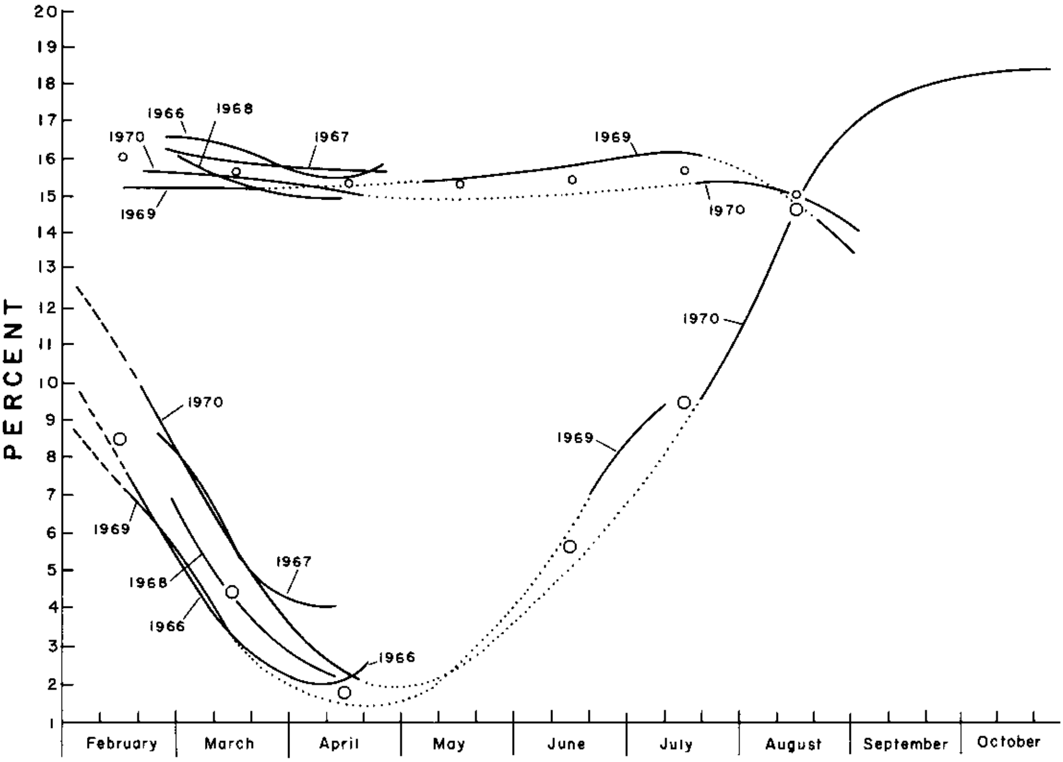


FIG. 54. Seasonal variation in fat and fat-free solids (upper curves) in Barents Sea capelin over a 5-year period as determined at a fish meal plant in northern Norway. Circles represent monthly averages.

TABLE 6. Weighted monthly average of thousands of samples of Barents Sea capelin landed in Norway in a 6-year period. (Source: personal communication, W. Jacobsen and E. Heen, Norwegian Fisheries Research Institute, Bergen.)

	Fat g/100g[a]						Fat-free solids g/100g					
Month	1967	1968	1969	1970	1971	1972	1967	1968	1969	1970	1971	1972
Jan.	–	–	10.9	12.9	15.2	13.2	–	–	15.3	15.2	14.3	14.7
Feb.	8.9	7.1	7.5	9.7	11.4	9.0	16.3	16.4	15.9	15.2	15.0	15.1
Mar.	6.4	4.8	4.3	6.0	6.2	5.0	15.6	15.5	15.5	15.6	15.0	15.0
Apr.	5.3	2.9	3.7	3.0	3.3	7.7	15.4	14.9	15.4	15.2	14.9	15.0
May	5.0	–	2.6	2.5	–	–	16.4	–	16.2	15.7	–	–
June	–	7.3	7.4	–	–	–	–	17.0	16.1	–	–	–
July	–	7.8	10.5	10.0	9.5	11.0	–	16.2	15.7	15.3	15.8	15.2
Aug.	–	12.4	14.3	14.5	9.8	14.6	–	16.2	14.6	14.6	16.0	14.2
Sept.	–	15.9	17.7	19.0	19.2	–	–	14.3	14.3	13.7	14.7	–
Oct.	–	–	–	17.9	19.0	–	–	–	–	14.4	14.6	–
Nov.	–	12.9	–	–	–	–	–	15.0	–	–	–	–

[a]Benzene method.

