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DISTRIBUTION, ABUNDANCE AND MORTALITY OF YOUNG AND ADOLESCENT NORWEGIAN SPRING SPAWNING HERRING (*Clupea harengus* Linné) IN RELATION TO SUBSEQUENT YEAR-CLASS STRENGTH

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INTRODUCTION

Doubts regarding the reasons for a decreasing yield of the herring fisheries in the southern North Sea and in the Norwegian Sea during the 1950s and early 1960s have caused fishery biologists to pay close attention to problems concerned with recruitment to the fishable stocks of herring. Nursery areas have been identified, and variations in distribution and abundance of young herring in relation to subsequent year-class strength in the adult stock have been studied (e.g. BERTELSEN and POPP MADSEN, 1956, 1957, DRAGESUND and OLSEN 1965, SAVILLE 1968, WOOD 1968). Growth and migration of adolescent herring in relation to recruitment to the adult stock were investigated by CUSHING (1962), ZIJLSTRA (1963), PARRISH and SAVILLE (1965) and ØSTVEDT (1965), and the fisheries for young herring and their effects on subsequent yield of the adolescent and adult herring fisheries have been analysed by DEVOLD (1953, unpublished), CUSHING (1959), MARTI and FEDOROV (1963) and PARRISH and SAVILLE (1967).

Until recently little was known about the biology of the early stages of Norwegian spring spawning herring, subsequently referred to as Norwegian herring. LEA (1929) was of the opinion that most of the 0-group herring entered the fjords of western and northern Norway and were distributed in coastal waters, but at that time no attempt had been made to search for 0-group herring in the open sea. DEVOLD (1950) showed that 0-group herring of the rich 1950 year-class were distributed far offshore in the northeastern part of the Norwegian Sea, and he suggested that only a small part of the total 0-group population entered the Norwegian fjords. This view was not shared by MARTI (1956), who held that most of the 0-group herring were to be found along the coast and in the fjords of Norway.

LEA (1929) held the opinion that 0-group herring entering the fjords emigrated during the fat-herring stage (at an age of two to three years).

He demonstrated that the development from the immature fat-herring to the adult herring took place through an intermediate oceanic stage. The fat-herring which migrated from the fjords of northern Norway did not appear on the spawning grounds the following year but arrived two to four years later, having remained in the open sea during this period.

From more recent investigations (DRAGESUND and HOGNESTAD 1960, DRAGESUND and OLSEN 1965, DEVOLD 1968, JAKOBSSON 1968, ANON. 1969) it can be stated that the distribution of young and adolescent Norwegian herring is widespread and ranges from the fjords of northern Norway to the open ocean of the Norwegian Sea and the Barents Sea and varies with the different year-classes.

A fishery which is of considerable importance to the population dynamics is carried out on young and adolescent herring in Norwegian coastal waters. This fishery can be divided into two components, (1) that based on the small-herring (småsild), i.e. mainly 0- and I-group fish with the former predominating, and (2) that based on the fat-herring (feitsild), i.e. I- to IV-group herring with the II- to III- group predominating. Since the industrial small-herring fishery started in the 1910–1914 period, great attention has been paid to the effects this fishery may have on the recruitment to the older age groups. Although LEA (1924) and DEVOLD (1953) did not find any connection between the catch of small-herring and the subsequent yield of the fat-herring fishery and could not recommend any regulation of the 0- and I-group herring fishery, many Norwegian fishermen have maintained that the exploitation of small-herring affected both the fat-herring fishery and the fishery for adult herring.

Soviet scientists have seen the low recruitment to the adult stock during the late 1950s and early 1960s as a consequence of the industrial fishery on small-herring in the Norwegian fjords (MARTI and FEDOROV 1963). DEVOLD (1963), however, argued that the decline of the Norwegian winter herring fishery was caused by a series of poor year-classes, which were the results of changes in environmental factors and the migration pattern and subsequent changes in the time and area of spawning. Since no clear relationship has been found between the exploitation of 0- and I-group herring and subsequent year-class strength in the adolescent and adult stocks, the Norwegian Government has so far not introduced any rigid regulation of the small-herring fishery. However, since 1963 it has been prohibited to land catches of small-herring from 1 February to 30 April consisting of more than 50% of herring below a total length of 15 cm (north of 64° N) or 16.5 cm (south of 64° N).

Comprehensive investigations of distribution, abundance and mortality of young and adolescent herring in coastal and offshore waters of northern Norway were initiated in the autumn of 1959 by the Institute of Marine Research, Bergen, in order to examine whether the exploitation of 0- and I-group herring in the Norwegian fjords has any primary impact on subsequent year-class strength in the adult stock. In a previous paper (DRAGESUND 1970) spawning characteristics and environmental conditions during early larval development were analysed as factors which may have influenced the strengths of the 1959–1965 year-classes of Norwegian herring.

The aim of the present paper is to:

1) describe the distribution of the 1959–1965 year-classes during the young and adolescent phases;
2) determine when the 0-group herring, which enter the fjords in autumn, migrate from the fjords, and investigate whether 0-group herring occurring far north and east off northern Norway migrate as adults to the spawning grounds off Møre;
3) study the variations in abundance of young and adolescent herring, i.e. small- and fat-herring;
4) estimate the mortality rates of 0- and I-group herring in the Norwegian fjords.

These items are discussed in relation to subsequent year-class strength in the adult stock.

MATERIAL AND METHODS

The material includes data from acoustic surveys, tagging experiments, herring samples and catch statistics. The statistical methods applied are those given in text books of statistical analysis (SNEDECOR 1956, GODSKE 1966). Geographical names and code numbers for areas appearing in the text are shown in Fig. 1.

ACOUSTIC SURVEYS

Every autumn during the period 1959–1965 the distribution and abundance of young and adolescent herring in the coastal and offshore waters of northern Norway were studied from combined acoustic surveys and fishing experiments with pelagic trawl and purse seine (MIDTTUN 1959, DRAGESUND 1959, 1961, 1962, 1964, DRAGESUND and HOGNESTAD 1962, HOGNESTAD 1963a, OLSEN 1960, ANON. 1965a). More detailed investigations during the same period were carried out in the fjords of northern Norway in collaboration with the Marine Biological Station, Tromsø. Special attention was paid to the Hamarfjord–Ullsfjord–Lyngen-

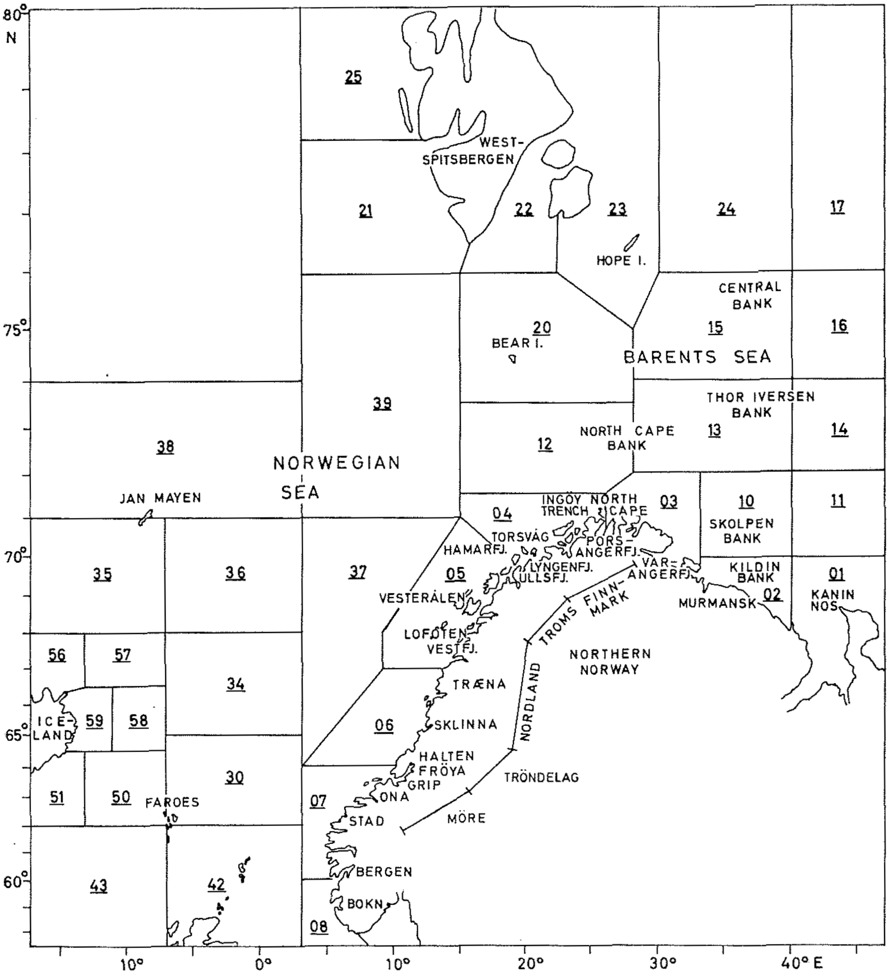

Fig. 1. Names and code numbers of areas mentioned in the text.

fjord complex and to the Porsangerfjord, and usually these fjords were investigated twice a month from September to May (HOGNESTAD 1960, 1961, 1962, 1963b, 1964). In 1962 and 1963 observations were also made during early summer in limited regions off Troms and Finnmark, and for the years 1960–1963 information is available from acoustic surveys carried out in winter and early spring off Finnmark and in the Barents Sea (MIDTTUN 1960, 1961, MØLLER *et al.* 1961, MØLLER 1963).

