Biology, abundance estimates and management of the Icelandic stock of capelin

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ABSTRACT

The Icelandic capelin inhabit the area between Iceland, Greenland and Jan Mayen. Continuous systematic research on this stock has been carried out since 1966, gradually increasing in scope and volume.

The Icelandic capelin spawn when 3–4 years old in coastal waters, mainly off South and West Iceland in March-April. The larvae drift with the coastal current in a clockwise direction to the west, north and east of the country where capelin spend the first year of their life as 0-group. During the feeding season juvenile and adult capelin have a more oceanic distribution, the oldest and largest fish even migrating to the waters north of Jan Mayen. These stock components assemble in early winter north and northwest of Iceland from where the spawning migration starts in December/ January. From there the mature fish follow the edge of the shelf to the east and south of Iceland. Growth is quite rapid during the first 2–3 years. Average lengths and weights of I-, II- and III-group fish after the feeding season were calculated for the period 1966–1983. These show considerable changes, both from year to year and also on a longer time scale, apparently in correlation with changes in temperature. Data on the natural mortality coefficient have been obtained by comparing successive acoustic estimates of abundance, taking into account the catch during the intervening period. The results are near the level previously assumed for the maturing stock in August-December, i. e. $M = 0.04$/month. However, spawning mortality is very high and evidence is presented which suggests that the survival rate of spawners is practically zero.

The fishery of the Icelandic capelin began in 1964 in the coastal waters southwest of Iceland in winter. The fishery was conducted only in winter until 1976, when a summer/autumn fishery was started off North and Northwest Iceland. In the following two years catches increased from around 500,000 tonnes to over 1,000,000 tonnes. The fishery collapsed in 1981/82 and a complete fishing ban was imposed, practically lasting from December 1981 to November 1983. The fishery was conducted by Icelanders only until in 1978, when they were joined by the Norwegians and two years later by the Faroese as well as EEC countries.

Because of the short life of the capelin, fishery independent assessment of stock size has to be used. An 0-group index of the size of each year class is available from 1972 onwards. Tagging experiments have been successful in case of adult capelin. The results, however, do not become available early enough for management purposes. Acoustic estimates of the abundance of the adult stock are available from 1978, both from the autumn period and also from the early part of the year. The results show a dramatic reduction in stock size for 1978–1982, from over 2 million tonnes in the beginning of the 1978 summer/autumn season to 300–400 thousand tonnes in the summer of 1982. There was a considerable recovery in 1983. A high degree of accuracy of the acoustic estimates of the abundance of adult Icelandic capelin has been established. Nevertheless, these measurements have been strongly contested by fishermen and authorities, and as a result management has been inefficient and the stock overfished. It is suggested that the effect of overfishing has been accelerated by a prolonged period of unfavourable environmental conditions.

INTRODUCTION

The capelin, *Mallotus villosus* (Müller), is a boreoarctic, pelagic and schooling, salmonid species with a more or less circumpolar distribution. Although capelin seldom grow larger than 20 cm in size and are short-lived (3–6 years) their biomass in certain areas may reach millions of tonnes.

The largest known stock of capelin inhabits the Barents Sea and adjacent waters while smaller but nevertheless important stocks are found off Iceland, Greenland, Newfoundland and Labrador as well as in the North Pacific.

During the last 2–3 decades capelin have become an important source of raw material for the production of meal and oil and lately on a smaller scale for human consumption. Because of its pelagic schooling nature capelin have fallen easy prey to modern purse seining, and capelin stocks have collapsed because of overfishing. In addition, they are a major prey of many commercially important northern fish species.

The stock of capelin which inhabits the area between Iceland, Greenland and Jan Mayen is referred to as the Icelandic capelin, since its spawning grounds are found in Icelandic coastal waters.

Although the Icelandic capelin are available as food for other fish and indeed eaten by them throughout the year (Pálsson 1983), most of the maturing capelin and part of the juveniles migrate to feed in arctic waters between Iceland, Greenland and Jan Mayen in summer and are then out of reach of its main fish predators. On returning to the Icelandic shelf area in late autumn these capelin again become available as food for larger fish such as cod (*Gadus morhua* (L.)) and remain so until spawning in March/April some 4–5 months later. Thus the Icelandic capelin may through their long feeding migrations transfer large amounts of biomass and energy from the cold arctic waters to warmer areas.

Prior to the present period of exploitation (1964–1983) work on the Icelandic capelin stock was limited. Jespersen (1920) investigated its post-larval stage, Sæmundsson (1926) described its biology and Fridriksson (1943) pointed out some of its racial characeristics. These publications as well as unpublished biological data collected by various workers in the 1947–1966 period were reviewed by Vilhjálmsson (1968).

Continuous systematic research on the Icelandic capelin stock has been carried out since 1966, gradually increasing in scope and volume. In this paper the present knowledge of the general biology and migrations of the stock is outlined. The exploitation of the Icelandic capelin which resulted in the near collapse of the stock in 1981–82 is described. Research on the abundance of the Icelandic capelin in the years 1978–1983 is reported and the subsequent management advice and execution are discussed.

The present communication is largely based on a paper submitted by the author to the FAO Expert Consultation to Examine Changes in the Abundance and Species Composition of Neritic Fish Stocks, held in San José, Costa Rica, 18–29 April 1983 (Vilhjálmsson 1983).

BIOLOGY

Spawning

The Icelandic capelin spawn on the seabed in shallow coastal waters, mainly off South and Southwest Iceland in the second half of March and the first half of April (Fig. 1). Usually the spawners migrate clockwise from the area north of Iceland to the coastal waters southeast of Iceland, the first arriving at the southeast coast in late January or February. In some years spawners also arrive at the southwest coast directly from the banks off Northwest Iceland in March (Vilhjálmsson 1974a, 1977, 1980; Vilhjálmsson and Malmberg 1977). In both cases the spawners enter the warm waters at or near

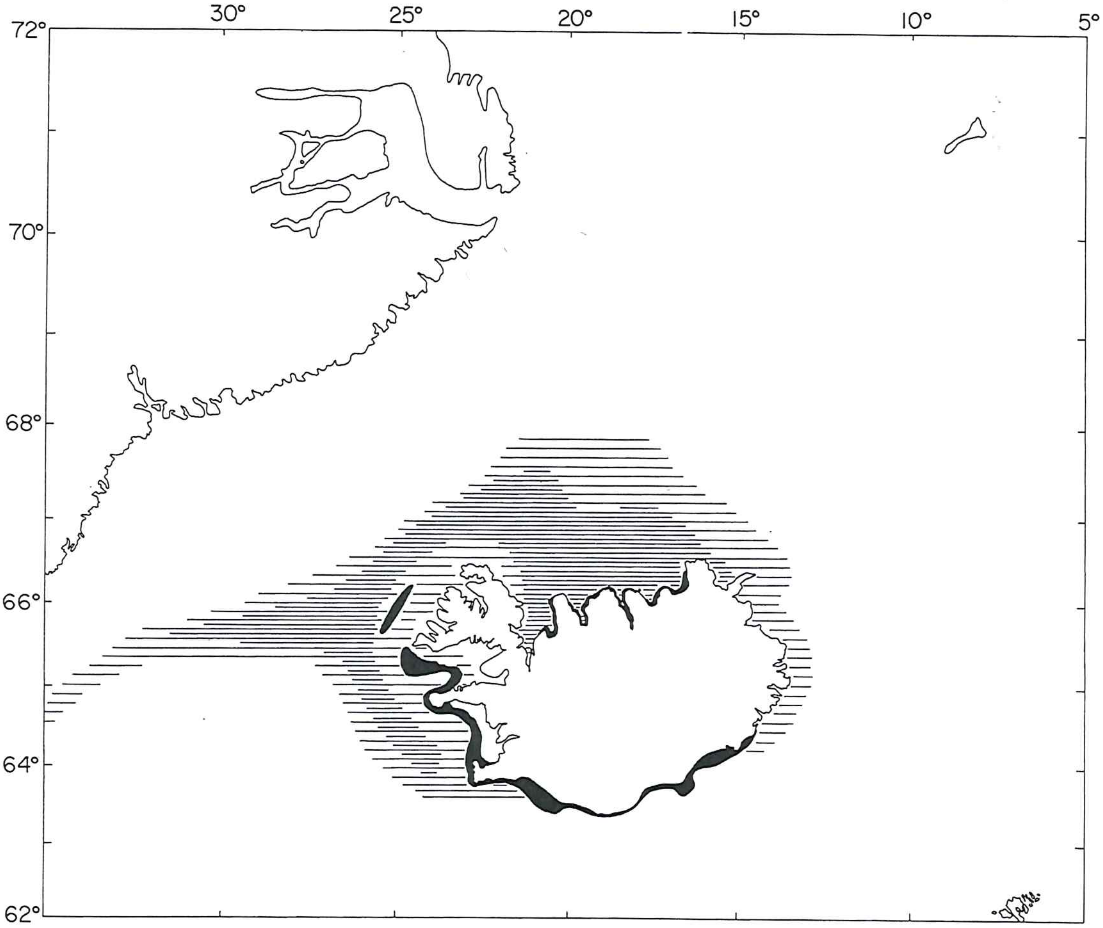

Fig. 1. The spawning grounds of the Icelandic capelin (black), the common distribution pattern of 0-group capelin in August (shading) and maximum density (dark shading).

the spawning grounds, when the weight of the ovaries of the females has become about 8–10% of the total body weight. During the next 2–3 weeks there is an increase to about 20% followed by a sharp increase to 25–30%, when spawning begins (Vilhjálmsson 1974b, 1977).

During most of the capelin's lifetime the sex ratio is about 1 : 1. When the spawning season approaches, the sexes begin to segregate. This is borne out by the highly uneven sex distribution often observed in commercial catches from the time shorthly before spawning is about to begin and onwards. The spawning act is played in pairs and sometimes threes whereupon the spent females seem to leave the spawning grounds and the immediate vicinity, while the males are left behind to repeat their performance until they become exhausted and die. Thus, if a fishery is conducted throughout the spawning season, the catch will in the end consist exclusively of males. It has been possible to observe these processes directly in aquarium tanks (Fridgeirsson 1976).

The substrate preferred is sand or fine gravel to which the eggs will stick during the incubation period. At South and West Iceland the spawning zone extends from near the coastline down to at least 50–70 m depth. Beach spawning proper, common among some capelin stocks (Templeman 1948), is not the rule off South and West Iceland. This is probably due to the exposed nature of the coastline and the resulting heavy surf which may throw considerable quantities of fish spawning in shallow waters on to the beach. Beach spawning is, however, well known to exist locally in sheltered fjords on the north coast of Iceland.

In aquarium tanks hatching was found to take place 20–30 days after fertilization, when the temperature was kept at 7°C (Fridgeirsson 1976). This is the temperature found on the main spawning grounds off the south coast. In the shallower part of that area as well as in the coastal regions off the west and north coasts, the temperature may be considerably lower than 7°C (Malmberg 1979). Lower temperatures will further prolong the incubation period.

Spawning grounds outside Icelandic waters do not seem to be of importance for the stock as a whole. Although the presence of spawners in the vicinity of Jan Mayen in spring has been established, their abundance is low (Anon. 1979a). The same holds true for capelin spawning in spring and early summer in East-Greenland fjords. Larvae that could originate from such a spawning have been rare in catches of 0-group capelin off E-Greenland in August and apparently drift south along the Greenland plateau out of the East-Greenland area (Anon 1983a).