TABLE 7. Fat and moisture content of Barents Sea capelin caught on Soviet research cruises (Prokhorov 1965).

Date caught	Location	Moisture	Fat
Oct. 27, 1961	Nadezhda Island region	65.4	20.9
Oct. 30, 1960	Central Bank	64.2	21.1
Nov. 11, 1960	Persey Bank	66.8	17.8
Nov. 30, 1960	Persey Bank	68.0	19.0
Dec. 20, 1960	Central Trough	67.1	18.0
Jan. 9, 1961	Northern portion of Novaya Zemlya shallows	62.3	20.6
Feb. 10, 1963	Novaya Zemlya Bank	74.4	9.4
Apr. 8, 1961	Central Trough	72.7	10.6
Apr. 13, 1961	Motov Bay (spawning area)	82.6	2.4

Other analyses — Kjosbakken (1970) reported on the qualitative and quantitative characterization of the main nitrogen extractives in newly-caught capelin, as compared to herring and mackerel. Creatine, trimethylamine oxide, trimethylamine, free amino acids (including taurine and anserine), ammonia, nucleotides, and purine bases were determined in extracts of the light muscle of these fishes. Creatine, trimethylamine oxide, trimethylamine, taurine, histidine, and ammonia were determined in extracts of whole fish, dark muscle, heart, liver, roe, and milt. Creatine occurred in higher concentrations in the light muscle than in any other part of the fish. The values found in capelin ranged from 30 to 34 μmoles per gram wet weight, compared to 47–57 for herring and 41 for mackerel. The content of creatine was also high in the dark muscle and the heart. Phosphocreatine was not found in any of the fish sampled.

Trimethylamine oxide occurred in higher concentrations in light muscle than in any other part of the fish, with capelin having considerably higher values (49-64 μmoles/g) than herring (21–48) or mackerel (28). Other parts of capelin also contained considerable concentrations of TMAO: dark muscle (38–44), heart (34), liver (16–23), and milt (17–23). The lowest values were found in roe (11–17). The values for whole fish were 35–47 μmole/g.

A number of common amino acids were present in free form in light muscle of capelin, herring, and mackerel. Most of these were in about the same concentration in the three species. However, some of the same amino acids, especially the imidazole derivatives, were present in very different concentrations. Whereas light muscle of capelin contains 4–7 μmoles of anserine per gram wet weight, none was detected in light muscle of herring and mackerel. Light muscle of capelin contained only 0.1–0.2 μmoles/g of histidine as compared to 26 in mackerel and 5–6 in herring.

The only nucleotide of quantitative importance detected in capelin light muscle samples was inosine-5′-phosphate (1.5–4.2 μmoles per gram wet weight). Inosine (0.7–1.4) and hypoxanthine (0.3–1.2) were also found. According to Kjosbakken (1970) these findings agree with literature reports that the adenosine-5-triphosphate of the muscle is rapidly converted to inosine-5′-phosphate and further to inosine and hypoxanthine by enzymes in the tissues which start to act soon after the fish are killed.

As capelin are near the bottom of the food chain, it is unlikely that any significant accumulation of heavy metals or chlorinated compounds will occur. The mercury content of a sample of capelin from Hudson's Bay was reported by Bligh (1970) to be 0.04 ppm, which was lower than the concentrations found in other species from that body of water. Analyses of capelin from the waters around Iceland had similar values (0.02–0.04 ppm Hg) (Anon. 1973b).

CAPELIN PRODUCTS

Meal and protein concentrate (FPC) — The importance of capelin as raw material for the production of meal and oil has been increasing in the past decade, especially in Norway and Iceland where capelin meal has replaced herring meal as the most important product. As a result, the chemical and nutritional composition of capelin meals have been studied.

The most extensive experiments were carried out at the Research Institute of the Norwegian Herring Meal and Oil Industry (SSF). Olsen (1967) and Opstvedt et al. (1970) reported on the proximate compositions and nutritional data of a number of samples of meal from capelin and other fish species. Their results were used by Sparre (1971) to compare the nutritional value of capelin meal with other fish meals. The results showed that capelin meal has a high nutritional value, with protein equal in quality to that of herring meal. Similar results were obtained in studies of Canadian and Icelandic capelin meals (Jangaard et al. 1974; Anon. 1970; Miller 1970).

Fish protein concentrate (FPC) prepared from capelin by the Halifax Isopropanol Extraction Process has been approved by the Canadian Food and Drug Directorate (FDD) for use in human nutrition. Extensive nutritional and toxicological studies were carried out on this product (Department of Industry, Trade and Commerce, undated; Ke et al. 1970).