All the ships were equipped with vertical echo sounders and horizontal ranging sonars, and during the surveys the acoustic instruments were operated continuously. Except on the cruise in early summer of 1963, when the ship was equipped with a Kelvin Hughes echo sounder (MS 29, 30 kHz) and sonar (Mk2, 48 kHz), Simrad echo sounders (513–1, 38.5 kHz and 513–5, 18 kHz) and sonar (580–1, 30 kHz) were used. The sensitivity control of the Simrad echo sounders is regulated in steps from 1 to 10 and during all surveys the 38.5 kHz echo sounder was set at step 7 and the 18 kHz echo sounder mainly at step 4. In 1962 the Norwegian research vessels "G. O. Sars" and "Johan Hjort" were equipped with Simrad Research Sonar (580–10, 11 kHz), and from that year onwards a third echo sounder working on 30 kHz (580–10) was also used. However, the 38.5 kHz echo sounder has been used as standard equipment, and all the recordings have been graded according to observations made with this machine.

For every five nautical miles steamed, the echo traces of 0-group herring were plotted according to the following density classification (Fig. 2):

1) very scattered (barely visible on the recording paper);
2) scattered (the middle stages between black and white paper);
3) dense (recording paper nearly black, but with no indication of "white-line effect", which occurs when the density of the scatterers is especially high);
4) very dense (recording paper black with "white-line effect").

The most favourable conditions for estimating the abundance of herring exist during darkness when the fish are dispersed (Fig. 2, A to D) and occur as a continuous series of traces (scattering layer) on the recording paper. However, the shoaling concentrations recorded during the day (Fig. 2, E and F) were converted to night time abundance values. By frequently surveying the same area both by day and by night, factors to convert the day recordings to night time abundance values were established.

During the surveys herring were caught either with Isaacs–Kidd ten foot midwater trawl (IKMT) (Isaacs and Kidd 1953) or a larger pelagic trawl (modified capelin trawl) with headline and footline of 18.3 m, sidelines of 15.3 m and mesh size from 100 mm (wings and square) graded down to 8 mm (cod end). On some cruises a commercial herring purse seine of 8 mm mesh size was also used. Table I gives more details of the fishing experiments conducted during the surveys. In order to establish the relationship between wire angle and depth of trawling, an echo sounder transducer was attached to the depressor of the IKMT during some of the cruises, and a depth-time recorder was used on the larger pelagic trawl. The towing speed of the IKMT was usually 5–6

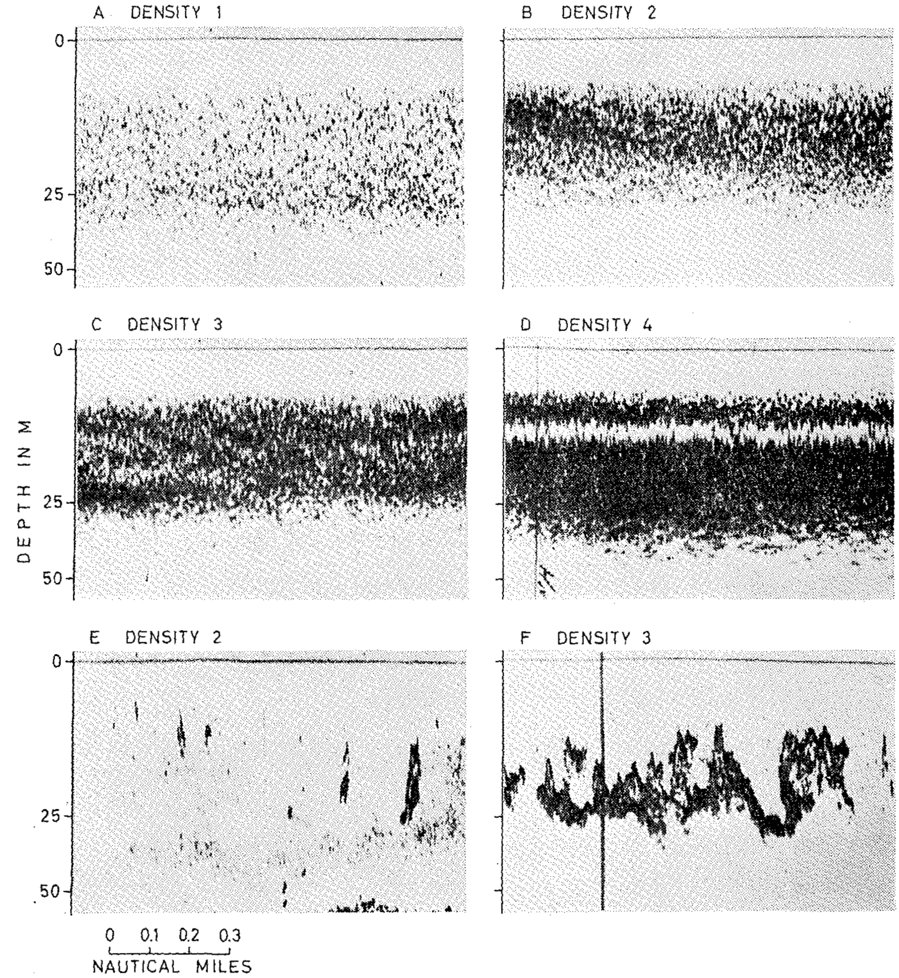

Fig. 2. Echo recordings (Simrad echo sounder 38.5 kHz set at step 7) of sound scatterers identified as 0-group herring, by night (A) to (D) and by day (E) and (F). The densities of recordings (E) and (F) are comparable with those of (B) and (C), respectively.

knots, and the larger pelagic trawl was towed at 3–4 knots. The dimensions of the pelagic trawl used by the research vessel of Marine Biological Station, Tromsø, were: Headline, 15.0 m, footline, 19.0 m, and sidelines, 4.0 m with mesh sizes graded from 50 mm to 8 mm.

IDENTIFICATION OF SOUND SCATTERERS

During the 1950s sound scatterers were frequently recorded in the top layers of water in the Barents Sea, and some success was achieved in identifying them by underwater photography (MIDTTUN and SÆTERSDAL

1959). However, no systematic routine programme of identification was developed until 1959. From material collected during the present surveys it has been demonstrated (DRAGESUND and OLSEN 1965) that during late summer and early autumn 0-group fishes of different species, such as herring, cod (*Gadus morhua* Linné), haddock (*Melanogrammus aeglefinus* Linné), redfish (*Sebastes marinus* Linné), capelin (*Mallotus villosus* Müller), and long rough dab (*Hippoglossoides platessoides* Fabricius) occurred pelagically as scattering layers in the upper 100 m of water in the Barents Sea and adjacent waters.

The 0-group herring generally were found in the upper 50 m of water. During daytime they were found at depths from 25 to 50 m, while at night they came closer to the surface, dispersed and appeared as a continuous layer on the recording paper. In the daytime the herring clustered in shoals (Figs. 2 and 3). Both experimental fishing and analysis of the echo traces as well as underwater photography have been used to identify the sound scatterers during the acoustic surveys for 0-group fish. Comparisons between the IKMT and the larger pelagic trawl catches showed that the former trawl was not catching 0-group herring efficiently during the daytime and that older age groups were caught only occasionally. At night, however, when 0-group herring were distributed in typical scattering layers, they were caught frequently with IKMT. The 0-group herring were easily caught with the larger pelagic trawl both at night and day whenever they were present. The larger trawl was not reliable for catching fat-herring when these occurred in daytime shoals, but when the herring dispersed at night they could be caught with this gear. The purse seine was definitely the most reliable gear for identification of the sound scatterers, but because of the rather complicated fishing procedure involved, it was not found suitable for routine sampling. It was found necessary to identify the scatterers rather frequently, and therefore the larger pelagic trawl was chosen as the most convenient sampling gear, supplemented with the purse seine at selected stations.