Distribution and abundance of larval and 0-group capelin

After hatching at a size of 5.0–7.5 mm and some 3–4 weeks from spawning the capelin larvae ascend towards the surface waters. Their store of food, carried in the yolksac, generally lasts for 8–12 days during which time the larvae must come across suitable food, if they are to survive (Fridgeirsson 1976). The successful ones are then transported by currents (Fig. 2) in a clockwise direction to the areas west, north and east of Iceland. In some years a westward drift towards Greenland is observed along

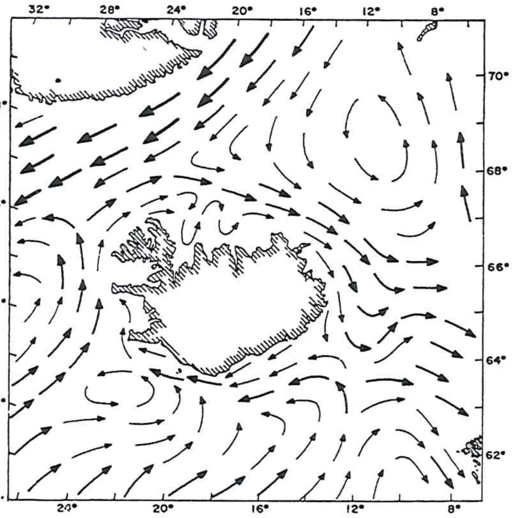

Fig. 2. Surface ocean currents in the Iceland-Greenland-Jan Mayen area and south of Iceland. (After Stefánsson 1961).

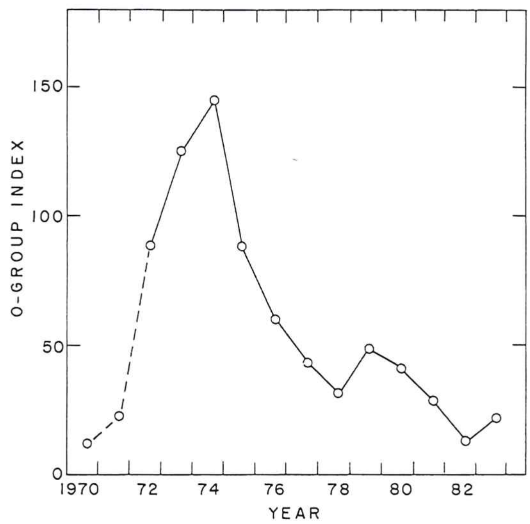

Fig. 3. Changes in the 0-group abundance index, 1970–1983. The graph is based on data collected during the 0-group surveys in August 1970–1983. (The figures for 1970 and 1971 are questionable).

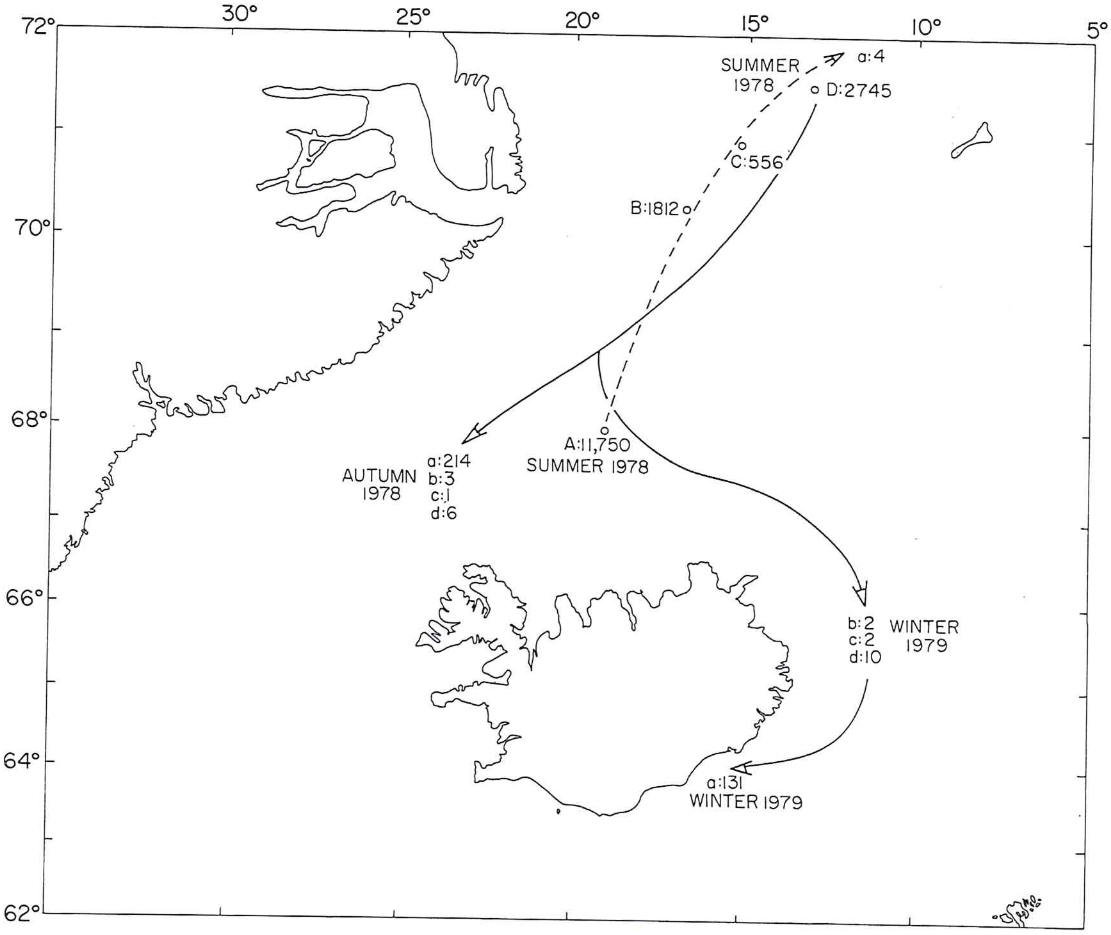

Fig. 4. The migrations of maturing capelin in the period summer/autumn 1978 — winter 1979 as indicated by tagging with internal steel tags. A, B, C, D indicate positions of release, and a, b, c, d position of recapture. The numbers of tagged fish and retrieved fish tags are also given.

the southern part of the Iceland-Greenland Ridge.

The distribution and abundance of 0-group capelin in the Iceland-Greenland area have been studied in August each year since 1970 (Vilhjálmsson and Fridgeirsson 1976; Anon. 1978, 1979b, 1980, 1981a; Vilhjálmsson et al. 1980; Vilhjálmsson and Magnússon 1981, 1982, 1983). During this period (1970–1983) considerable changes in the size of the distribution area have been observed as well as in the densities of 0-group capelin within subdivisions of this area. Thus the relative magnitude of the westward drift towards Greenland has varied between years from virtually zero to about 16%, with an average of around 5% for the 14 year period (Anon. 1983a). A schematic representation of an average distribution pattern of 0-group capelin in August is shown in Figure 1.

The annual abundance indices calculated for 0-group capelin from the August survey data during the above period show a more definite trend (Fig. 3). The apparently poor years of 1970–1971 were followed by very

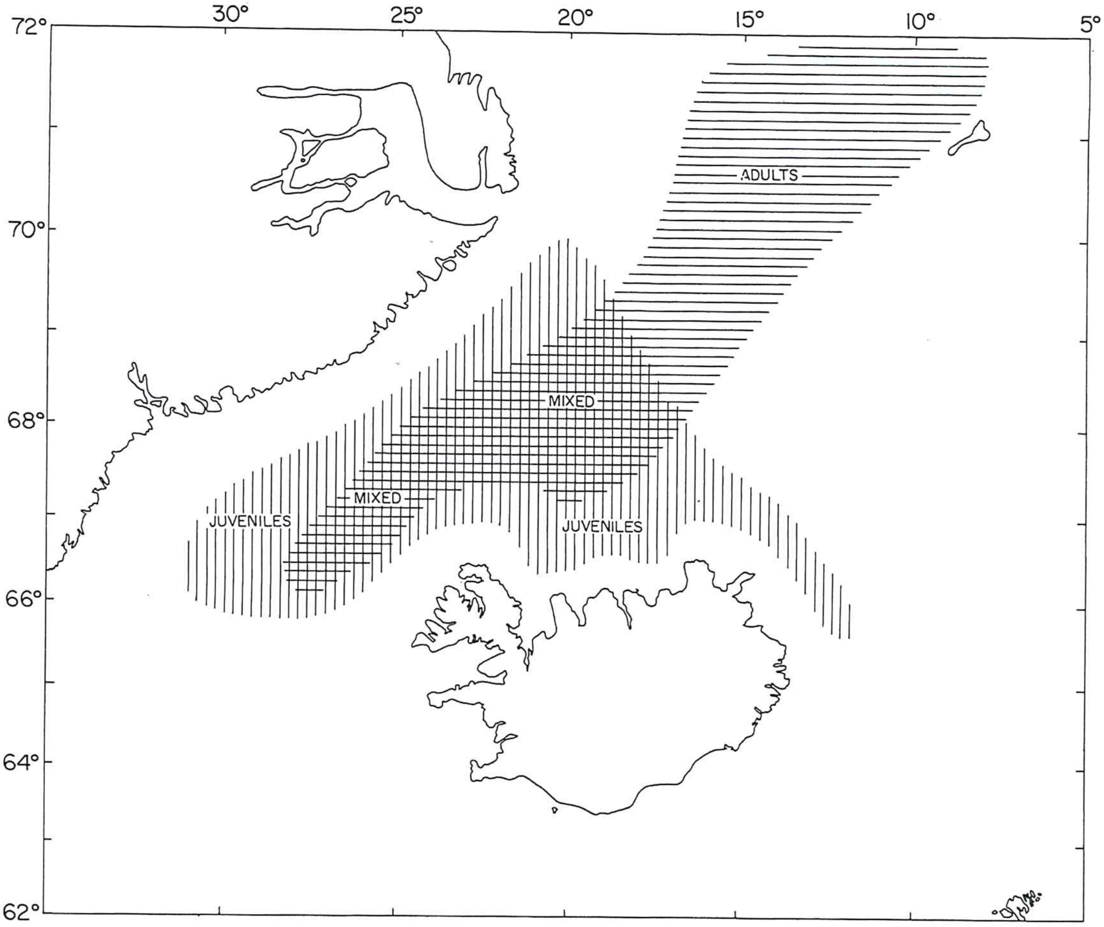

Fig. 5. Typical geographic distribution of juvenile and adult capelin in the feeding season. Horizontal shading: adults; vertical shading: juveniles.

rich 0-group year classes in 1972–75. After that there was a rapid decline in 0-group abundance which has remained at a comparatively low level since 1977. However, it should be pointed out that in 1970–71 sampling methods used in the August 0-group surveys were being developed with regard to the capelin. Consequently, abundance indices calculated for these years need not be comparable to those obtained for this species later in the series.

The above changes in the 0-group capelin abundance indices are illustrated in Figure 3.