Tables 8 to 11 list the results of various studies carried out on capelin meals, solubles, and FPC.

It can be seen from Table 8, which shows the proximate composition of capelin meal, that Norwegian commercial meals average about 69–70% protein and Icelandic average 67–69%. Under carefully controlled processing conditions, meals with 70% or more protein can be consistently produced. Unless capelin is ripened until a breakdown of fatty tissues occurs, meals with 15–18% fat can result from the processing. Of the meals studied by Opstvedt et al. (Table 8), only three of the nineteen samples had a fat (ether extract) content above 10%, indicating that the reduction plants in Norway have overcome problems in processing capelin.

Almost all meals produced today are so-called whole meals, in which solubles (evaporated stickwater) have been returned to the meals. However, analytical data for drum-dried solubles (average of five samples) are included in Table 8.

The mineral content of various meals and FPC from capelin is shown in Table 9. The large variations in some trace elements, especially iron and zinc, and probably also cadmium and lead, can be due to pick-up from the processing equipment. For instance, the FPC sample which was prepared in stainless steel equipment has a low iron content. Lunde (1968a, 1973c) found that the trace metal content of meals from a single species caught and processed in different areas often showed as much variation as the values for several species. He also studied the distribution of some of the trace elements in the meal itself and in lipids extracted from the meal. Some elements occurred in the lipid extract, and it has been suggested that phospholipids may be responsible for complexing inorganic ions. Arsenic had earlier been shown to occur as arseno-organic compounds which are soluble in the oil phase of capelin (Lunde 1968a). Selenium has been shown to be an extremely important trace element in animal nutrition; the levels found in capelin meals are similar to those found in other fish meals by Kifer et al. (1969).

TABLE 8. Proximate composition of capelin meals and protein concentrate (FPC).

	Meals				Solubles drum dried	FPC
	Canada[a]	Norway[b]	Norway[c]	Iceland[d]	Norway[c]	Canada[e]
Moisture	8.0	8.4	7.9	8.0	7.0	4.2
Fat (ether extract)	9.3	9.8	8.8	11.1	3.5	–
Fat (benzene)	–	10.8	–	–	–	–
Lipid (Bligh and Dyer)	–	–	13.5	–	–	0.1
Protein (N × 6.25)	72.2	68.9	70.2	65.0–68.0	69.6	83.8
Ash	8.8	10.1	9.8	–	18.3	11.2
Fiber	0.5	–	–	–	–	–
Salt	–	1.0	1.4	1.2	–	–

[a]Jangaard et al. (1974); single sample.
[b]Olsen (1967); average of five commercial sample analyses.
[c]Opstvedt et al. (1970); average of 19 commercial samples.
[d]Thorbjarnarson (1967).
[e]Department of Industry, Trade, and Commerce (undated).

TABLE 9. Mineral content of capelin meals and protein concentrate (FPC).

	Meals						FPC[e] Canada
	Canada[a]	Norway[bd]	Norway[c]	Norway[c]	Norway[d]		
			A	B	In meal	In lipid from meal	
Percent (%)							
Calcium	1.9	1.72	–	–	–	–	–
Magnesium	0.24	0.13	–	–	–	–	–
Phosphorus	1.6	1.75	–	–	–	0.55	–
Potassium	1.1	1.13	–	–	–	–	–
Sodium	0.66	0.50	–	–	–	–	–
Sulfur	0.67	0.80	–	–	–	–	–
µg/g (ppm)							
Aluminum	97	–	–	–	–	–	–
Arsenic	2.5	–	2.6	19.1	–	12.0	1.1
Barium	2.0	–	–	–	–	–	–
Boron	7.9	1.5	–	–	–	–	–
Cadmium	0.34	0.12	–	–	0.13	–	–
Chromium	1.5	–	–	–	–	–	–
Cobalt	0.10	0.02	0.05	0.13	–	0.07	–
Copper	12	4.2	1.7	4.1	4.3	–	3.3
Iodine	0.50	2.0	–	–	–	–	0.5
Iron	575	137	–	–	288	11.5	3
Lead	13.4	1.56	–	–	1.7	–	0.2
Manganese	5.8	4.0	–	–	–	–	–
Mercury	0.10	–	0.026	0.13	–	–	0.2
Molybdenum	3.8	0.35	0.2	0.06	–	–	–
Selenium	1.7	1.75	1.3	1.7	1.2	0.3	–
Strontium	100	–	–	–	–	–	–
Zinc	142	101	108	134	118	5.4	–
Fluoride	–	–	–	–	–	–	47–93

[a]Jangaard et al. (1974); single sample.
[b]Opstvedt et al. (1970).
[c]Lunde (1968b).
[d]Lunde (1973c).
[e]Department of Industry, Trade, and Commerce (undated).