When bad weather prevented fishing, identification was made from the echo traces, showing the shoaling behaviour of the fish and the difference in target strengths of the various species. By comparing the echo traces at the fishing stations with the catches obtained, it was found that 0-group capelin and long rough dab had a lower target strength than 0-group herring, redfish, cod and haddock. The four latter species, however, were difficult to separate on the basis of target strength alone. The 0-group cod and haddock were usually found somewhat deeper than the herring, and during daytime they showed a different shoaling pattern (Fig. 3, A and B). The 0-group herring formed shoals of somewhat denser concentrations and could easily be distinguished by sonar also

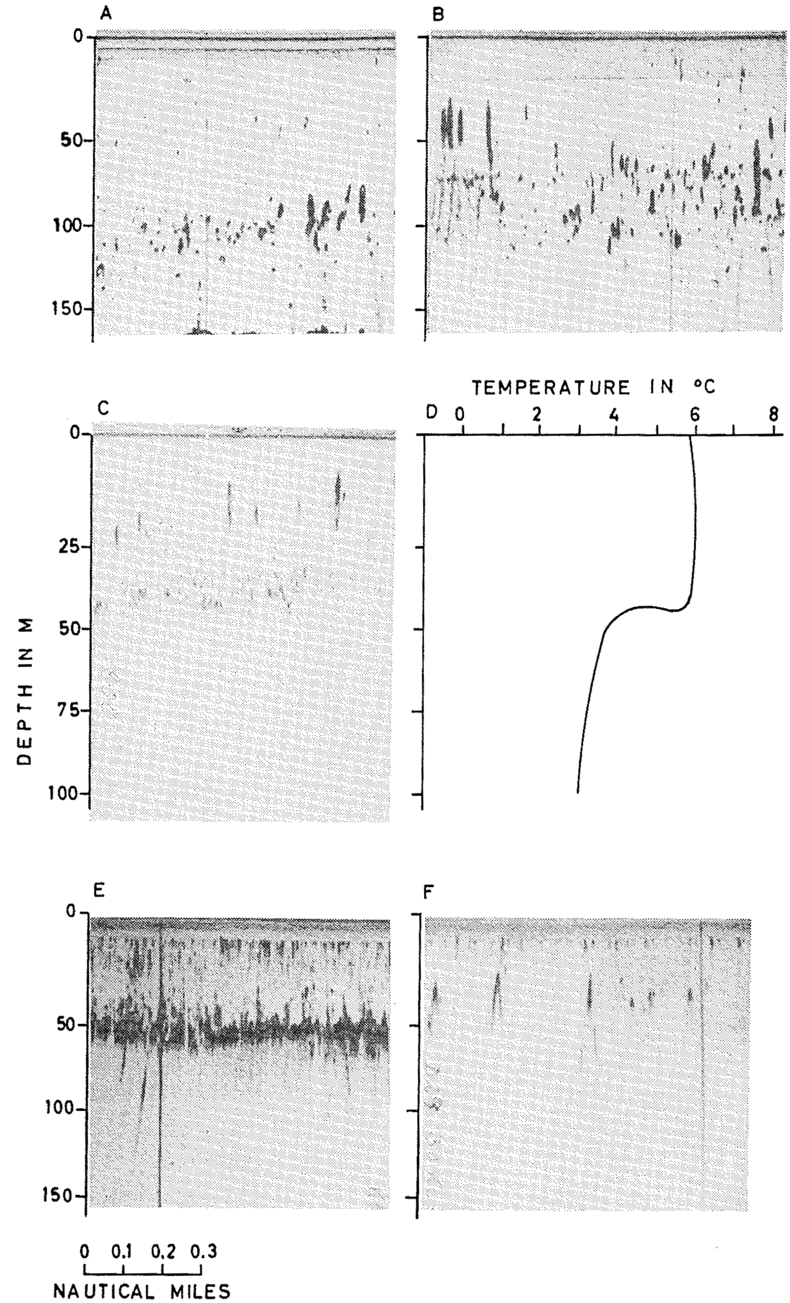

Fig. 3. Echo recordings of 0-group fish by day, (A) cod or haddock or both and (B) herring (top left) and cod or haddock (Simrad research echo sounder 30 kHz set at step—18db), (C) herring recorded above the thermocline (Simrad echo sounder 38.5 kHz set at step 7), (D) bathythermogram from the same region, (E) herring and redfish and (F) herring (Simrad research echo sounder 30 kHz set at step—18db).

when they occurred in the scattering layer together with other 0-group fishes, e.g. redfish (Fig. 3, E and F).

The shoal pattern of older age groups of herring is very characteristic and could usually be identified on the echo recordings, except in the western part of the investigated area where shoals of adult herring sometimes were difficult to distinguish from blue whiting (*Micromesistius poutassou* Risso). In such cases a distinction was made possible by increasing the resolution of the sounder by decreasing the pulse length. During early autumn fat-herring and adult capelin were rarely encountered in the same areas, while during winter and early spring fat-herring and adult capelin frequently occurred together, especially off the Finnmark coast. In this period echo recording analysis together with fishing experiments were necessary to identify the sound scatterers.

Only on a few occasions during the Barents Sea surveys was underwater photography used for identification (MIDTTUN 1959, HOGNESTAD 1963a, OLSEN 1966), mainly because the equipment was technically inadequate for routine use. Fishing experiments combined with analysis of echo trace pattern thus have been used as principle methods for identification of the sound scatterers.

TAGGING EXPERIMENTS

Most of the tagging experiments were carried out during acoustic surveys with the R/V. "G. O. Sars", which on these occasions was equipped for purse seine fishing. The herring were tagged with internal steel tags which measured $15 \times 2 \times 0.5$ mm for 0-group herring and $20 \times 3 \times 1$ mm for adolescent herring. A special tagging device was developed for the small tags (DRAGESUND and HOGNESTAD 1960). The large tags were inserted by means of Aasen's tagging gun (FRIDRIKSSON and AASEN 1952). The fish were taken individually from the purse seine and released into the open sea immediately after tagging. The fat-herring tagged in 1963 were obtained from commercial purse seiners, the herring being transferred to a depository net before tagging. The number of herring tagged in the different localities are listed in Table II.

Although experiments on I-group and older herring tagged with internal steel tags show relatively low tagging mortality and low shedding of tags (FRIDRIKSSON and AASEN 1950, 1952, DRAGESUND and HARALDSVIK 1968), these factors are the most important causes of loss of tagged herring. No decisive experiments have been carried out on 0-group herring, but the experiments performed with I-group herring in tanks (DRAGESUND and HARALDSVIK 1968) showed a tagging mortality of 10.1% and a shedding of tags of 5.1%. These figures are used in this analysis to calculate the number of effectively tagged herring.

Nearly all tags were recovered at Norwegian reduction plants where magnets are installed for detecting the tags. The magnets were tested every autumn. The efficiency of the magnet at each factory multiplied by the quantity of herring processed gives the effective quantity of herring processed. The procedure for testing the magnets and the routine for collecting data on the catches reduced and tags recovered at Norwegian plants are described by AASEN (1958) and DRAGESUND and HARALDSVIK (1968).

HERRING SAMPLES

In addition to samples collected during the acoustic surveys, herring samples, generally consisting of 100 specimens, were collected throughout the year from commercial catches. The herring were examined fresh, or frozen material was brought to the laboratory for examination. The weight was recorded in g. Total length was measured to the nearest half cm until January 1963. After this date, following a recommendation by the International Council for the Exploration of the Sea (ANON. 1963), the length was measured to the half cm below. A correction of 0.25 cm has therefore been added to the mean lengths of herring in samples collected after this date to make the mean lengths comparable with earlier recordings. No correction can be made for comparisons of the length frequency distributions and lengths of individual fish. The discrepancy, however, is of minor importance in the present study. Frozen herring showed a total length shrinkage of about 1.5% when compared with fresh specimens. No correction has been applied to compensate for this shrinkage.

Scales were used for age determination, and estimates of $l_1, l_2 \ldots l_n$ (the total length of a fish at the formation of the first, second, etc. winter ring) were obtained from scale measurements by using the simple proportional growth formula

$$l_n = \frac{s_n}{S} L$$

where s_n refers to measurements on the scale from the basal line to the n^{th} winter ring, S to the edge of the scale, and L is the total length of the fish (LEA 1910, ANON. 1963). Because the method of measuring the total length was changed, there is a bias in $l_1 \ldots l_n$ for samples collected after January 1963 compared with those collected prior to this date. However, back-calculations were based on the 1959 year-class, and the bias in mean annual increments for this year-class is relatively small because the mean length of the scales ($\bar{S}$) is large compared with the mean annual increment on the scales ($\bar{s}_n - \bar{s}_{n-1}$) from 1963 onwards. Therefore,

$$\Delta \bar{t} = \frac{\bar{s}_n - \bar{s}_{n-1}}{\bar{S}} \Delta \bar{L}$$

may be almost negligible. $\Delta \bar{L} = 0.25$ cm, which is the difference between means of total lengths measured before and after January 1963.

CATCH STATISTICS

Catch statistics of small- and fat-herring of the Norwegian landings were obtained from the official fishery statistics (ANON. 1961–1962, ANON. 1963–1969). Statistics for landings by foreign vessels were derived from a report of the Atlanto-Scandian herring working group (ANON. 1969). Supplementary catch data were also recorded at reduction plants by inspectors who classified every landing of small- and fat-herring into size groups according to the number of fish per kg. Statistics on catch and participation of vessels in the small- and fat-herring fisheries also were supplied from the fishermen's sales organization, Feitsildfiskernes Salgslag.

DISTRIBUTION AND MIGRATION

RECORDS FROM ACOUSTIC SURVEYS

Young herring

The 1959 observations were the first in the present series, and the research programme had not been fully established at that time. Additional observations on the 0-group herring distribution, therefore, were procured from catch data and echo recordings of other fish surveys in the areas around Bear Island and on the western banks off West-Spitsbergen (G. SÆTERSDAL personal communication, J. CORLETT personal communication).

In the autumn of 1959 0-group herring were observed over large areas and in dense concentrations (Fig. 4). The distribution this year, therefore, is of particular interest. The concentrations of herring along the coast were generally scattered south of Vestfjord. Dense concentrations were observed particularly in the outer part of the Vestfjord, off Vesterålen and at the entrance of the fjords between Hamarfjord and Varangerfjord. At the time of the surveys only scattered shoals were found in the inner parts of the fjords of northern Norway. The records clearly demonstrated that the 0-group herring had a wide oceanic distribution with the densest concentrations in the southern part of the Barents Sea, but that they were also numerous in the northern part of the Barents Sea and towards the edge of the shelf off Bear Island.