Distribution and migration of I-, II- and III-group capelin

Through extensive acoustic surveying and sampling, first in connection with scouting for the fishing fleet and later for stock assessment purposes, the migrations of the Icelandic capelin have been mapped and may be described as follows:

In winter (November-April) juvenile 1–2 group capelin are most frequently found in waters over or near the continental shelf off North and Northwest Iceland, but sometimes also farther east. Although these

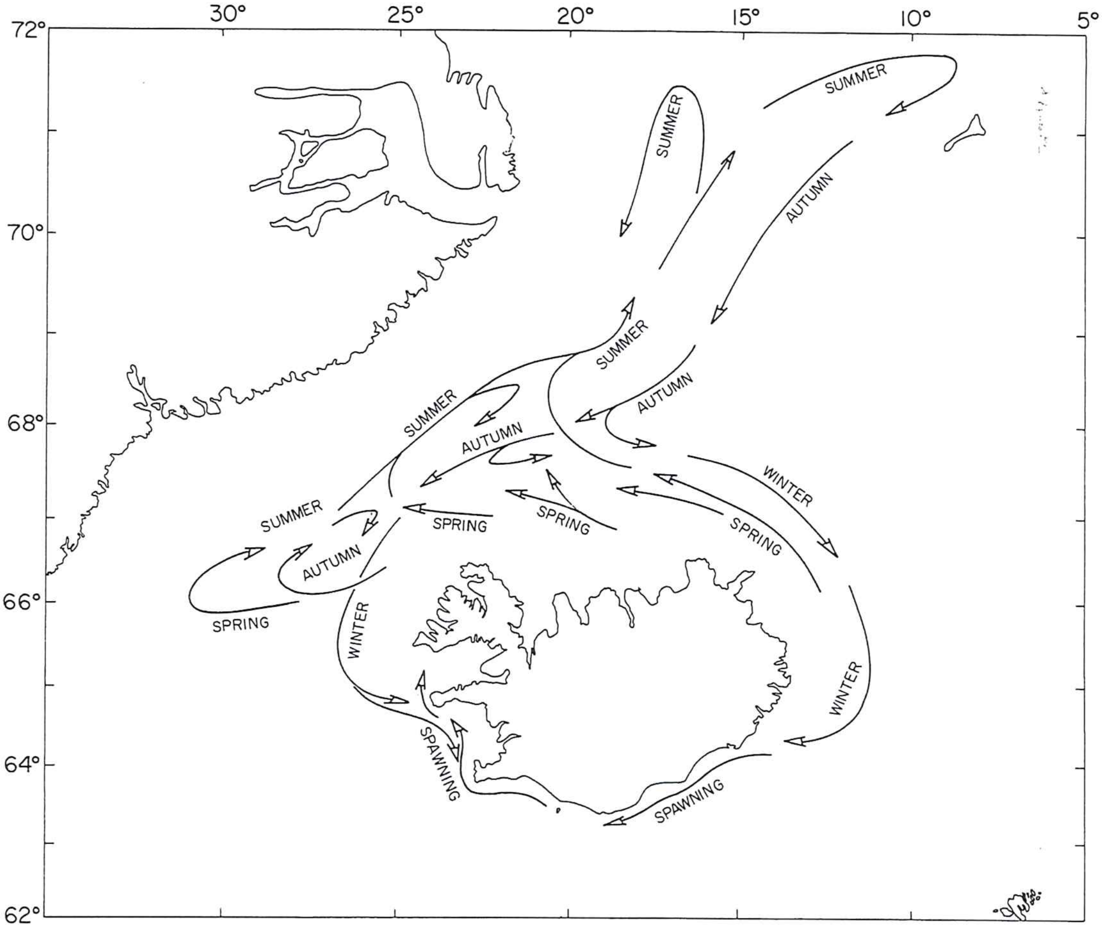

Fig. 6. The general migration pattern of the maturing capelin stock from April/May until March/April in the following year.

capelin may at times be found with considerable quantities of food in their stomachs, feeding during the winter period seems to be somewhat oportunistic.

In spring a varying proportion of the juvenile stock component migrates farther offshore into colder waters to feed pelagically during the summer months. Thus at that time of the year capelin may also be recorded in oceanic areas between Iceland and Greenland and over the East Greenland plateau from the Scoresby Sound south to the Dohrn Bank. Juvenile capelin, probably belonging to the stock which spawns at Iceland, have also been recorded farther to the west, particularly at the edge of the continental shelf off the Angmagsalik bay.

In autumn and early winter the immature capelin retreat with the advancing cold waters from the north and overwinter off Northeast and North Iceland or in the Iceland-Greenland Channel area (northwest of Iceland) as the case may be.

Maturing II–III group capelin show a somewhat similar migration pattern, but as a rule they have a much wider distribution. Thus most of these capelin migrate to oceanic regions in spring and early summer.

In recent years the maturing stock has been divided in two parts during the feeding season. These may be referred to as northern and southern components.

The southern component feeds on the Iceland-Greenland Ridge and off North Iceland and is often mixed with juveniles. The northern component, consisting of the oldest and largest fish, undertakes a long northward migration to the area between Greenland and Jan Mayen and to the north of Jan Mayen to 72–73°N. These capelin stay out of the distribution area of the juveniles for at least 2–3 months in summer and autumn.

Towards autumn both components of the maturing stock start migrating back south and gradually assemble on the overwintering grounds off North or Northwest Iceland in October-November. From there the main spawning migration begins in December-January and in a clockwise direction follows the edge of the continental shelf north and east of Iceland south to the boundary of the warm Atlantic water, whereupon they head westwards towards the southeast coast.

These movements of the maturing stock were observed during acoustic scouting and stock assessment surveys in 1976–1983 and were also very clearly demonstrated by a tagging experiment in 1978/79 (Vilhjálmsson and Reynisson 1979). The migration as indicated by this experiment is shown in Figure 4.

In those years when capelin migrate directly southwards from the north and northwest to spawn at West or Southwest Iceland, part of the spawning stock remains in the overwintering area off Northwest Iceland until late February when its southward migration begins (Vilhjálmsson and Reynisson 1979; Vilhjálmsson et al. 1982). It is also possible that in some of the years, when spawning migrations from the north and northwest take place, part of the stock may have been feeding in the Dohrn Bank area or farther west, arriving on the West Iceland spawning grounds more or less directly from there. In winter, however, weather and ice conditions are generally not suitable for surveying in the waters between Northwest Iceland and Greenland, and such migrations have never been directly observed.

The distribution areas of juvenile and adult capelin are outlined in Figure 5 and the general migration pattern of the maturing stock in Figure 6.

Changes in length and weight at age

Growth is very rapid during the second year of the capelin's life (Table 1) as can be seen by the fact that the weight increase is on the average about 8-fold during the second summer, i. e. for I-group fish. For II-group fish the weight still increases by a factor of 2.3 but drops to a factor of 1.3 on the average among members of age group-III.

TABLE 1

Average length and weight at age of Icelandic capelin (both sexes combined) for the 1966–83 period as measured in late autumn and early winter. The table also gives the range within which annual averages have fallen.

Age group	*Length (cm)*		*Weight (g)*	
	Average	*Range*	*Average*	*Range*
0	~ 6.5	5.0– 8.0	~ 1.0	0.5– 1.5
I	12.1	10.5–14.3	8.0	3.8–10.4
II	15.4	14.3–17.7	18.3	14.9–22.3
III	16.5	15.5–18.1	24.7	20.0–31.0

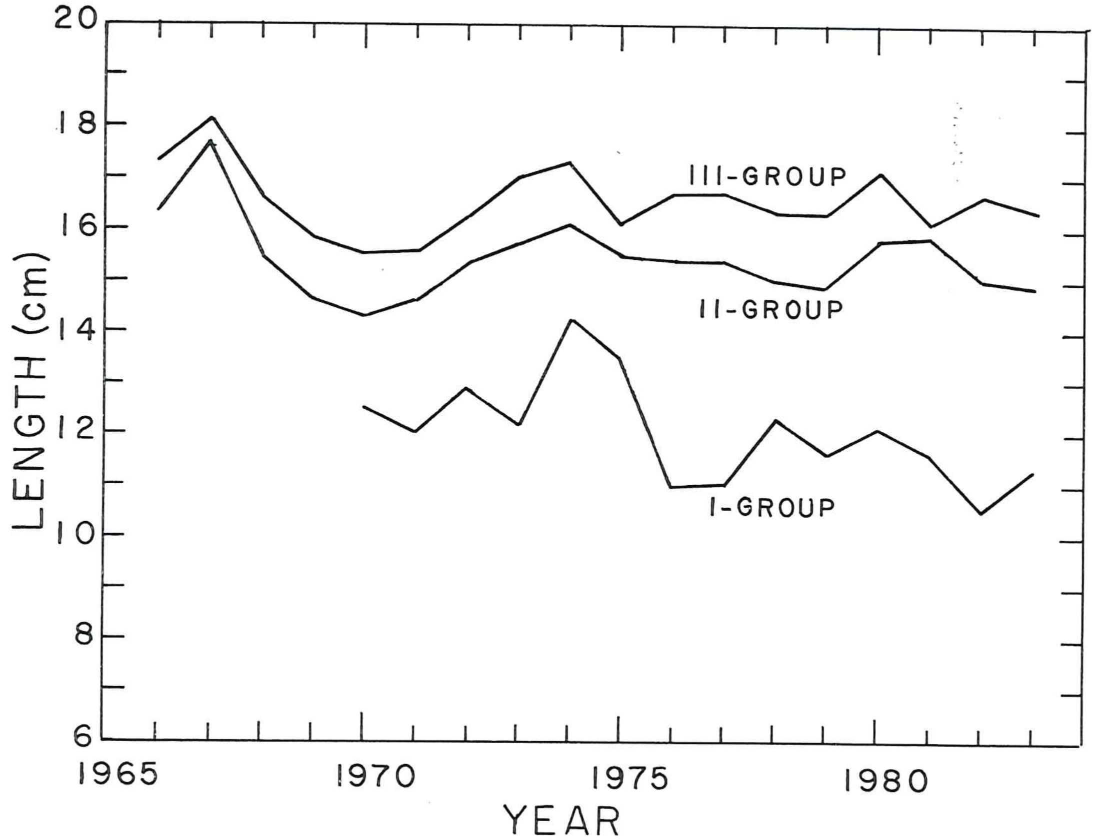

Fig. 7. Variations between years in mean length of I-, II- and III-group capelin. Mean length for the period 1966–1983: I-group: 12.1 cm; II-group: 15.4 cm; III-group: 16.5 cm.

It is well known that male capelin grow faster than females. In the Iceland-Greenland-Jan Mayen area the difference in length between sexes has, in the spawning population, varied from 1.1–1.7 cm during the 1971–1980 period with an average of about 1.4 cm in all age groups (II, III and IV). During the same period the corresponding difference in weight has varied between 3.7 and 10.5 g. In this case, however, the difference between the sexes increases with age, the average being 5.7, 7.4 and 9.4 g for II-, III- and IV-group spawners respectively.

Before the onset of the maturing process it is difficult to distinguish between the sexes except under the microscope. However, microscopic analysis of capelin samples is time consuming and has, as a rule, not been practised. Therefore, information on the age or size at which the above sexual dimorphism in growth sets in, is not available. Where this phenomenon has been examined in more detail, it has been found that the growth rate of the sexes begins to diverge during the second year of the capelin's life (cf. Jansgaard, 1974). It should be noted that except during the actual spawning season the sex ratio in the stock is generally 1 : 1.

Average lengths and weights recorded annually for I-, II- and II-group capelin as measured after the feeding season 1966–1983 are shown in Figures 7 and 8.