The amino acid composition of capelin meals is given in Table 10. Of the more important essential amino acids likely to be limiting factors when the meals are constituents of animal feeds, only glycine seemed to be slightly lower than in other fish meals (Sparre 1971). Norwegian and Icelandic meals were slightly lower in arginine and histidine than Canadian meals.

The effect of excessive heat in the drying process has been documented in Icelandic experiments, as shown in Table 11 (Anon. 1970). Vacuum-dried capelin presscake (no solubles) is not affected by drying, and available lysine and digestibility are high. Drying in a flame dryer to 24.3% moisture and in a steam dryer to 2.6% moisture has only a minor effect on the proteins. However, drying in a flame dryer to 3.4% moisture lowers the content of lysine and available lysine, and also the digestibility of the protein. Commercial whole meal also shows effects of having been dried excessively in a flame dryer. The high lysine content of the Canadian sample results from the fact that it is a presscake meal and that it was dried in an experimental steam dryer.

The vitamin content of capelin meals (in µg/g (ppm), given below) indicates that the nutritionally significant levels of vitamins

TABLE 10. Amino acid composition of capelin meals and protein concentrate (FPC) g/16gN.

	Meals from			FPC
	Canada[a]	Norway[b]	Iceland[c]	Canada[d]
Lysine	8.23	7.77	6.86	9.40
Histidine	2.50	2.03	2.03	2.23
Arginine	6.18	5.69	5.38	6.77
Aspartic acid	9.01	9.18	8.58	10.54
Threonine	4.61	4.28	4.14	5.00
Serine	4.30	4.05	4.46	5.27
Glutamic acid	13.86	13.43	14.18	15.85
Proline	3.63	3.07	2.75	4.50
Glycine	5.25	4.98	4.04	6.18
Alanine	5.94	6.12	5.20	6.58
Valine	4.87	5.24	4.60	5.59
Methionine	3.10	2.83	2.86	3.44
Isoleucine	4.27	4.51	4.15	4.66
Leucine	9.66	7.56	7.23	8.75
Tyrosine	3.67	3.64	3.34	3.65
Phenylalanine	4.18	3.81	3.54	4.24
Tryptophan	1.17	1.15	–	–
Cystine	1.32	1.29	0.97	1.79
Ammonia	0.82	1.40	–	1.36
Taurine	–	0.81	–	–
Available lysine, % of protein	6.2	6.8	6.72	6.3
Protein efficiency ratio (PER)	–	2.3	–	2.6
Metabolizable energy kcal/kg	–	3613	–	–

[a]Jangaard et al. (1974).
[b]Opstvedt et al. (1970).
[c]Anon. (1969).
[d]Department of Industry, Trade, and Commerce (undated).

present in capelin meals could be important when least-cost rations are being formulated.

	Canada[a]	Norway[b]	Norway[c]
Thiamine	1.20	–	–
Riboflavin	7.55	9.2	7.8
Pantothenic acid	19.6	37	19.2
Niacin	54.1	80	61.3
Choline chloride	6100	–	7150
Biotin	0.469	–	–
Folic acid	0.408	–	–
Vitamin B-12	0.107	0.28	0.23

[a]Jangaard et al. (1974).
[b]Sola and Kalhagen (1957).
[c]Sparre (1971).

Oils and total lipids — (*Physical and chemical constants*) — Capelin oil is produced in considerable quantities in Norway and Iceland and has replaced herring oil as the most important commercial marine oil. The oil yield is especially high in the Norwegian summer and fall fishery, when the fat content of capelin is 15–20%. However, due to the necessity of storing the capelin until ripe in the winter and spring fishery, and the distance from the fishing grounds in the summer and fall fishery, capelin oil is usually darker in color and has a higher content of free fatty acids than top quality herring oil.

Capelin oil is considered a low-iodine-value oil, generally from 95 to 115 (Jangaard 1967; Notevarp and Chahine 1972; Thorbjarnarson 1967). The oil pressed from cooked fish in reduction plants consists mainly of triglycerides, most of the more highly unsaturated phospholipids remaining in the meal. Urdahl and Nygård (1971) studied the composition of oil and lipids at various stages of reduction of two lots of capelin. The iodine values they obtained are given below.