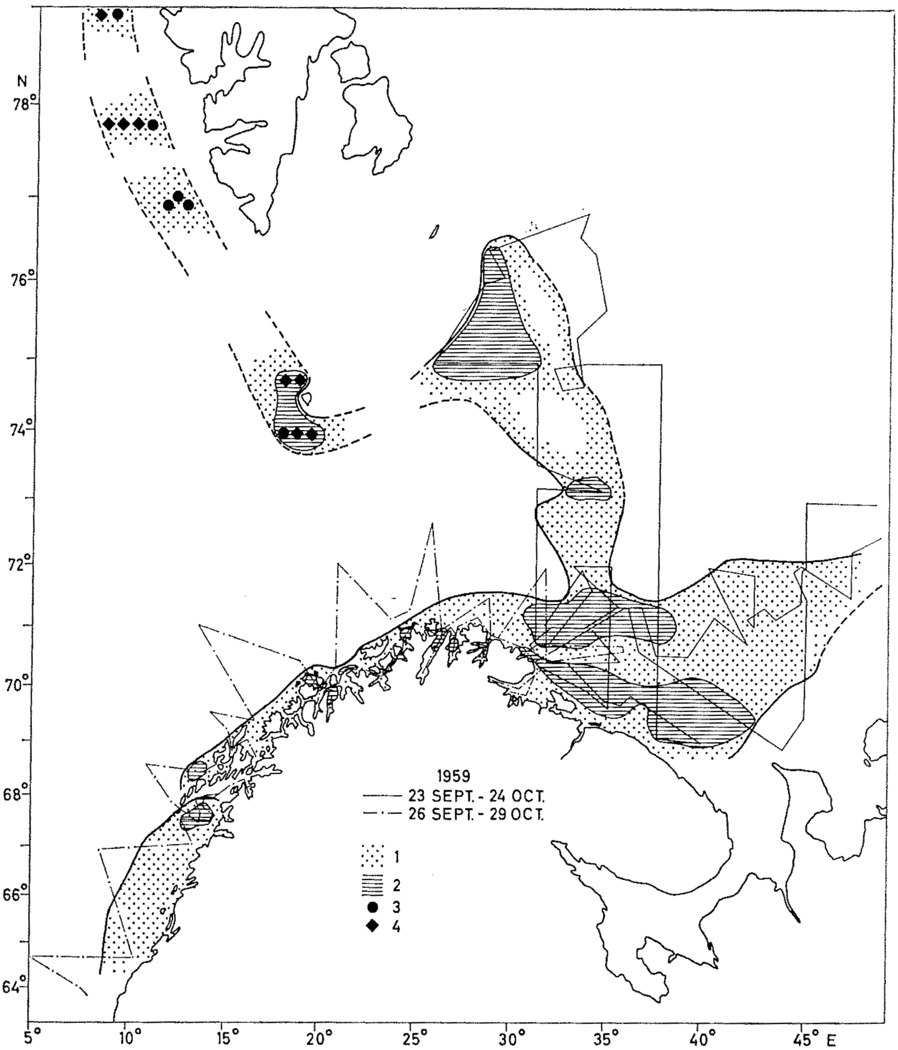

Fig. 4. Survey routes and distribution of 0-group herring in the autumn of 1959, (1) very scattered and scattered, (2) dense and very dense concentrations, (3) 0-group herring caught by bottom trawl with cover net and (4) 0-group herring identified from stomach contents of cod.

A similar pattern was found in 1960 and 1964 (Figs. 5 and 9) and partly also in 1963 (Fig. 8), whereas in 1961 and 1962 (Figs. 6 and 7) the 0-group herring were more restricted to the coastal belt. In 1965 herring were observed in two separated small regions in the open sea, i.e. between Bear Island and the Norwegian coast and along the edge of the continental shelf towards northwest of Bear Island to the southern part of West-

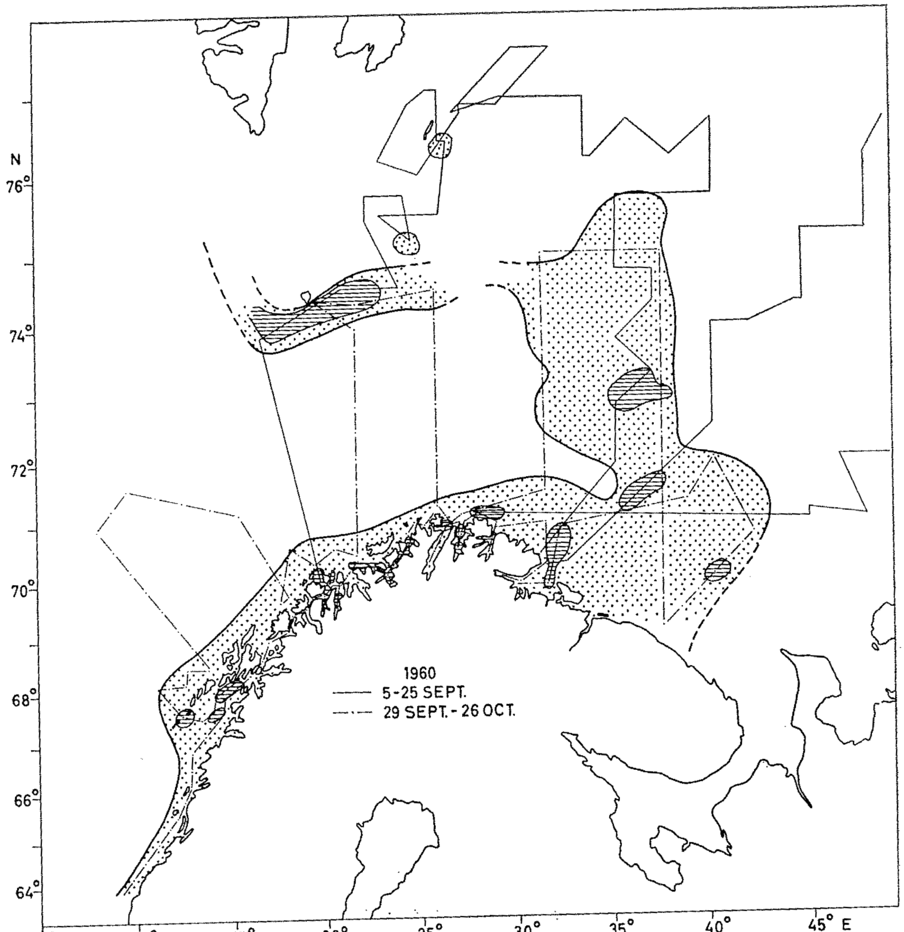

Fig. 5. Survey routes and distribution of 0-group herring in the autumn of 1960. Legend as in Fig. 4.

Spitsbergen (Fig. 10). In all the years concentrations of 0-group herring were observed along the coast, particularly at the entrances to the fjords. Between the coast of northern Norway and Bear Island 0-group herring were recorded in 1964 and 1965, but in these years the surveys were carried out somewhat earlier than in the previous years, and the herring would have moved farther east at a later date. The densest concentrations were observed in 1959, but dense concentrations were also recorded in 1960. In 1962 and 1965 the concentrations were very small.

The distribution of 0-group herring indicates that postlarval fish are transported along the path of the most important water currents off northern Norway and in the Barents Sea (Fig. 11). The herring larvae

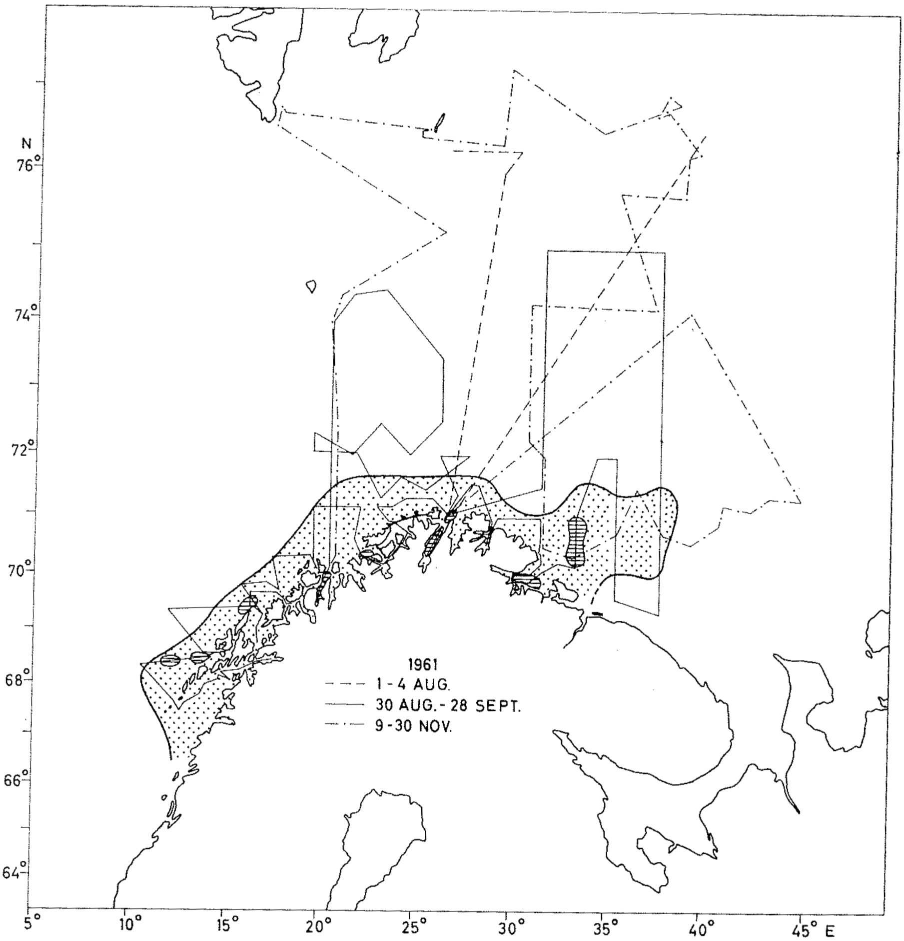

Fig. 6. Survey routes and distribution of 0-group herring in the autumn of 1961. Legend as in Fig. 4.