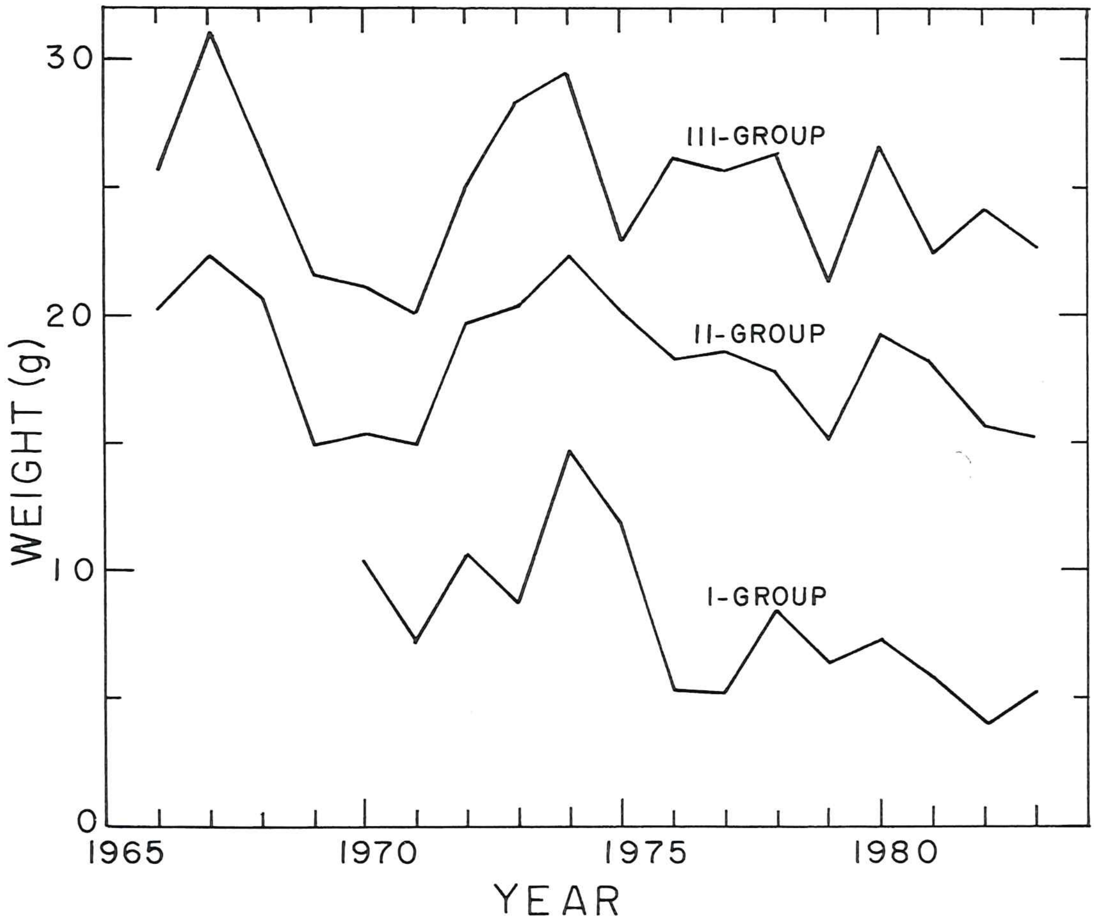

Fig. 8. Variations between years in mean weight of I-, II- and III-group capelin. Mean weight for the period 1966–1983: I-group: 8.0 g; II-group: 18.3 g; III-group: 24.7 g.

In a recent paper, Ástthórsson et al. (1983) examined changes in the abundance of zooplankton in Icelandic waters during the period 1961–1982. A comparison between changes in plankton abundance off central North Iceland and the mean weight of capelin is shown in Figure 9. With the possible exception of the last few years in the series, there is no apparent correlation between plankton abundance and growth of capelin. It should be noted, however, that the plankton in question consists mostly of *Calanus finmarchicus,* while the capelin relies also largely upon Euphausiids as well as arctic species of copepods for its food. Data on these groups of animals suitable for comparison with growth of capelin are unfortunately not available.

Malmberg and Svansson (1982) have reported on changes in temperature in North Icelandic waters as measured in May-June in the period 1961–1980. Comparable data for 1981–1983 are available in reports on joint Soviet-Icelandic research on hydrography, plankton biomass and occurrence of pelagic fish (Anon. 1981b, 1982a and 1983b). The general correlation between anomalies of mean weight of capelin and

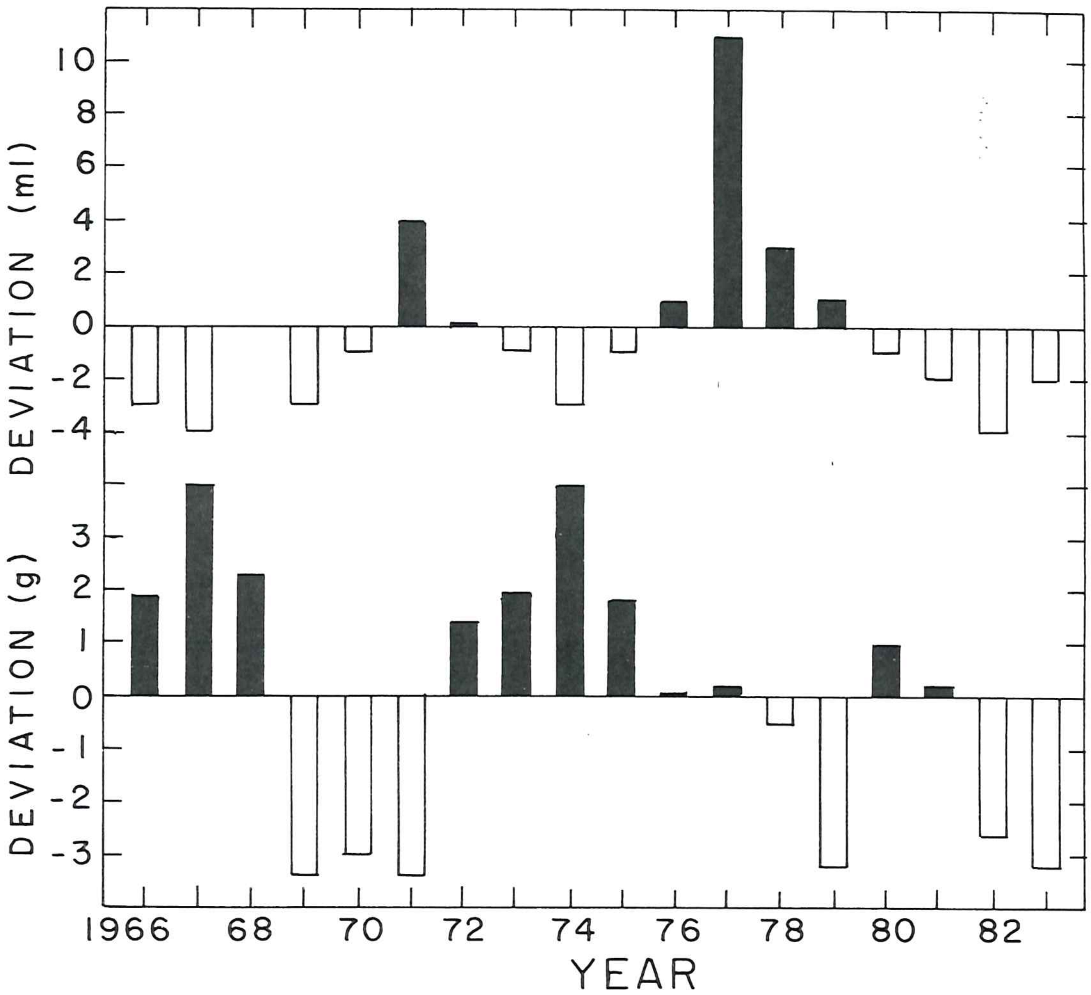

Fig. 9. Comparison between deviations from mean zooplankton volumes (ml/21m^3) and deviations from mean weight of capelin (g) in the period 1966–1983.

temperature off the central north coast of Iceland is striking in 1966 and in most years from 1969 onwards (Fig. 10). The correlation fails, however, in 1967 and 1968.

Several interesting deductions can be made from these data, especially with regard to changes in weight:

1) Growth conditions have been highly variable throughout the period, even from one year to another. A measure of the magnitude of these fluctuations is the change in the average weight of a year class by as much as 20–30 percent from one year to another.
2) There is a severe reduction in growth during the very cold years 1969–1971 followed by a rapid recovery already by the end of 1972. This reduction in growth does not seem to apply to the years 1967 and 1968 which were also very cold, possibly due to inadequate sampling during the initial stages of the present research programme.

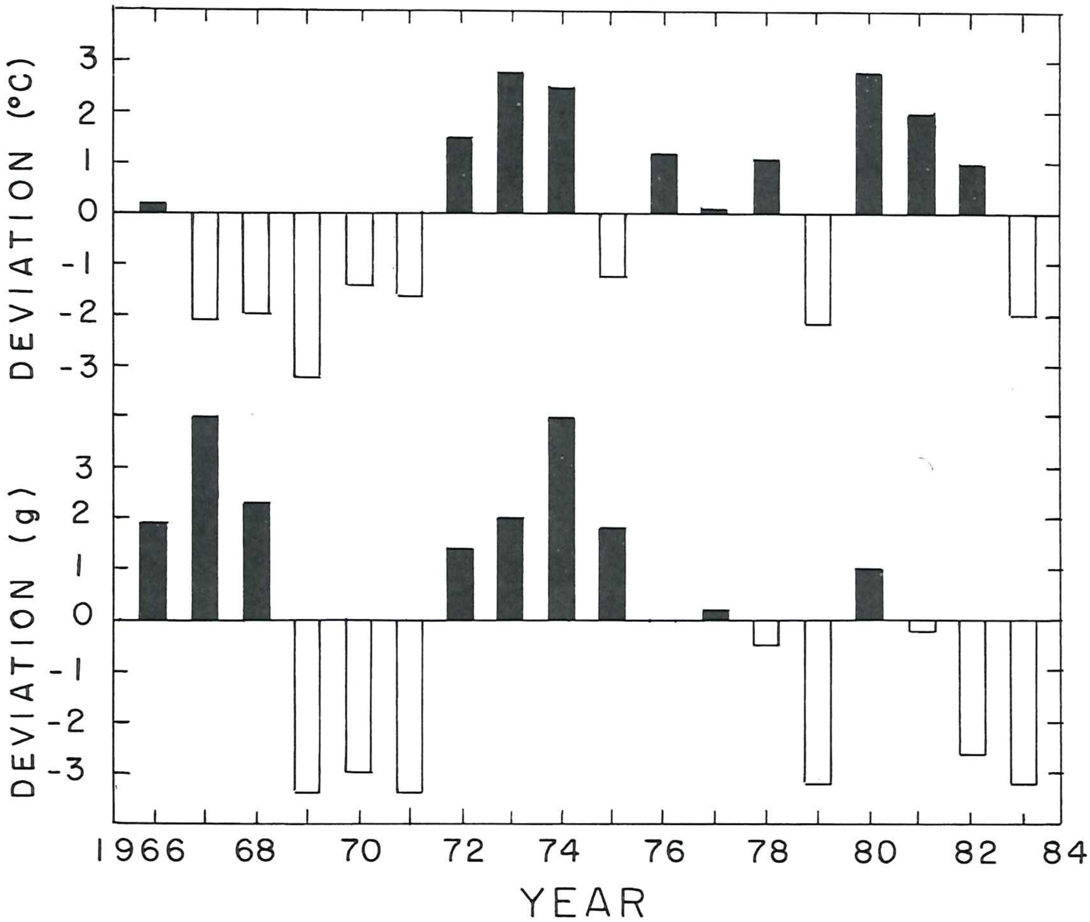

Fig. 10. Comparison between deviations from mean temperature (°C) and deviations from mean weight of capelin (g) in the period 1966–1983.