	Capelin	
	I	II
Raw material	125.4	130.7
Pressed oil	96.7	110.5
Presscake	173.0	176.4
Presscake + stickw. concn.	170.2	171.0
Meal	166.5	164.0

The phospholipid content in the extract from the presscake was as high as 24%. The high iodine values in phospholipids are due to the content of highly unsaturated long-chain fatty acids, as shown in the tables giving the fatty acid composition.

Saponification values range from 181 to 190, and the specific gravity from 0.916 to 0.921. The oil from prespawning and spawning capelin has a fairly low content of unsaponifiable matter, usually 1.3–1.8%; but when the fish are feeding heavily in the summer and fall, the gut content can push the values much higher. Lambertsen (1972) determined the unsaponifiable matter in commercial capelin oils produced at various times of the year and its composition (Table 12). The composition was similar to that of the copepod *Calanus*

TABLE 11. Effect of drying on capelin meal. (Source: Anon. 1970.)

1. Proximate composition

	Protein (%)	Fat (%)	Salt (%)	Moisture (%)
Presscake meal				
Vacuum dried	71.2	7.8	1.1	10.2
From flame dryer I	58.8	8.1	0.9	24.3
Flame dryer I + vacuum dried	71.7	10.1	1.1	7.7
Flame dryer II	74.4	9.3	1.2	3.4
Steam dryer	75.7	9.4	1.1	2.6
Whole meal				
Flame dried	65.9	11.2	2.2	10.0

2. Amino acid composition

	Presscake meals				Whole meal
	Vacuum dried	Flame dried I	Flame dried II	Steam dried	Flame dried
Lysine	8.36	8.20	7.62	8.20	6.93
Histidine	2.36	2.27	2.31	2.35	1.58
Arginine	6.10	6.06	5.82	6.18	5.53
Aspartic acid	9.73	9.87	9.68	9.73	8.46
Threonine	4.99	5.06	4.78	4.92	4.21
Serine	4.47	4.56	4.17	4.44	3.91
Glutamic acid	15.39	15.39	15.51	15.29	14.26
Proline	4.08	3.67	3.84	4.12	3.45
Glycine	4.98	4.90	4.98	5.14	5.38
Alanine	5.91	5.98	6.01	5.98	5.81
Valine	5.61	5.86	5.66	5.70	5.11
Isoleucine	4.91	5.19	4.96	5.03	4.45
Leucine	8.47	8.59	8.55	8.49	7.56
Tyrosine	3.22	3.34	–	3.65	2.41
Phenylalanine	4.17	4.54	–	4.37	3.14
Methionine	3.11	3.00	3.06	3.10	2.49
Cystine	1.20	1.14	1.14	1.18	0.93
Available lysine	7.97	7.66	6.48	7.57	6.12
Protein availability	100%	96%	81%	95%	77%

TABLE 12. Unsaponifiable constituents in capelin oil (Lambertsen 1972).

Fish caught in:	% unsaponifiable matter	Composition of unsaponifiable matter (%)			
		Hydro-carbons	Fatty alcohols	Sterols	Glyceryl ethers
July	3.20	6	63	28	3
Sept.	3.10	7	68	23	2
Sept.	7.99	6	76	16	2
Oct.	4.47	15	65	20	–
Mar.	1.36	16	5	75	4
Fillet (19% fat)	0.98	23	26	51	–
Stomach content (10% fat)	15.59	5	80	15	–
Rest of intestines (29% fat)	3.89	46	38	16	–

finmarchicus, which is an important food of capelin (Lambertsen and Myklestad 1972).

The oils produced from feeding capelin often have a definite pink color. Lambertsen and Braekkan (1971) showed that this was due to a high content of astaxanthin in the oil; two oils they examined had values high enough to consider using them as a source of pigmentation in trout and salmon foods. Their data follow:

Sample no.	Astaxanthin µg/g	% astaxanthin as Diester	Monoester	Free
1	94.3	59	26	15
2	39.5	53	33	14
3	6.6	(100)	tr.	tr.
4	5.7	(100)	tr.	tr.

Fatty acid composition — The fatty acid composition of capelin lipids and commercial oils has been determined by several authors. Ackman et al. (1963, 1969) and Urdahl and Nygard (1971) have published fatty acid analyses of samples of lipids and oils from various sources. A summary of these is given in Table 13.

From this table it can be seen that commercial or pressed capelin oils have a fairly high content of long-chain monounsaturated acids and a relatively low content of long-chain polyunsaturated acids. The composition is quite typical of marine triglyceride oils from North Atlantic pelagic fish, and several of these oils have been analyzed, compared, and discussed by Ackman and co-workers (Ackman et al. 1967, 1969; Ackman and Eaton 1966, 1970, 1971a, 1971b; Ackman et al. 1967).