are transported northwards by the coastal current during the first few months after hatching (DRAGESUND 1970). When passing the banks off Troms, the drift of the larvae becomes more influenced by Atlantic water which in this area is intensively mixed with the coastal water (LJØEN 1962). At the entrance of the Barents Sea the water masses split into several branches (Fig. 11). One branch proceeds northwards to form The West-Spitsbergen Current, and two eastward branches separate off Torsvåg (N 70° 30′) where the shelf is wide. One of these flows along the coast of West-Finnmark (The North Cape Current) and the other continues towards the northern Barents Sea (Central Bank). The North Cape Current again splits into two branches, one along the southern and

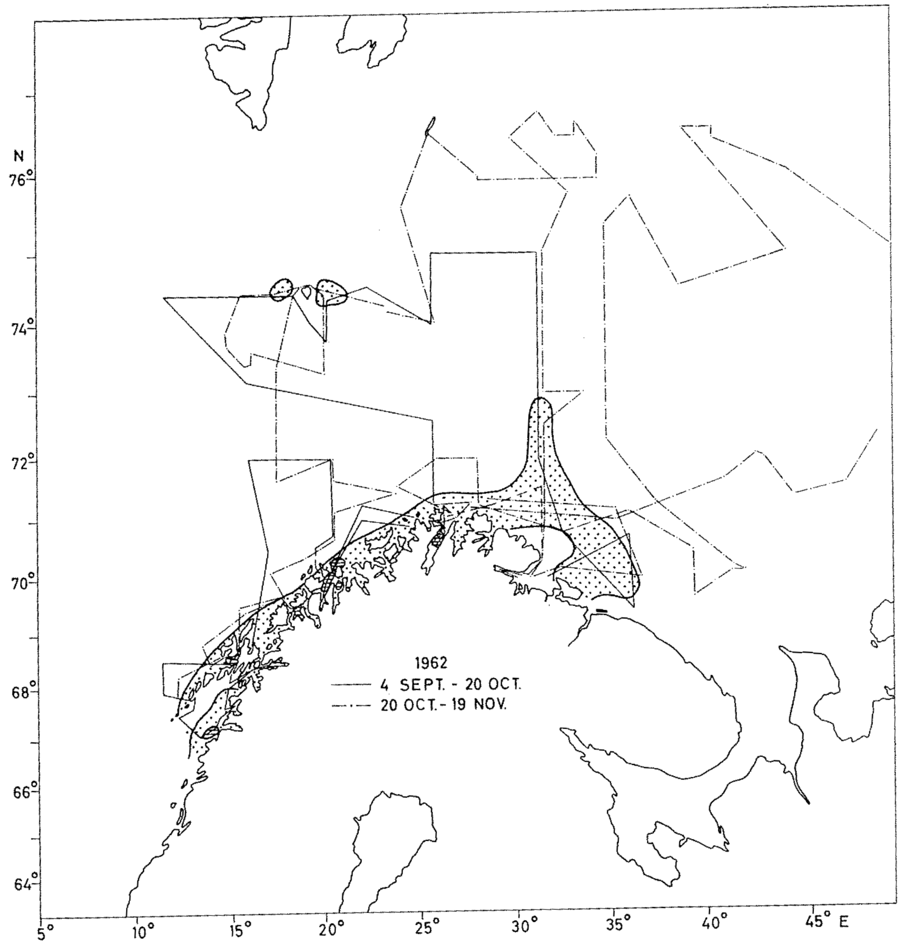

Fig. 7. Survey routes and distribution of 0-group herring in the autumn of 1962. Legend as in Fig. 4.

northern slopes of Goose Bank and the other passing near the Murman coast. Therefore, 0-group herring are always found along the coast. When the main spawning grounds are located as far north as off Møre, 0-group herring are generally more abundant on the northern than on the western coast of Norway. It cannot be determined from the present material whether the difference in distribution found between the different years was caused by hydrographic conditions during the postlarval drift phase. However, evidence was found that larvae were more widely dispersed in 1959, 1960 and 1964 than in 1961 and 1962 (Dragesund 1970). This may explain why subsequent northward drift resulted in a wide oceanic distribution in 1959, 1960 and 1964. The particularly dense concentra-

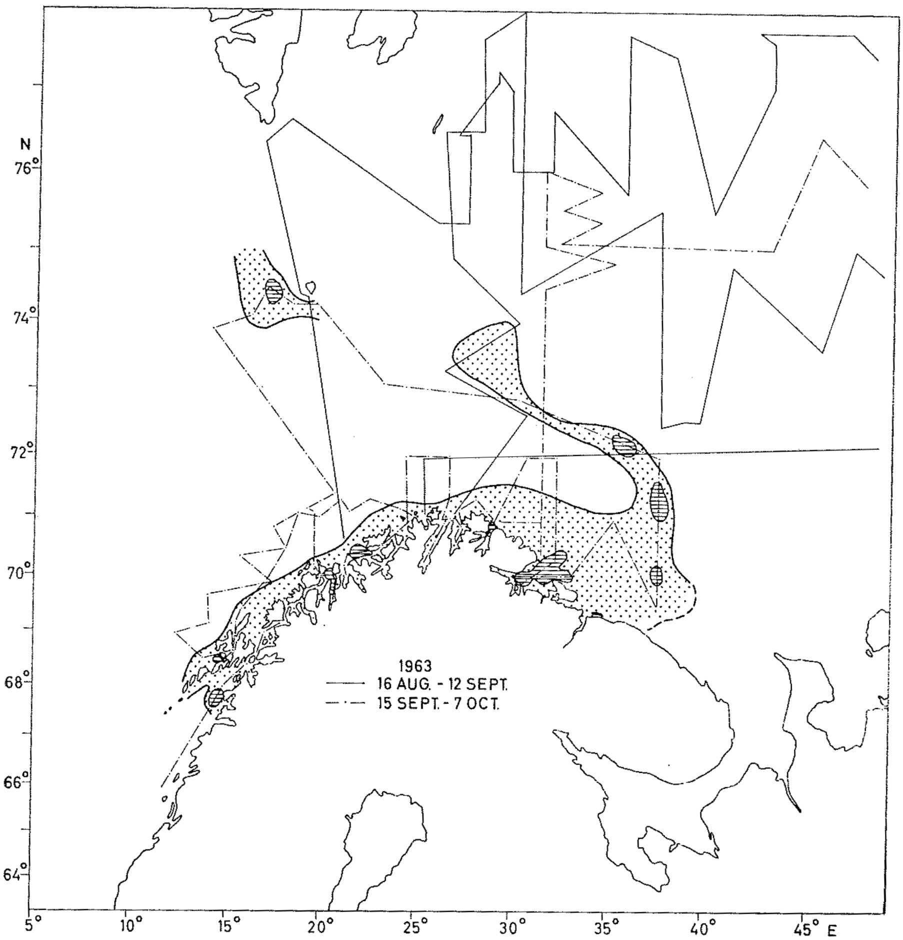

Fig. 8. Survey routes and distribution of 0-group herring in the autumn of 1963. Legend as in Fig. 4.

tions of 0-group herring in 1959 and 1960 indicated that the survival during the larval and postlarval phases was relatively high.

In late autumn a major part of the 0-group herring in offshore waters is concentrated along the fronts between the cold arctic water and the warmer water masses which cover the area west of Spitsbergen–Bear Island and the central and southeastern parts of the Barents Sea. Herring in this area will generally live in colder water during the late 0-group and early I-group stages than those accumulating along the coast and in the fjords, especially west and south of North Cape. The distribution of 0-group herring in relation to temperature is shown for the two extreme years 1959 and 1961 (Fig. 12).