3) Superimposed on the observed annual fluctuations in growth rate there is a definite trend towards reduced growth in all age groups (I, II and III) after 1974.
4) The weight of a year class at age at the end of a feeding season will mostly depend on conditions during that feeding season and not upon the initial physical condition of the fish, when feeding is resumed in spring. An example is the 1977 year class which was above the average weight as I-group in 1978, far below average as II-group in 1979 and well above average weight as III-group fish in 1980.

From acoustic surveys of the abundance of II-, III- and IV-group capelin of the 1976–1981 year classes (Vilhjálmsson et al. 1982; Anon. 1983c) it is possible to calculate the abundance of these year classes as I-group fish. This has been done and the resulting abundance figures plotted against the mean weight of the same year classes as I-group at the end of the feeding season. On the whole these data do not reveal any density dependence (Fig. 11).

It is a well known fact which applies to all species of fish that growth is a function of several variables. Thus in the case of the capelin its growth is complicated by its feed-

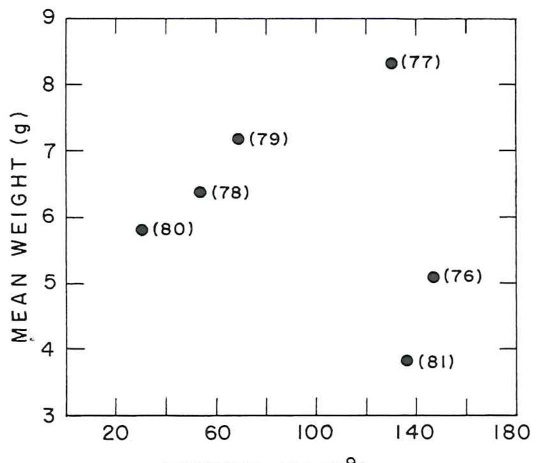

Fig. 11. The relation between mean weight and the estimated number of I-group capelin of the 1977–1981 year classes.

ing on members of two different plankton communities. In its younger stages the capelin relies largely upon the North Atlantic type of plankton, indigenous to the waters over the shelf off North Iceland, while the larger proportion of the maturing stock component as well as some of the juveniles feed mainly on Arctic species farther to the north and northwest.

Estimation of natural mortality

During the summer feeding season and in autumn most of the adult and part of the juvenile capelin are distributed in the cold oceanic area between Iceland, Greenland and Jan Mayen. While the capelin remain in that area, they are out of reach with respect to most of the major fish predators. During the spawning migration, which generally starts in late December or early January, the capelin enter the Icelandic shelf area and then become easily available as food for cod as well as other large fish.

Initially the natural mortality coefficient (M) for mature capelin was calculated from the difference between acoustic abundance estimates obtained in late October 1978 and in early February 1979, taking into account the catch during the intervening period. The resulting value was 0.12 for the 3 month period or M = 0.04/month. In view of the increased availability of the capelin to its most important predator, the cod during the winter period, it was decided to use two different values of M when projecting stock abundance estimates in time. Thus the calculated natural mortality coefficient of 0.04/month has been used throughout the year for juveniles as well as for mature capelin in summer and autumn and 0.08/month for mature capelin during the period January-April.

At present six sets of data are available which may be used for calculating the natural mortality coefficient. The resulting values of M are given in Table 2. The mean monthly M = 0.035 ± 0.010 is near the level which has been assumed for the maturing stock in the summer/autumn season. With the present knowledge, however, it seems inadvisable to adopt this value of M for the whole life span of the capelin. Further data are needed for the January/March period, when the highest natural mortalities are to be expected.

TABLE 2

Natural mortality rates of the Icelandic capelin as calculated from successive acoustic estimates of spawning stock abundance and catch.

Estimate	*Period*	*Mortality rate per month*
I	Nov. 1, 1978 – Jan. 31, 1979	0.045
II	Nov. 1, 1979 – Jan. 31, 1980	0.026
III	Nov. 1, 1980 – Jan. 31, 1981	0.030
IV	Nov. 15, 1981 – Jan. 31, 1982	0.048
V	Dec. 1, 1981 – Jan. 31, 1982	0.035
VI	Nov. 1, 1982 – Jan. 31, 1983	0.028
	Mean	0.035
	Std. dev.	0.010

TABLE 3

Percentage age composition of the spawning stock 1971–1983.

Year	Age groups			
	II	*III*	*IV*	*V*
1971	+	65	35	+
72	3	88	9	+
73	5	66	29	+
74	4	77	19	+
1975	3	80	17	+
76	1	50	49	+
77	1	48	51	+
78	3	47	50	+
79	2	77	21	+
1980	3	79	18	+
81	9	71	20	+
82	2	87	11	+
83	3	91	6	+

Age and mortality at spawning

Most of the Icelandic capelin spawn when 3 year old. A varying proportion of each year class does not mature, however, until one year later. In addition, a very small percentage of each year class matures to spawn as II-group fish and a small fraction of samples taken from the spawning stock have been aged as V-group. Thus the spawning stock consists mainly of two age groups where the ratio between 3 and 4 year old spawners varies somewhat depending on growth conditions and relative year class strength.

The percentage age composition of samples taken from the spawning stock in 1971–1983 is given in Table 3. The very small ratio of 4 year old spawners in the last two years may well be connected with increased mortality rates of I- and II-group capelin during the summer and autumn fishery in 1979 and 1980.

The survival rate of spawners is generally considered very small in all capelin stocks and second time spawners are not thought to contribute significantly to the spawning stock.

Generally, the percentage of IV-group spawners is low. Nevertheless, in the years 1976–1978, IV-group capelin contributed each year to about one half of the spawning stock in numbers. The year classes responsible are those of 1972–1974. These year classes together with that of 1975 are by far the most abundant ones as measured by the 1972–1983 series of 0-group indices. An increased proportion of large year classes would of course be expected to be late maturing as compared to the less abundant ones and consequently raise the percentage of IV-group spawners, when they reach that age.

In the spring of 1974 spent III-group females were found to be actively feeding on Euphausiids at considerable distances away from the nearest spawning grounds (Vilhjálmsson 1974a). Although no absolute measure of the abundance of this capelin could be obtained at that time, it was this author's estimate that their quantity would probably be of importance to the next years spawning stock, should they survive. Nevertheless, the proportion of 4 year olds in the 1975 spawning stock was only 18 percent and the contribution of females to that age group was certainly not larger than usual (Vilhjálmsson 1976). Apart from a small amount of spent females recorded off East Iceland in the spring of 1973 (Vilhjálmsson 1973) this is the only record of spent capelin outside the immediate vicinity of the spawning grounds. On the contrary, masses of dead capelin, particularly males, are frequently reported in trawl catches at the south and west coasts of Iceland in April and May.

Without risking oversimplification it seems therefore, that for practical purposes the survival of spawners among the Icelandic capelin may be set at zero.

THE FISHERY

The developments of the fishery on the Icelandic capelin stock are described in the Annual Reports of the Icelandic Capelin Board (Loðnunefnd, Anon. 1973–1981) as well as reports of the Atlanto-Scandian Herring and Capelin Working Group of ICES (Anon. 1982b, 1983d).

The total annual catches from the Icelandic capelin stock by season and countries for the period 1964–1982 are given in Table 4. Prior to this period capelin belonging to the Icelandic stock were exclusively caught for bait and the catch amounted to only a few hundred tonnes a year.

In the mid sixties Iceland started a capelin fishery for the production of meal and oil. This was a purse-seine fishery carried out by the local herring fleet outside the traditional herring season.

Until 1973 the capelin fishery was limited to coastal waters during the spawning season from late February to the first half of April. But with the depletion of the Atlanto-Scandian herring stocks in the late sixties and the North Sea herring in the seventies the capelin fishery gained momentum and importance.

By 1969 almost all the Icelandic herring fleet had become involved in the winter capelin fishery, and it soon became obvious that processing facilities were a limiting factor. Thus the catch did not exceed 200,000 tonnes during the 1969–1971 period.

In the 1972 winter season a coordinating body, the Capelin Board, was established in order to synchronize fishing and production. This was mainly accomplished by dividing the coastline into price zones with higher prices allocated for longer trips. This system had the immediate effect of increasing the catch by about 50 percent as compared to

TABLE 4

The total annual and seasonal catch (in thousands of tonnes) of capelin in the Iceland, E-Greenland, Jan Mayen area taken by Iceland, Faroes, Norway and EEC countries.

	Winter season		*Summer and autumn season*				
	Iceland	*Faroes*	*Iceland*	*Norway*	*Faroes*	*EEC*	*Total*
1964	8.6	—	—	—	—	—	8.6
1965	49.7	—	—	—	—	—	49.7
1966	124.5	—	—	—	—	—	124.5
1967	97.2	—	—	—	—	—	97.2
1968	78.1	—	—	—	—	—	78.1
1969	170.6	—	—	—	—	—	170.6
1970	190.8	—	—	—	—	—	190.8
1971	182.9	—	—	—	—	—	182.9
1972	276.5	—	—	—	—	—	276.5
1973	440.9	—	—	—	—	—	440.9
1974	461.9	—	—	—	—	—	461.9
1975	457.6	—	3.1	—	—	—	460.7
1976	338.7	—	114.4	—	—	—	453.1
1977	549.2	25.0	259.7	—	—	—	833.9
1978	468.4	38.4	497.5	154.1	—	—	1158.4
1979	521.7	17.5	441.9	126.0	2.5	—	1109.6
1980	392.0	—	367.2	118.6	24.4	14.3	916.5
1981	156.0	—	484.6	91.4	16.2	20.8	769.0
1982	13.0	—	—	—	—	—	13.0

the average for the previous 3 years. The price zone system was operated until 1979 when it was discontinued. From then on the board mainly functioned as an information centre for catch statistics, available landing spaces and waiting time in the various ports where the factories were located.

As early as 1969 it had been indicated that, at least in some years, capelin could easily be caught in January and February, when the spawning migration still was in deep waters off East and Northeast Iceland (Jakobsson 1979). Such a fishery was attempted in 1970. Difficulties were encountered by the fishing fleet and another attempt was not made until 1973. This time success was immediate and the winter catch jumped to 440,000 tonnes.

The annual catch during the winter season in the 6 year period 1973–1979 ranged between 440,000 and 575,000 tonnes. An exception is the year 1976, when the fleet went on a lengthy strike. Since 1979 the winter fishery has been subject to increasingly severe restrictions ending in a total fishing ban in 1983. Apart from a limited Faroese participation in 1977–1979 the winter fishery has been conducted by Icelanders only.

In 1975 an attempt was made to catch capelin on the feeding grounds north of Iceland in July and August. At that time there was much drift ice in the area and the experiment failed. A summer fishery was again attempted in the following year and this time with success. The catch amounted to about 115,000 tonnes in spite of the fact that most of the fishing fleet was occupied in the North Sea herring fishery during that summer and autumn. In the 5 year period 1977–1981 the average Icelandic summer and autumn capelin catch was around 410,000 tonnes taken by about 50 vessels.

The number of Icelandic vessels participating in the capelin fishery in the period 1973–1983 is given in Table 5. It must be stressed that in this case changes in the number of fishing boats do not measure the effort. The increase in size of vessels and fishing gear and the technological improvements in the acoustic search systems more than make up for the reduction in the number of vessels participating in the winter fishery during this period.