The lipids remaining in the presscake contain a high proportion of phospholipids, since these are not normally liberated by cooking and pressing. The fatty acid composition of the lipids extracted from the presscake shows the typical fatty acid distribution associated with phospholipids, i.e. relatively high contents of 20:5 and 22:6 acids, lower contents of 20:1 and 22:1, and a slightly higher content of 16:0 as compared to the triglycerides. Urdahl and Nygard (1971) found that the presscake lipids contained 21% phospholipids. In most fish the content of phospholipids in the fish muscle is relatively constant (0.6–1.0%) and shows little seasonal variation (Jangaard et al. 1967).

The lipids extracted from whole fish have, as expected, a fatty acid composition intermediate to that of pressed oil and presscake lipids. The lipid composition of capelin from Newfoundland and Norway is generally quite similar, although the ratios of some of the acids are different. For instance, the ratio 16:1/18:1 is greater than 1 in Newfoundland capelin and less than 1 in Norwegian fish in the samples analyzed.

Other studies—Most capelin oil, following hydrogenation and refining, is used as an edible oil in margarine and shortening. The trace amounts of certain substances present in the oil can be detrimental to the refining process and to the subsequent quality of the oil. Mörk (1973) studied the hydrogenation of oils from mackerel and capelin, and found that the nickel catalyst was "poisoned" quite rapidly when hydrogenation was carried out at 170°C at atmospheric pressure. He presumed that this effect was due to sulfur compounds in the oil. The poisoning effects of various sulfur and phosphorus compounds in the hydrogenation of marine oils have recently been determined (Magnusson and Notevarp 1971; Ottesen 1971).

The occurrence of trace elements in oils from capelin and other fish has been reported (Lunde 1967, 1971, 1972, 1973a, b, c; Notevarp and Chahine 1972). Selenium, bromine, and arsenic occur as organo-compounds in capelin oils in the following amounts: selenium, 0.05–0.12 ppm; bromine, 3.4—7.5 ppm; and arsenic, 7.8–13.2 ppm. Slightly higher values were found in the lipids extracted from commercial fish meals.

The effects of handling and treatment of the raw material on the iron and copper content of capelin oils were dramatically demonstrated by Notevarp and Chahine (1972). They found that oil from good quality raw material, when carefully processed and stored, contained 0.07 ppm iron and 0.03 ppm copper. In contrast, the poorest quality oil contained up to 10.1 ppm iron and up to 0.40 ppm copper. Most representative commercial oils contained 1–2 ppm iron and 0.05–0.25 ppm copper. During hydrogenation and refining, the iron and copper content was drastically lowered to 0.04 and 0.02 ppm, respectively.

The same authors also studied the effect of these elements, and of the natural content of the antioxidant tocopherol, on the oxidative

TABLE 13. Fatty acid composition of capelin lipids.