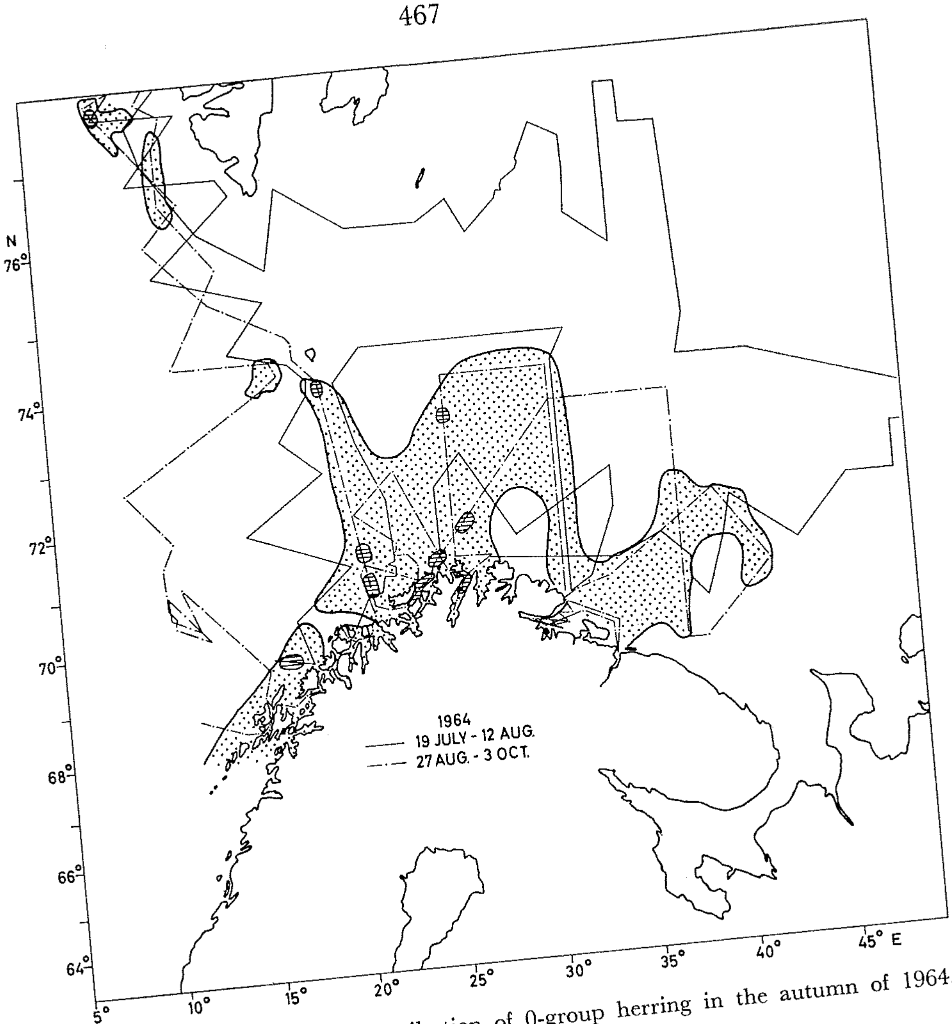

Fig. 9. Survey routes and distribution of 0-group herring in the autumn of 1964. Legend as in Fig. 4.

The herring in the northern part of the Barents Sea are mainly found in water of 1 to 4°C. In 1959 some of the herring were also found in water with a temperature as low as 0°C. In the southern part of the Barents Sea and along the coast of Finnmark, herring are mainly observed in water of 5 to 7°C. In 1961 when no herring were observed in the northern and eastern parts of the Barents Sea, the herring lived in a more uniform environment with considerably warmer water during the late 0-group stage than in 1959. This feature which may have caused a more variable growth pattern for the 1959 year-class than for the 1961 year-class, will be discussed further in a later section.

The herring accumulating at the entrances to the fjords during early

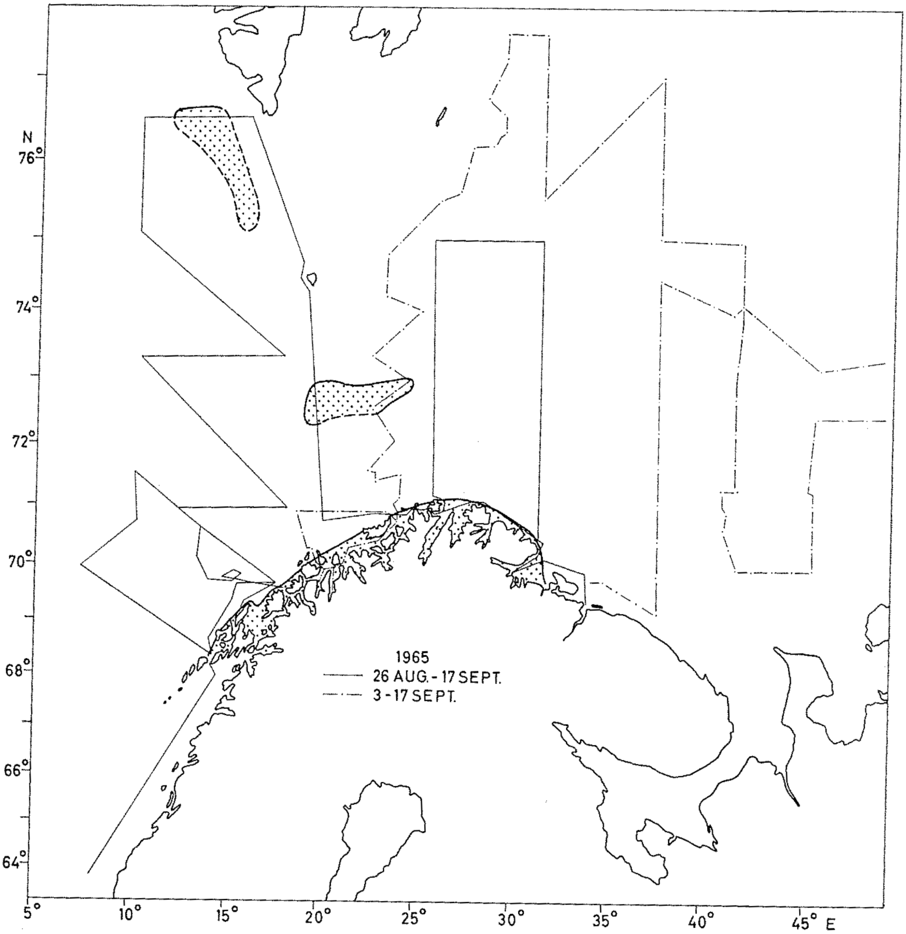

Fig. 10. Survey routes and distribution of 0-group herring in the autumn of 1965. Legend as in Fig. 4.

autumn migrate farther into the fjords later in the autumn. The situation in 1959 has been chosen to illustrate the characteristic distribution of 0-group herring during the immigration period (Fig. 13). Investigations carried out in northern Norway, mainly in the Ullsfjord region (Hamarfjord, Ullsfjord and Lyngenfjord) and in the Porsangerfjord, demonstrated that the 0-group herring remained in the fjords throughout the autumn and as I-group the following winter, i.e. the wintering period. A gradual emigration took place from March to May.

This general distribution pattern was also found in many other fjords along the coast of northern Norway. Slight variations in the behaviour during the immigration and wintering periods were found between fjords

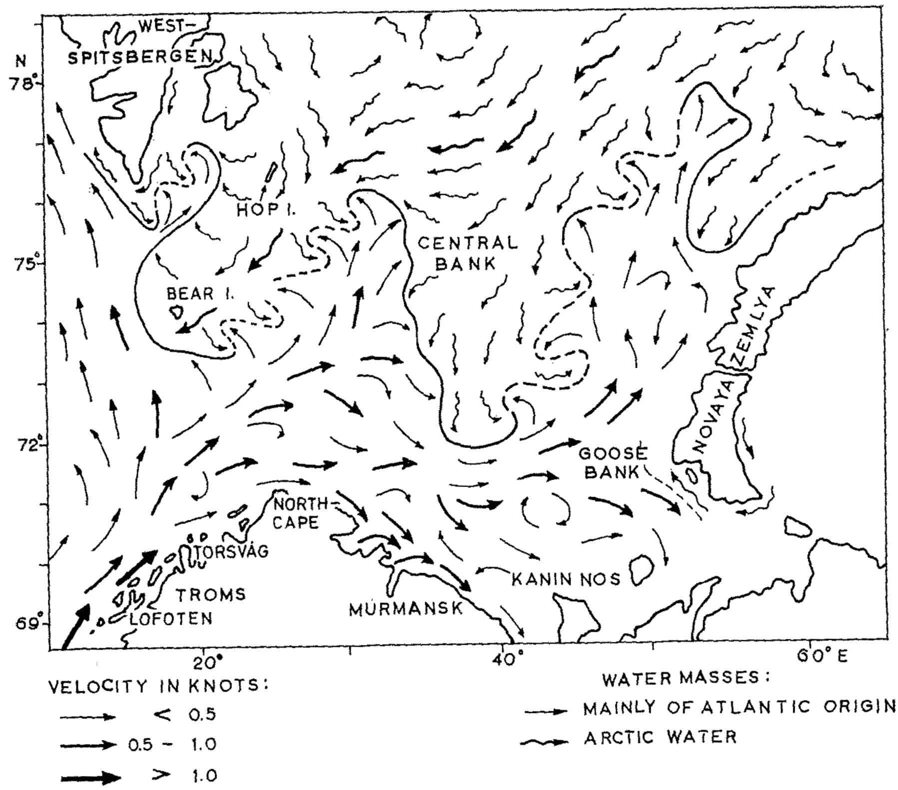

Fig. 11. General system of water currents off northern Norway and in the Barents Sea (modified from TANTSURA 1959).

and from one year to another. The Ullsfjord region in Troms and the Porsangerfjord in Finnmark were selected to study these variations. A description is given only for the wintering period from the autumn of 1959 to the spring of 1960 as this is assumed to represent the normal conditions.