TABLE 5

The number of Icelandic vessels participating in the capelin fishery during the period 1973–83.

Year	*Winter season*	*Autumn season*
1973	90	—
1974	136	—
1975	107	3
1976	86	29
1977	88	39
1978	82	56
1979	65	52
1980	51	52
1981	52	52
1982	8	0
1983	0	52

In the summer of 1978 the Norwegian capelin fleet started a purse-seine fishery of that part of the stock which migrates to feed in the area between Jan Mayen and Greenland. The catch during that first season was 154,000 tonnes but has since been subject to restrictions agreed upon bilaterally by Norway and Iceland. The Norwegian catch quota has always been fished, while the Icelanders have had to reduce their winter catch severely, as stated previously. In 1980 and 1981 vessels from the Faroes and the EEC countries, mainly Denmark, caught about 40,000 tonnes each year lending an international atmosphere to the capelin fishery in the Iceland-Greenland-Jan Mayen area.

Apart from 13,000 tonnes caught during the 1982 winter season a complete ban on fishing from the Icelandic capelin stock was imposed in 1982 as well as during the 1983 winter season. The fishery was reopened in early November 1983.

STOCK ABUNDANCE

Because of the capelin's short life span and extremely high spawning mortality, large and sudden changes in stock abundance may be expected. In a previous section it was shown that individuals belonging to a small year class do not necessarily grow faster than those of a large year class. Therefore, changes in numerical abundance may often directly reflect changes in biomass, i. e. the stock does not necessarily compensate for decrease in numbers by a faster growth rate. Furthermore, the capelin is a schooling species and as such belongs to those stocks of fish which experience has shown that can sustain large catch rates until practically the last shoal has been taken from the sea.

Under such circumstances catch and effort statistics are of little value in assessing the state of the stock and certainly not for future stock prognoses. Therefore, capelin researchers have to resort to direct, fishery-independent methods in order to assess stock abundance and changes therein.

The 0-group abundance index

Comparative measurements of the abundance of 0-group capelin have been obtained in August annually since 1972 (Fig. 3). This information has been collected by a combination of sampling by trawling and acoustic methods and is intended to serve as a rough index of recruitment. During the period 1972–1975 the 0-group abundance index indicates a very high level of recruitment followed by a sharp downward trend and a much lower level during 1976–1983.

The 0-group indices can be compared to changes in parent stock size as calculated from annual acoustic surveys in January/February 1973–1983. Unfortunately, these sets of data do not include the years of high 0-group abundance. For the period which they cover there appears to be a significant positive correlation between the parent stock abundance and the resulting 0-group index (Fig. 12).

The size of a year class as measured by the 0-group index can also be compared to its abundance as I-group, by back-calculating its size measured as II-group fish in acoustic surveys. The results of such a comparison for the 1976–1981 year classes are given in Table 6. Contrary to the positive 0-group/parent stock correlation there is no obvious relationship between the 0- and I-group abundance of a year class, when compared in this way. This suggests a much more variable mortality rate during the one year period following the 0-group surveys than

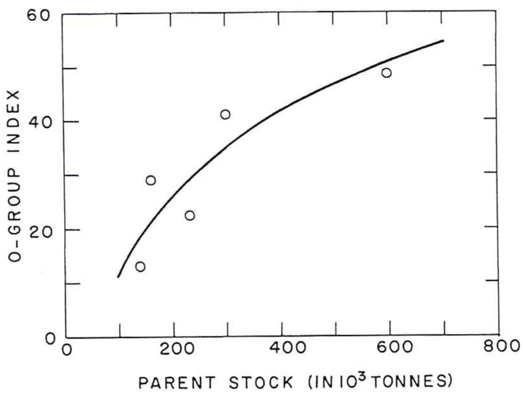

Fig. 12. The relationship between the 0-group abundance index and the parent stock size. The graph shows the logarithmic regression curve.

TABLE 6

Year class size as measured by the 0-group index and as I-group on August 1, calculated from acoustic estimates of II-group capelin.

Year class	*0-group index*	*Number of I-group capelin (in 10^9 fish)*
1976	60	145.6
1977	43	129.1
1978	31	54.0
1979	49	66.0
1980	41	27.7
1981	29	135.4

during the 4–5 months which elapse between spawning and the 0-group surveys. The inadequacy of these data must, however, be stressed and more and better information is needed.

Tagging

In the seventies several tagging experiments were carried out in order to evaluate the size of the Icelandic capelin stock (Vilhjálmsson and Reynisson 1979). The marking was done with internal steel tags which were recovered by means of magnets in the processing plants ashore. Because of the small size of the fish, the tagging mortality of juvenile capelin proved very high and consequently returns of tags were extremely low.

On the other hand, the tagging of adult capelin was successful and estimates of the 1979 spawning stock abundance from tag returns indicated a spawning stock size of 1,230,000 tonnes on January 1, 1980 as compared to about 1,350,000 tonnes obtained by the acoustic method. If carefully executed, tagging can give information on the size of the maturing stock. However, the final results do not become available until during or after the spawning season and therefore are of little value for real-time management.

Acoustic estimates of abundance

Timing. Echo surveying of capelin at Iceland has been conducted since the mid-sixties. The main purpose used to be to record the distribution and movements of the stock and the behaviour of the fish. The information was relayed to the fishing fleet over the ship's radio-telephone and greatly reduced the time spent in search of fishable shoals. With the rapid increase in catches following the advent of the multi-national summer and autumn fishery, the need for an accurate assessment of the size of the stock became of paramount importance.

On the basis of the information collected during the many scouting cruises, it was possible to decide at which times of the year the most reliable information on stock abundance could be obtained by acoustic methods. The main requisitions were: a relatively limited area of distribution, and minimum danger of interference by drift ice, weather, other scatterers, near surface shoaling and bottom echoes. For the maturing or fishable part of the stock the choice was the autumn period, when the capelin were in the process of assembling or had already assembled on the wintering grounds north and northwest of Iceland. Surveys have also been conducted in January/February during the earlier stages of the spawning migration, before the spawners enter the shallow waters at the southeast or southwest coasts of Iceland.

On the other hand, surveying of adult capelin during the summer months is difficult because of varying and sometimes extensive distribution of drift ice as well as the formation of small clusters of feeding capelin in the surface layers. These small and sometimes dense shoals are often recorded by sonar at depths of less than 10 m. They are then out of transducer range of conventional echo sounders and consequently not included in the acoustic abundance estimate.

When the spawning migration has entered the coastal waters south and west of Iceland, the capelin often form large shoals extending from surface to bottom. Considerable quantities may then also go undetected in the near surface layers. At this time an additional problem is posed by the fact that integration must stop just off the bottom. This is necessary in order to avoid bottom interference but will result in a reduction of the abundance estimate. In the coastal waters both number and frequency of other scatterers increases as compared to the deeper waters. This further complicates the picture.

Survey technique and calibration of instruments. The basic technique was decribed by Nakken and Dommasnes (1975) and the modification adopted for the Icelandic capelin stock by Vilhjálmsson et al. (1982). A summary of the technique is as follows:

Echo intensities from fish are registered continuously from the depth column along the ships' track and the values obtained integrated and recorded as the average per nautical mile for every 5 nautical miles sailed. Trawling is undertaken when necessary in order to ensure adequate biological sampling and to check changes in the echo recordings. In all instances a Simrad 38 kHz acoustic system has been used.

The survey area is divided into suitable subareas depending on variations in the length composition of the capelin as observed from the trawl catches. The integrated echo intensity is converted to fish densities using the equation:

$$N = C \cdot M \cdot A$$

where N is the total number in subarea A, C is the number of capelin per unit area and dependent on the mean length of the fish and instrument characteristics, M is the mean integrated echo intensity for the relevant subarea and A is the subarea measured in square nautical miles.

The sum of the number of fish calculated for each subarea then gives the total stock size. On the basis of the trawl samples this figure can be divided into age or size groups and converted to biomass, if preferred.

The C value is dependent on the target strength of the species of fish to be assessed as well as the characteristics of the instrumentation used. These factors had been previously established with reference to the instrumentation of the Norwegian R/V G.O. Sars and used in abundance surveys of the Barents Sea capelin stock. The G. O. Sars C value was adopted in the surveys of the Icelandic capelin stock through instrument and inter-ship calibrations as follows:

1) By calibration with a standard reference target (Foote et al. 1981) simulating echo intensity over 1 nautical mile. This served as a check of the C value for each vessel as well as giving an inter-ship relation irrespective of transducer directivity.
2) By Norwegian-Icelandic and Icelandic-Icelandic inter-ship calibration by recording, for at least 25–35 nautical miles, a scattering layer consisting mostly of 0-group capelin and plankton. Readings were taken every nautical mile. This calibration also includes the directivity of the transducers (Röttingen 1978).

The performance of the acoustic instruments of the vessels employed has always been remarkably similar and consistent. Thus, the correlation coefficient (r) for inter

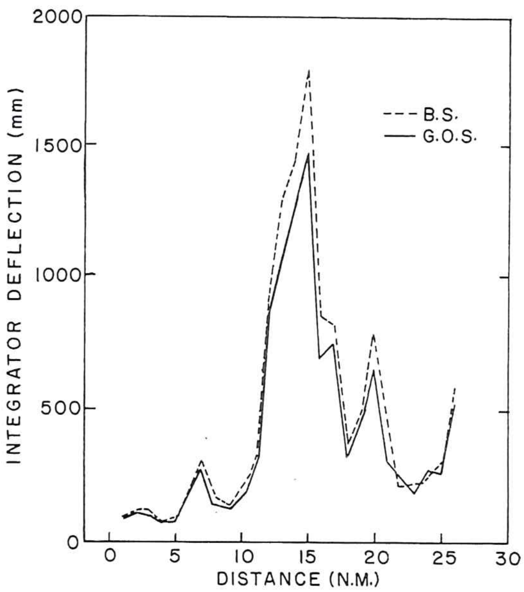

Fig. 13. The results of an intercalibration of the research vessels G. O. Sars and Bjarni Sæmundsson, on a scattering layer of 0-group capelin and plankton, October 21, 1982. The linear relationship between the integrator deflection of the two ships can be expressed by the regression equation $D_{BS} = -1.23 + 1.21 D_{GOS}$. The correlation coefficient, $r = +0.99$.

ship calibrations has varried between 0.96 and 0.99. An example from October 1982 is shown in Fig. 13.

Surveys of the 1979–1984 spawning stock abundance. Since 1978 the stock has been surveyed jointly by Icelanders and Norwegians in October. The Icelandic Marine Research Institute carried out an additional survey in November 1981, when the October survey failed because of adverse ice conditions. Furthermore, Icelandic investigators have carried out annual surveys of the abundance of the same spawning stocks in January/February 1979–1983 for comparison with the autumn estimates.

Although it is known that the northern component of the stock feeding in the Jan Mayen-Greenland area does not always return to the wintering grounds until November and shoaling at the surface may in places still exist up to that time, the joint autumn surveys have generally been scheduled for the first 3 weeks of October. The reason for this is of course the need for an assessment of the fishable stock as early as possible. The October surveys have been successful with the exception of a survey during the period September 25 – October 5, 1979 as well as of the joint autumn survey in 1981 which had to be repeated in November, mainly because of adverse ice conditions. The most recent survey grid and the fish distribution in October 1983 is shown in Figures 14 and 15.