	Canada				Norway		Norway					Canada
	Whole fish total lipids[a]		Commercial oils[c]		Whole fish total lipids[b]		Commercial oil[a]	Pressed oil[b]		Presscake lipids[b]		Roe lipids
	♂	♀	Inshore fish	Grand Bank fish	1	2		1	2	1	2	F
Fatty acid												
14:0	9.3	7.4	8.8	8.2	6.7	7.6	7.9	8.1	8.2	3.4	4.3	6.4
14:1+15br	0.4	0.2	0.4	0.8	0.6	0.7	0.7	0.7	0.8	0.5	0.4	0.4
15:0	0.3	0.3	0.3	0.2	0.4	0.3	0.5	0.4	0.4	0.4	0.3	0.5
16:0	8.5	11.1	9.2	8.2	11.3	14.9	11.1	9.0	13.5	17.3	16.9	14.7
16:1w7[d]	15.1	15.0	11.7	9.4	8.2	7.4	11.1	8.7	7.6	6.6	6.1	14.7
16:2w4+br	0.4	0.9	0.8	–	0.4	0.2	0.3	0.3	0.3	0.6	0.4	1.3
17:0+br	0.7	0.1	0.9	0.7	0.1	0.4	0.5	0.2	0.4	0.2	0.6	1.0
17:1w8[d]	0.5	<0.1	0.1	0.3	0.2	0.1	0.4	0.2	0.1	0.2	0.1	0.5
18:0	1.8	1.5	0.6	1.4	1.3	1.6	1.0	1.1	1.3	1.8	1.8	1.5
18:1w9[d]	7.6	10.7	11.7	12.5	17.3	20.3	17.0	17.4	22.9	16.1	17.8	12.4
18:2w6	0.4	0.8	0.9	0.7	1.2	1.6	1.7	1.2	1.5	1.4	1.5	1.9
18:3w6	0.2	0.5	0.1	0.1	–	–	0.2	–	–	–	–	0.4
18:3w3	0.1	0.2	0.2	0.2	0.2	0.7	0.4	0.1	0.8	0.7	0.9	1.3
18:4w3	0.9	1.5	0.8	0.6	0.9	2.5	2.1	1.0	2.5	1.4	2.6	2.8
19:0 and 19:1	0.1	0.3	<0.1	0.1	0.1	0.2	0.3	0.2	0.2	–	0.1	0.6
20:1w9[d]	22.7	14.8	24.6	27.4	20.5	13.0	18.9	24.9	14.7	7.9	6.3	6.3
20:4w6	0.1	0.1	<0.1	0.1	–	–	0.1	0.2	0.3	–	0.4	0.4
20:4w3	–	0.4	0.1	0.1	0.2	0.3	0.3	0.1	0.3	0.3	–	0.8
20:5w3	6.1	10.1	3.9	2.8	5.3	6.1	4.6	2.9	4.6	11.6	11.1	11.1
22:1w11[d]	19.6	12.7	23.0	25.0	15.6	12.2	14.7	19.5	13.9	5.0	5.8	4.1
22:5w3	0.4	1.0	0.5	0.2	0.3	0.2	0.3	0.1	0.2	0.9	0.7	1.1
22:6w3	2.6	7.3	2.2	1.0	7.4	7.0	3.0	1.7	3.7	22.2	19.1	11.7
24:1	0.9	1.2	0.8	–	0.9	0.7	1.0	1.2	0.8	0.3	1.0	0.8

[a]Ackman et al. (1969).
[b]Urdahl and Nygård (1971).
[c]R. G. Ackman (1973) personal communication.
[d]Other isomers are included.

stability of capelin oils. The tocopherol content was found to range from 0.07 to 0.38 mg/g. The oxidative stability was found to be dependent more on the tocopherol content and benzidine value of the crude oils than on their content of trace metals. Capelin oils had a much better oxidative stability than herring oils; the authors suggest this may be due to the lower iodine value of the capelin oils (95–103 compared to 129 and 142). Perhaps this explains the excellent stability of capelin in frozen storage, although the fat in lean capelin muscle would have a high iodine value due to the phospholipid content.

Summary and Conclusions

The capelin is a cold-water pelagic fish and occurs in northern regions of the Atlantic and Pacific oceans. Mature males are generally 17–19 cm long and females 15–17 cm. The spawning stock consists almost exclusively of 3- and 4-year-old fish, and spawning takes place both on beaches and in deeper water in March and April in northern Norway and Iceland, and in June and July in Newfoundland–Labrador.

There are large underutilized stocks in the northwest Atlantic, where exploitation is just beginning. In the Barents Sea the stocks are heavily exploited, especially by Norwegian fishermen. Capelin are fished with purse seines and midwater trawls in offshore areas, and with various seines, traps, and dipnets inshore.

Most of the word's catch of capelin is processed into meal and oil. Relatively small but increasing quantities are frozen, canned, dried, or smoked for human consumption. The fat content of capelin varies from 16–20% in the fall to 1-3% in spring and early summer immediately after spawning. Capelin oil is classified as a low-iodine-value oil similar to herring oil. Capelin meal has a protein content of 67–70%.

As capelin and capelin products are nutritionally of high quality, the use of capelin for human consumption will no doubt show a rapid increase over the next few years.

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Preparation and Cooking of Fresh or Frozen Capelin

Clean, trim heads and tails, wash, and drain fish on paper towel. If fish have been frozen, allow to thaw completely. For best results do not overcook.

Pan Fried Capelin

12 capelin	1½ tsp salt
4 tbsp cooking oil	1 cup bread crumbs
1 egg	lemon
1 tbsp cold water	

Heat cooking oil to 350–375°F (177–190°C), 3 parts cooking fat or oil and 1 part butter may be used. Beat together egg, water, and salt. Dip fish in egg mixture, allow excess to drain. Roll in bread crumbs, covering thoroughly. Corn meal or flour may be substituted for bread crumbs. Fry until golden brown on both sides. Serve hot with lemon wedges.

Deep Fried Capelin

Heat fat (vegetable oil or hydrogenated fat preferred) to 375°F (190°C). Bread fish as for pan fried capelin, 4–5 fish at a time. Drop into hot fat, cooking 4–6 minutes or until golden brown. Remove from fat, drain on paper towel.