In early October dense concentrations of herring were located just inside the entrance of Hamarfjord, while in Ullsfjord only few and scattered shoals were observed (Fig. 14A). During the following two weeks a further immigration took place, and in late October dense concentrations were recorded from the entrance to the central part of Ullsfjord (Fig. 14A and B). During the migration from Hamarfjord to Ullsfjord the herring were distributed at depths of 10–40 m. At night the herring dispersed, and in the day the fish clustered more closely together. During immigration, the temperature in the surface water in Ullsfjord was uniform except for a slightly lower temperature in the upper 20 m in the innermost part of the fjord (Fig. 14C).

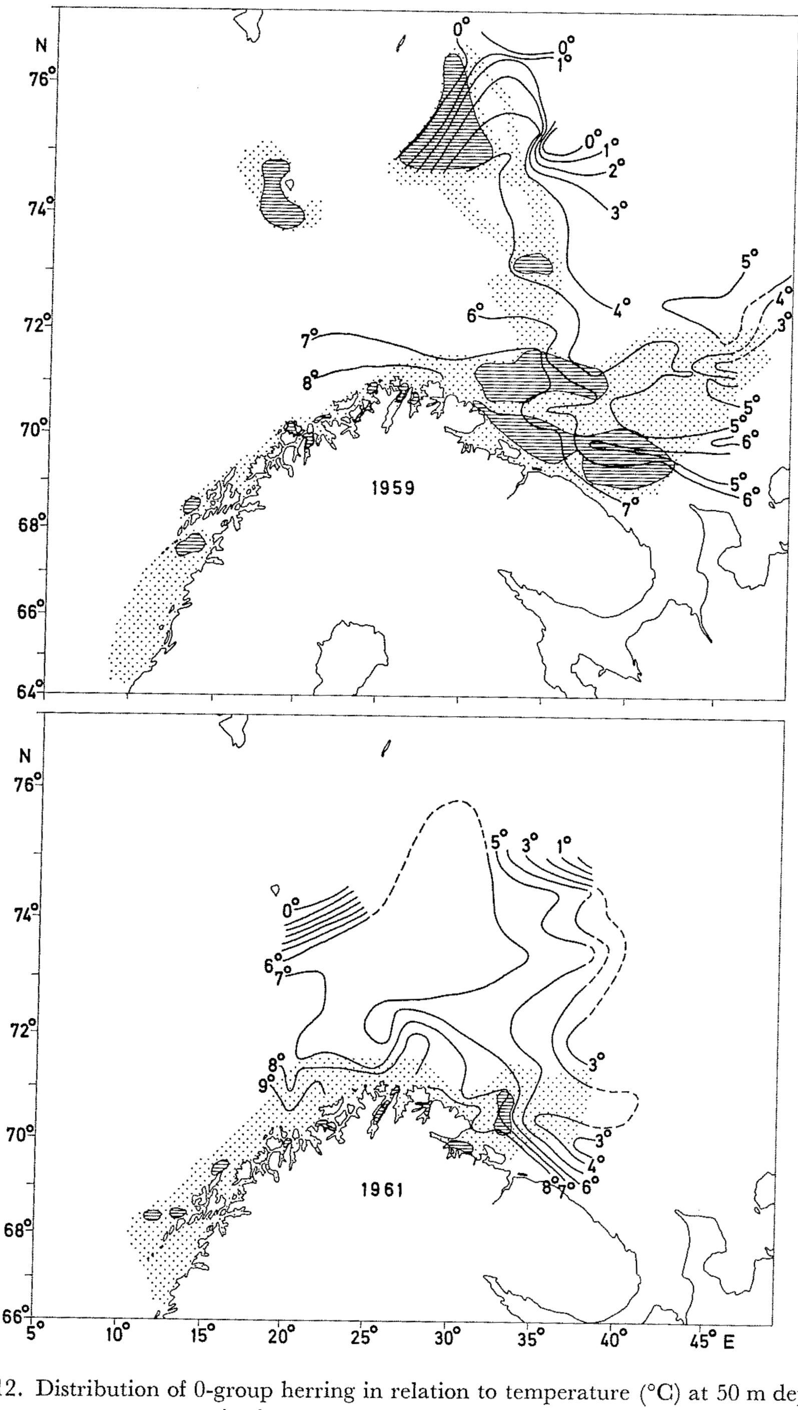

Fig. 12. Distribution of 0-group herring in relation to temperature (°C) at 50 m depth in the autumn of 1959 and 1961.

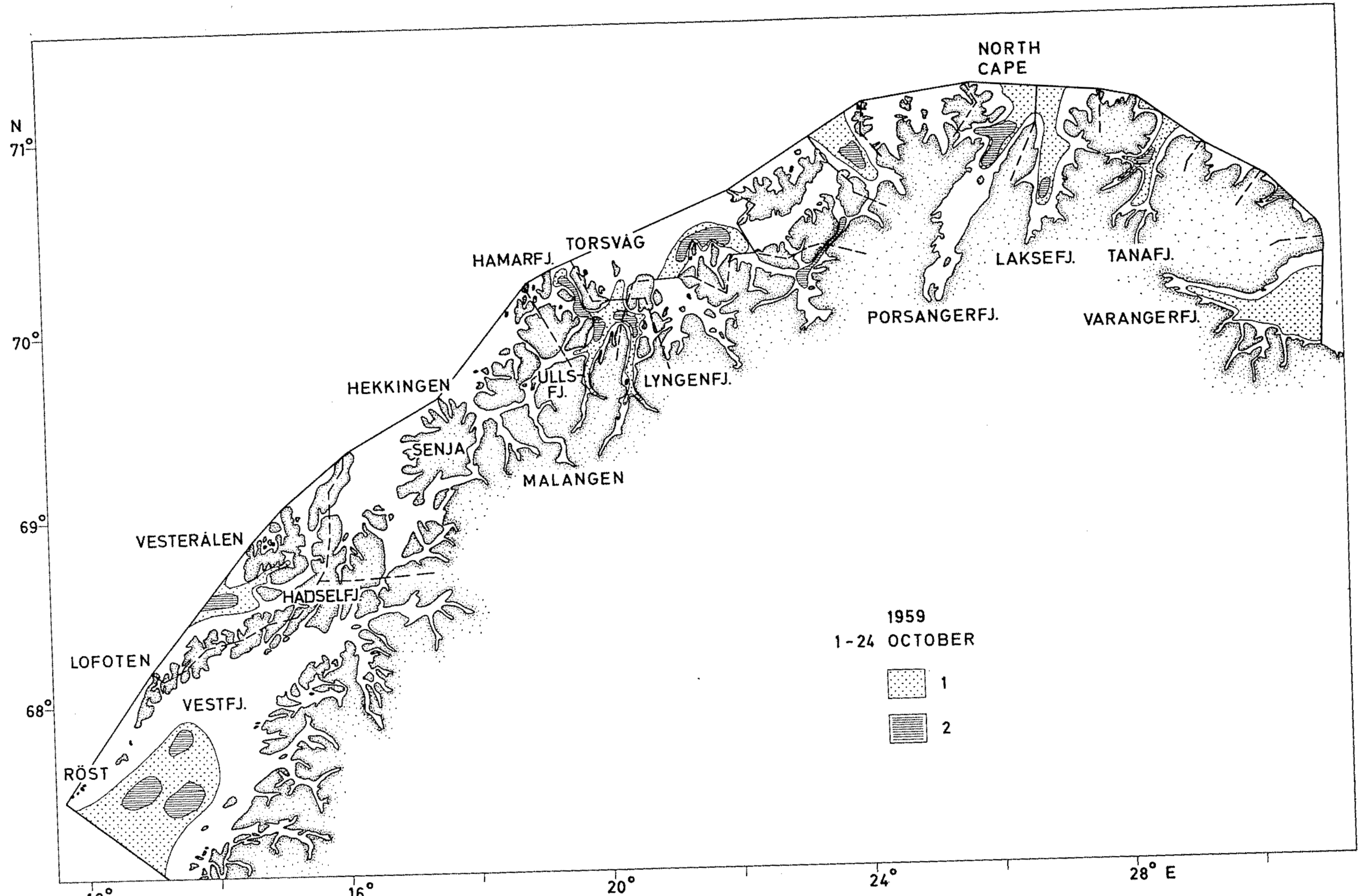

Fig. 13. Distribution of 0-group herring during the period of immigration to the fjords of northern Norway in 1959, (1) scattered and (2) dense concentrations. Herring observed inside the line drawn along the coast are later in the year subject to fishing.