The Icelandic surveys in January-February have been carried out with 1–2 ships at the time, when the spawning or fishable stock normally has a small distribution area. After having located the stock through

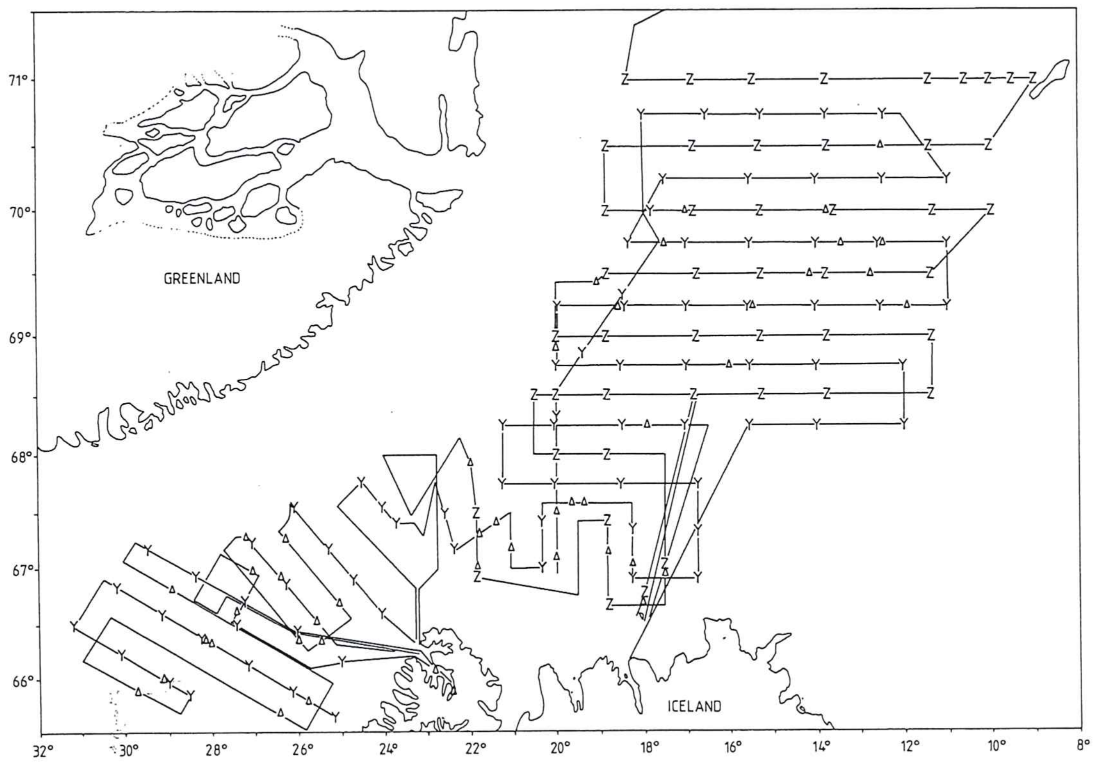

Fig. 14. The survey grid in October 1983. Triangles: pelagic trawl stations; Y: XBT stations; Z: STD stations.

rough scouting the actual assessment can, therefore, be carried out in a very short time. The location of the capelin may, however, vary considerably from year to year. But it should be emphasized that weather conditions in the Icelandic area in the winter time can often make acoustic surveying difficult to perform. Therefore, it has on several occasions been necessary to wait for a considerable time before a reliable survey could be carried out. In fact such a tactic is the key to success at that time of the year.

The results of five sets of autumn and winter estimates of the 1979–1983 spawning stock abundance of the Icelandic capelin, together with the first estimate of the 1984 spawning stock obtained in October 1983, are shown in Figure 16 (curves a and b). On the basis of these abundance estimates, catch statistics and natural mortality rates it is possible to calculate the size of the maturing or catchable stock as it was on August 1, before the start of the fishing season. This is shown by curve c in Figure 16.

Initially the acoustic stock abundance estimates were received with much scepticism. In 1980 the Union of Icelandic Fishing Vessel Owners therefore engaged an FAO expert to assess the quality and the calibration of the instruments used as well as data collection and handling. His main conclusion was that the acoustic abundance estimates obtained during the period 1978–1980 were reliable within reasonable confidence limits and a report to that effect was submitted in December 1980 (Jóhannesson 1980).

By taking into account the catch and natural mortality it is possible to determine

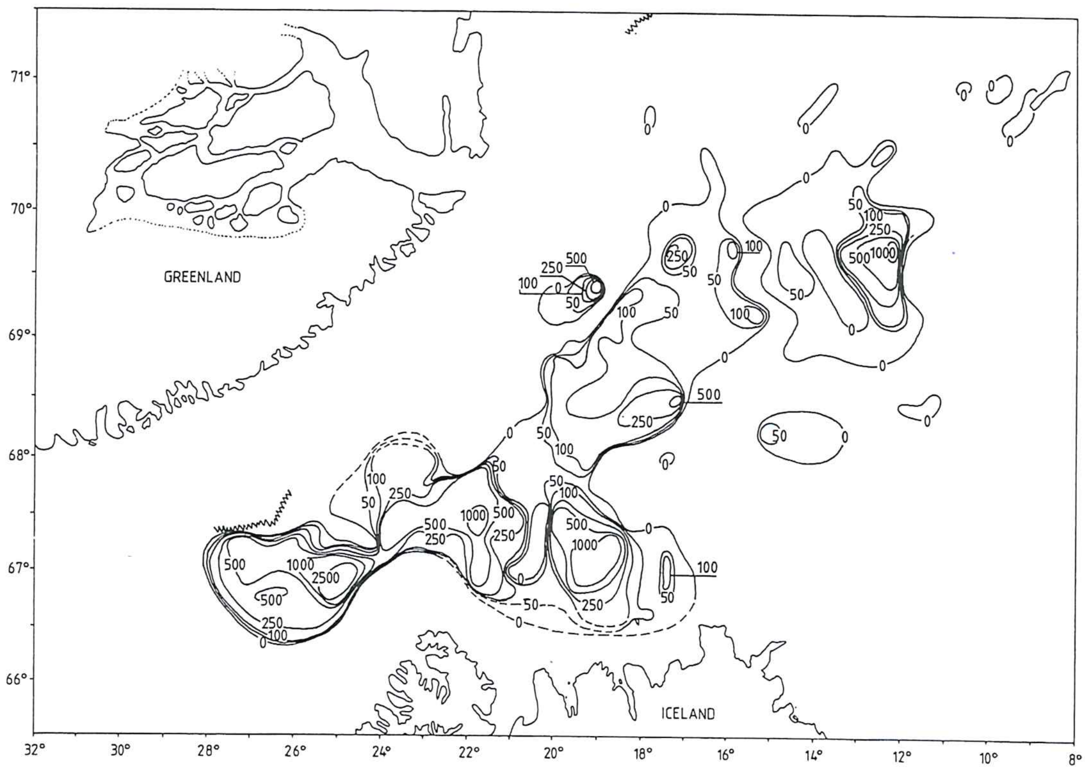

Fig. 15. The distribution and relative density of capelin in October 1983. The numbers denote integrator deflections (mm).

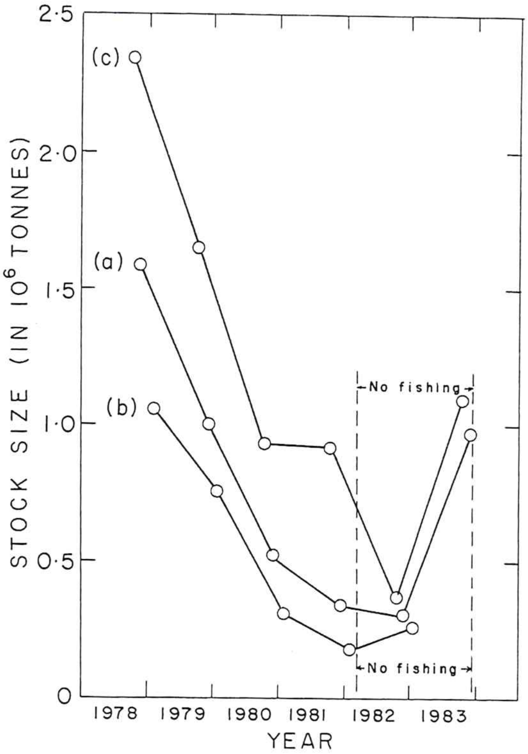

Fig. 16. Acoustic abundance estimates of the 1979–1983 spawning stocks, (a) in October/November, (b) in January/February. The graph (c) gives the abundance on August 1 as calculated from the October/November estimates.

the difference between the autumn abundance estimates and those obtained early in the following year. With the exception of surveys which were obviously faulty because of excessive drift ice and early timing (September 25 – October 5, 1979 and Octoval (10–30 days) as shown in Table 7. The surprisingly small. For the autumn 1979/winter 1983 period it was on the average in the range of 5–15%. However, the higher estimate was on all occasions obtained during the January/February surveys. In view of the reduced distribution area and less surface schooling in January/February as compared to October/November such a bias might be expected. Nevertheless, the difference might just as well result from an underestimate of the natural mortality during the intervening period.

On several occasions it has proved possible to survey the spawning stock component 2–3 times within a very short time interval (10–30 days) as shown in Table 7. The differences between such series of estimates have usually been small. This has established a further confidence in the applicability of the method to the mature capelin stock. In the rare instances when deviations were observed, they were immediately explainable. There are two main examples of this. One is Survey II in October 1978, when a short spell of strong winds caused a lowered abundance estimate and in the end prevented the completion of the survey. When comparing the results of surveys I and II in January 1981 immediately after they were completed, it was obvious that cruise tracks had been too widely spaced with respect to the highly variable distribution density observed at the time. A third and a much more detailed survey was then carried out yielding satisfactory results.

The results of acoustic estimates of the abundance of the catchable or spawning stock of the Icelandic capelin are, therefore, considered accurate in a relative and probably also in an absolute sense and show an alarming decline in stock size during the 1978/79–1982/83 period (Fig. 16).

It is a common misunderstanding that estimates of abundance of fish stocks need to be expressed in absolute terms of weight or number to be suitable for management advice. In order to understand them relative changes in abundance must of course be related to such variables as catches, spawning stock size and recruitment during a certain period of time. After such an experience has been gained, relative measurements can be used with confidence. The same is in fact also true of absolute abundance estimates expressed for instance in tonnes. The response of the stock to various fishing mortalities still has to be known. Stock

TABLE 7

Comparison of the results of repeated surveys of the same stock component. Numbers (N) in 10^9 and weights (W) in 10^3 tonnes. Surveys considered unsatisfactory are shown in brackets (For explanation see text).