Deep Fried Capelin with Sweet and Sour Sauce

12 capelin	1½ cup bread crumbs
1 tsp salt	2 eggs
pepper	vegetable oil
1 cup flour	

Beat eggs until frothy. Spread flour and crumbs on two separate plates. Sprinkle fish with salt and freshly ground pepper. Roll fish in flour, shake to remove excess. Dip in beaten egg, then roll in bread crumbs. Arrange breaded fish on wax paper and refrigerate for at least 15 minutes to allow coating to become firm. Pour

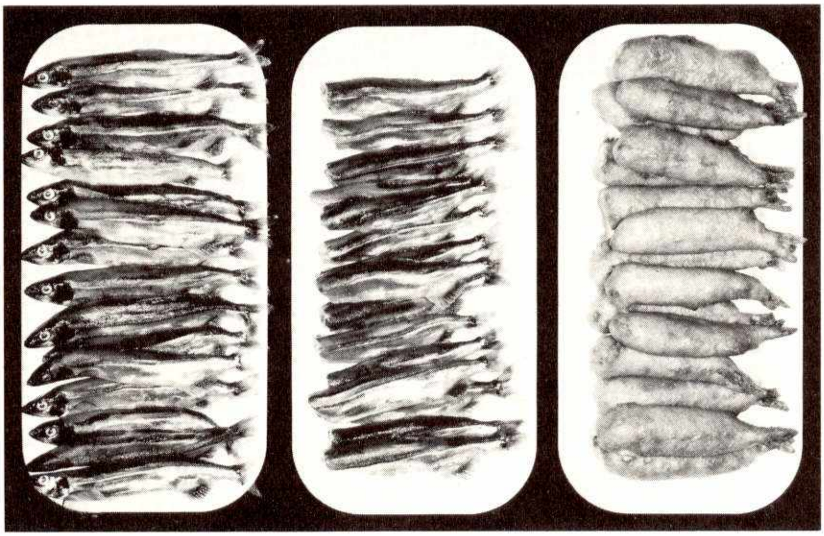

FIG. 55. Greenland capelin in puffed batter (Anon. 1971).

oil into deep fryer or heavy saucepan to a depth of 3 inches, heat to 375°F (190°C). Deep fry fish 4 or 5 at a time for 4–6 minutes, turning gently until they are crisp and golden on all sides. Remove from oil and drain on paper towel. Serve with sweet and sour sauce.

Sweet and Sour Sauce

1 can (7½ oz) tomato sauce	2 tbsp cornstarch
⅔ cup white vinegar	¼ cup water
⅔ cup water	½ tsp paprika
⅔ cup sugar	⅛ tsp ground allspice
1 tsp salt	

Combine tomato sauce, vinegar, water, sugar, and salt. Bring to a boil. Dissolve cornstarch in ¼ cup water. Add to sauce. Cook and stir until clear and thickened. Stir in paprika and allspice. Makes about 2 cups.

Broiled Capelin

Place fish in well oiled baking pan, 1½ inches below broiler. After 3 minutes brush fish with melted butter, sprinkle with salt and pepper. Broil 5–8 minutes longer or until fish are golden brown.

Baked Capelin

12 capelin	¼ tsp white pepper
1 cup milk	2-3 tbsp butter or margarine
1 tsp salt	

Dip fish in milk, roll in bread crumbs. Place in well-greased baking pan. Bake in moderate oven at 350°F (177°C) for about 15 minutes. Brush fish with melted butter or margarine during baking. Turning is unnecessary.

Capelin with Almonds

2 lbs capelin	2 tbsp slivered, blanched almonds
½ tsp salt	2 tbsp lemon juice
⅛ tsp pepper	¼ cup butter

Clean and bone fish. Arrange in greased baking pan, sprinkle with salt and pepper. Melt butter, add almonds and brown slightly. Stir in lemon juice, pour over fish. Bake in hot oven at 450°F (232°C).

Crispy Capelin

2 lbs capelin	½ cup grated Parmesan cheese
salt	
pepper	1 can (15 oz) tomato sauce
1½ cups flour	

Thaw fish, if frozen. Clean and remove heads and tails. Wash fish and pat dry. Sprinkle the inside with salt and pepper. Combine flour and cheese. Dip fish in tomato sauce, then roll in flour mixture. Place in a single layer in fry basket. Fry in deep fat at 350°F (177°C) for 2–4 minutes or until brown. Drain on absorbent paper. Keep hot in a warm oven until all are cooked. If desired, serve accompanied by a cocktail or chili sauce.

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