NW Iceland 16–29 Oct. 1978	*1974*		*1975*		*1976*		*Total*	
	N	*W*	*N*	*W*	*N*	*W*	*N*	*W*
Survey I	0.4	13.6	20.5	548.5	50.5	944.7	71.4	1506.5
(— II	0.3	10.6	16.0	426.8	39.3	734.8	55.6	1172.2)
— III	0.5	17.0	22.6	603.4	55.4	1036.1	78.5	1656.5

E-Iceland 1–7 Feb. 1979	*1974*		*1975*		*1976*		*Total*	
	N	*W*	*N*	*W*	*N*	*W*	*N*	*W*
Survey I	0.4	1.7	3.1	77.8	23.2	457.0	26.7	536.5
— II	1.0	3.1	3.2	80.3	24.0	472.8	28.2	556.2
— III	1.0	2.3	3.4	85.3	25.7	506.2	30.1	593.8

NW-Iceland Feb. 1979	*1974*		*1975*		*1976*		*Total*	
	N	*W*	*N*	*W*	*N*	*W*	*N*	*W*
Survey I	—	—	4.6	107.0	28.3	495.3	32.9	602.3
— II	0.1	3.1	6.0	132.0	23.5	411.3	32.6	574.4

E-Iceland 20–29 Jan. 1981	*1977*		*1978*		*Total*	
	N	*W*	*N*	*W*	*N*	*W*
(Survey I	4.3	117.5	15.2	312.5	19.5	430.0)
(— II	2.7	73.8	9.5	156.2	12.2	270.0)
— III	3.2	87.3	11.4	234.7	14.6	322.0

N-Iceland 3–30 Nov. 1982	*1978*		*1979*		*Total*	
	N	*W*	*N*	*W*	*N*	*W*
Survey I	0.3	7.5	18.1	334.7	18.4	342.2
— II	0.8	17.5	17.5	328.3	20.7	338.3

abundance expressed in tonnes or numbers is, however, much more convenient to work with than index figures and is certainly more intelligible to administrators and fishermen.

Abundance estimates of juvenile capelin. As yet it has proved difficult to assess the abundance of juvenile I and II-group capelin. The reason for that is the frequent distribution of this stock component in or near areas periodically covered by drift ice. With the periodic advance of the ice border in the Iceland-Greenland Channel in autumn, part of the juvenile stock often becomes inaccessible and is then not accounted for during the autumn surveys. This is indeed suggested by the highly variable proportion of juveniles observed on these occasions. A similar situation is encountered in winter.

There is a great need for a reliable abundance assessment of the juvenile I-group capelin. Such information would make it possible to provide management advice about one year before the fishing season instead of after it has already begun as was practised before the introduction of a fishing ban in 1982.

Experiments carried out during 0-group surveys in late August 1982 and 1983 have yielded promising results. As far as can be judged, it is possible to cover most of the distribution area of the juveniles at that time of the year. They are then frequently recorded in scattering layers which are most suitable for acoustic estimation of abundance. Difficulties encountered lie in occasional near surface distribution during the short period of darkness, and admixture of juveniles with 0-group and adult capelin. The further experimentation and experience is, therefore, needed.

MANAGEMENT

Minimum landing size, mesh size and closed areas

Initially, regulatory measures were mainly precautionary in nature. In Iceland there was a closed season in spring and summer from 1973 to 1978 lasting for 2–4 months. In 1979 the closed season was extended to last until August 20, and in 1980 until September 5. In 1981 Icelandic vessels were allowed to fish capelin from August 10, in the oceanic area north of 68°N and east of 21°W. The feeding grounds of the juvenile I- and II-group fish farther west and south were, however, closed to the fishery until September 15, 1981.

In 1975 a minimum landing size of 12 cm was introduced with a minimum mesh size of 19.6 mm. In order to improve the release ratio of the small juvenile capelin, Iceland increased the minimum mesh size to 21 mm in 1981. There is no doubt that minimum mesh size in purse seines is effective in preventing the catch of juvenile I-group capelin while retaining the older year classes and without causing excessive meshing. Thus I-group fish have seldom been among the summer and autumn catch. An exception to this was experienced in the autumn of 1980, because growth rate during the preceeding summer had been unusually large. Complaints of excessive meshing from skippers of Icelandic capelin boats are also rare. The reason is simply the large difference in size between I- and II-group capelin in the Iceland-Greenland area.

Total allowable catch

Since most of the capelin spawn only once and die thereafter, the major management objective is to prevent the spawning stock from being fished beyond the assumed level of reduced recruitment or even to recruitment failure.

In 1979 when the fishing was stopped in the 3rd week of March, about 600,000 tonnes were left to spawn as calculated from acoustic estimates of the stock size, the catch and the natural mortality rate.

In 1980 it was decided that while gaining further experience it would be inadvisable to reduce the spawning stock to less than two thirds of the 1979 level or to 400,000 tonnes. The main management objective since then has been that 400,000 tonnes of capelin should be allowed to spawn each spring.

It was soon recognized that overfishing could well have taken place already by the time the results from the October abundance survey became available. The reason for this is the large fishing power of the multi-national fleet during periods when the capelin are easily available. Already in 1979 the introduction of a precautionary catch quota was therefore recommended, to be revised if necessary, according to results from stock abundance surveys in autumn and winter (Anon. 1979a).

This advice was not accepted. Instead during the 1978/79, 1979/80 and 1980/81 seasons, preliminary and somewhat arbitrary catch quotas were set prior to the fishing season following bilateral negotiations between Iceland and Norway. These preliminary catch quotas were then allocated to individual vessels. Recommended catch quotas were based on results of the acoustic stock abundance surveys carried out in

October/November and January/February each season. By that time, however, the Norwegian vessels had always fished their quota and the same applied to a varying but usually a large part of the Icelandic boats. Thus it proved impossible to have the fishery stopped in time, and as a consequence the 1980 spawning stock was reduced to about 300,000 tonnes and the 1981 and 1982 spawning stocks to extremely low levels.

A summary of this unfortunate procedure as well as the actual catches taken from the 1980, 1981 and 1982 spawning stocks is given in Table 8.

In spite of difficulties in assessing the abundance of juvenile capelin it was evident from acoustic as well as 0-group survey results that the size of the 1980 year class, which was to spawn in 1983, was very small. The state of the stock was considered to be most serious, even without any fishery taking place. A fishing ban was, therefore, recommended for the 1982/83 season pending results from the 1982 October abundance survey. This recommendation was accepted by all parties concerned, i. e. Iceland, Norway, the Faroes and EEC countries.

The results of the October 1982 survey indicated that a stock of about 190,000 tonnes would spawn in March-April 1983 and the fishing ban was extended to cover the whole season. As expected, the 1983 January/February survey yielded a slightly higher stock estimate viz. that about 220,000 tonnes of capelin would spawn in March/April 1983. Estimates of the spawning stock abundance as calculated from the January/February acoustic surveys for the period 1979–1983 are shown in Figure 17.

The management objective of maintaining a spawning stock of at least 400,000 tonnes was therefore not attained except in 1979.

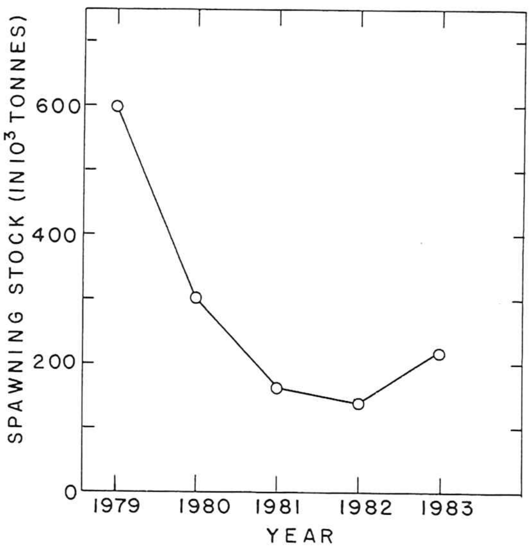

Fig. 17. The size of the mature stock at spawning as calculated from the January/February abundance estimates 1979–1983.

TABLE 8

A summary of the consequences of setting a preliminary total allowable catch quota (TAC), in thousands of tonnes, before the results of stock abundance surveys became available.

Autumn/winter 1979/80			*Autumn/winter 1980/81*			*Autumn/winter 1981/82*		
Preliminary TAC	*Recommended TAC*	*Catch*	*Preliminary TAC*	*Recommended TAC*	*Catch*	*Preliminary TAC*	*Recommended TAC*	*Catch*
650	850	962	775	450	680	700	381[1]	626

[1] The catch taken before November 1. Zero TAC was then recommended pending further survey results.

Discussion

The Icelandic stock of capelin does not carry a long history of exploitation. As has been related, the fishery began in a modest way in the mid-sixties and did not expand appreciably until in the early seventies. Then came a period of 5 years when the annual catch from the spawning stock approached the half million tonnes mark. In this period the fishery mainly took place during the 3 months preceding the spawning process and apparently did not lead to excessive mortality rates.

When the summer and autumn fishery came into effect, the catch increased to more than one million tonnes from 1976–1978, remained near that level for 2–3 years, whereupon the stock practically collapsed.

Unfortunately, information on the abundance of the maturing or fishable stock did not become available until in the autumn of 1978. Since then the abundance of each years' spawning stock (1979–1983) has been assessed twice by acoustic methods, i. e. in autumn and in January/February of the following year. There seems little doubt that these abundance estimates are reliable and give a correct picture of the development of the stock during the 5 year period which they cover.

Nevertheless, the validity of these abundance estimates has been sharply questioned most of the time by fishermen and authorities alike, and recommendations of catch quotas based on them have by no means been fully accepted. Restrictions of the fishery have been too lenient and have been imposed too late. The stock has been overfished.

There are several reasons for this:

1) General reluctance to face the economic consequences of suddenly having to limit catches to a fraction of what they were.
2) The exceptionally rapid decrease in stock abundance during the 1978–1982 period to a level that did not even reach the recommended spawning stock size.
3) Before the fishing season was opened the preliminary catch quota, generally set far too high, was divided between the vessels participating in the fishery. The Norwegian share of the quota has always been fished before the October survey results became available, while the Icelandic vessels were in varying stages of filling their respective quotas. Under these circumstances it proved impossible to have the fishery stopped in time.
4) The occasional failure of single acoustic surveys, especially that of October 1981. Although the inadequacy of this survey was recognized at the time and a new survey executed immediately afterwards, its results were used as a pretense for a long time afterwards by fishermen and authorities to throw doubt on the applicability of the method. Up to a point this is understandable. The success of the acoustic method of stock abundance evaluation does not only depend upon the performance of the vessels and instruments. Several other variables, both biological and environmental, also have to be taken into account. These effects must be judged by the people responsible for the execution of the surveys. Such circumstances will inevitably create controversies, especially at times of low stock abundance.
5) The nature of the capelin to aggregate in autumn and winter and become available in areas of limited size, the location of which may vary from year to year. The resulting concentration of the fishing effort will give the fishermen a false impression of abundance, if their scouting effort is reduced from what it used to be. As the catch quotas and the extension of the closed season, imposed in later years, have indeed greatly reduced scouting activity, many of the fishermen have

been under the impression that their own information on stock abundance is far better than it is in reality.

6) Also, the improved acoustic gear, installed in many vessels recently, seems in most cases to have established an illusion of continued high abundance rather than verified the actual decline in stock size.

The faith in acoustic methods as reliable means of management is, however, improving. This is borne out by the fact that the authorities of all parties concerned accepted the recommendation of a fishing ban for the 1982/83 season as described in a previous section.

In the absence of data on stock abundance prior to 1978 it is difficult to judge whether the recent decline in stock size is solely due to overfishing. Comparable data on the abundance of 0-group capelin are available from 1972 onwards. These 0-group indices point to a high level of recruitment until 1975/76, followed by a sharp downward trend and a much lower level since then.

This development coincides of course with the large increase in fishing effort brought about by the recent multi-national summer and autumn fishery. It should, however, be pointed out that since 1976 large year classes of other fish species as measured at the 0-group stage have, as a rule, not been observed in the Icelandic area. Therefore, the decline in the abundance and recruitment of the capelin stock, brought about by overfishing, has probably been accelerated by a period of unfavourable environmental conditions.

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