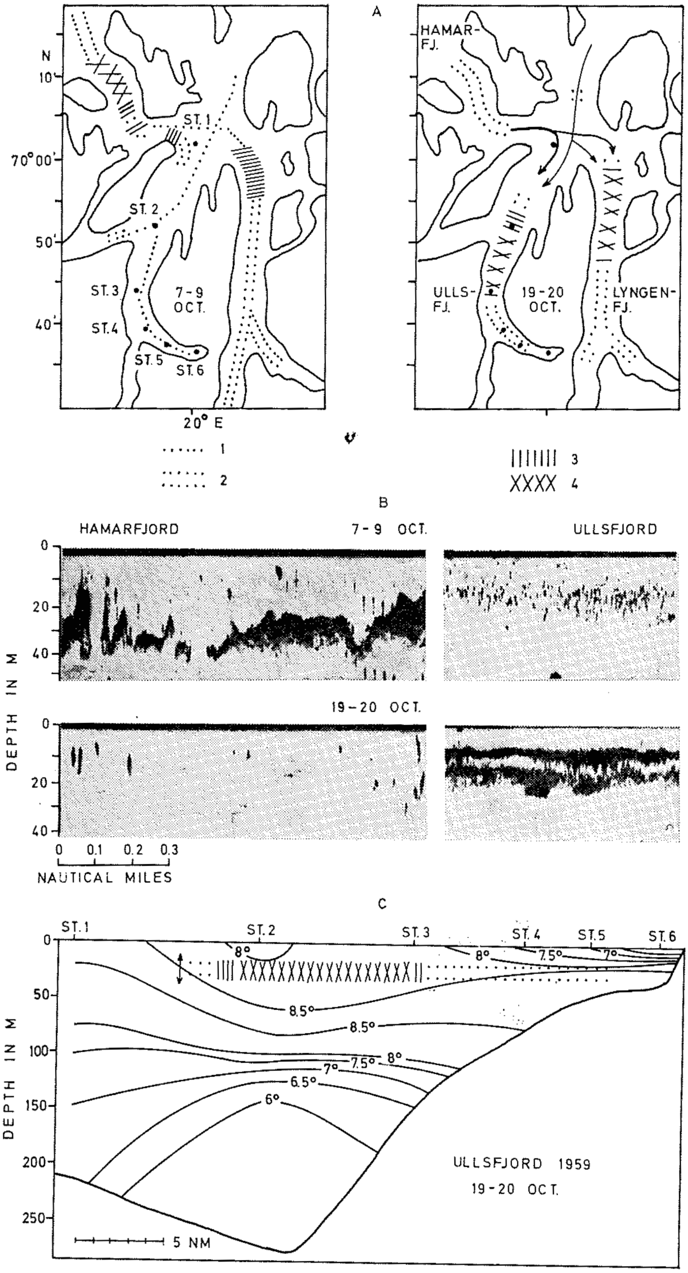

Fig. 14. Distribution of 0-group herring in the autumn of 1959, (A) in the Ullsfjord region, (1) very scattered, (2) scattered, (3) dense and (4) very dense concentrations, (B) echo recordings in Hamarfjord and Ullsfjord and (C) distribution of 0-group herring in relation to temperature (°C) in the Ullsfjord. Double pointed arrow denotes vertical extension of the distribution. Legend as in (A).

On 10 November (Fig. 15A) herring were concentrated in the inner part of Ullsfjord, and no herring were observed in Hamarfjord or off the entrance to this fjord. From October to November the fish moved from water of higher to slightly lower temperature. However, when the autumn and winter cooling started, the herring gradually moved into the central part of the fjord, where the water temperature was highest (Fig. 15B). The extent of the diurnal vertical migration increased during this period. The herring were observed near the surface at night and down to depths of 100–120 m in the daytime. In January no herring were observed in the innermost part of Ullsfjord, but herring were recorded near the surface farther out in the fjord. In February the herring were found mainly along the eastern side of the fjord and somewhat farther out. From the end of March the herring gradually migrated from the fjord, and in May the main concentrations had left the Ullsfjord region (Fig. 15C).

The migration from the entrance of Porsangerfjord and farther into the fjord started at the end of October, i.e. slightly later than in the Ullsfjord region. At that time only scattered concentrations of herring were observed outside the Porsangerfjord and in the inner parts of the fjord. The herring entered the fjord along its western shore (Fig. 16A), and from the end of November to mid-December most of the herring moved into the innermost branch of the fjord (Austerbotn), i.e. into water masses of lower temperature than those found farther out. In late autumn and throughout winter the temperature in Austerbotn was below zero, and from the end of December 1959 until April of 1960 the surface was covered with ice. The herring were found in Austerbotn when the ice broke up, and therefore probably remained in the cold water throughout winter (Fig. 16C). The emigration started in May, and the herring left the fjord within about three weeks.

A similar distribution and behaviour pattern was found for the other year-classes. The densest concentrations were observed in the autumn of 1959 and 1960, followed by 1961 and 1963. In 1962, 1964 and particularly in 1965 (Figs. 17 and 18), 0-group herring were few and scattered. In September 1965 insignificant numbers of 0-group herring were detected in the Ullsfjord region and in the Porsangerfjord. During the following two months, some small shoals migrated into the fjords. The herring concentrations were, however, more scattered than in any other year since the investigations started in the autumn of 1959.

Throughout the investigated period the immigration of 0-group herring was completed somewhat earlier in Ullsfjord than in Porsangerfjord, i.e. during the first and second half of October, respectively. In Ullsfjord the herring usually migrated to the central part of the fjord during winter, and when the winter cooling started, the extension of the

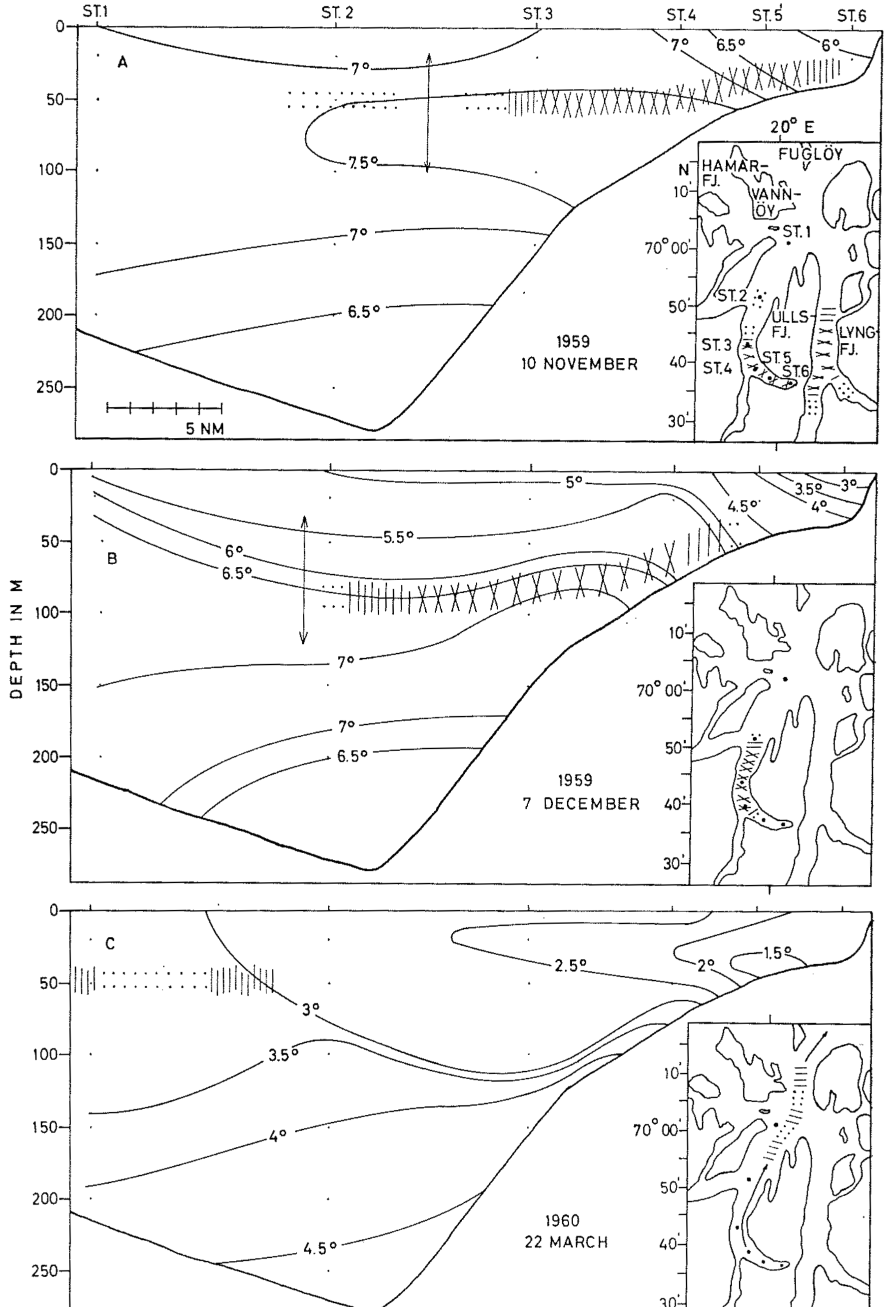

Fig. 15. Distribution of herring (1959 year-class) in relation to temperature (°C) in Ullsfjord during the wintering period 1959–1960. Double pointed arrows in (A) and (B) denote vertical extension of the distribution. Legend as in Fig. 14A.

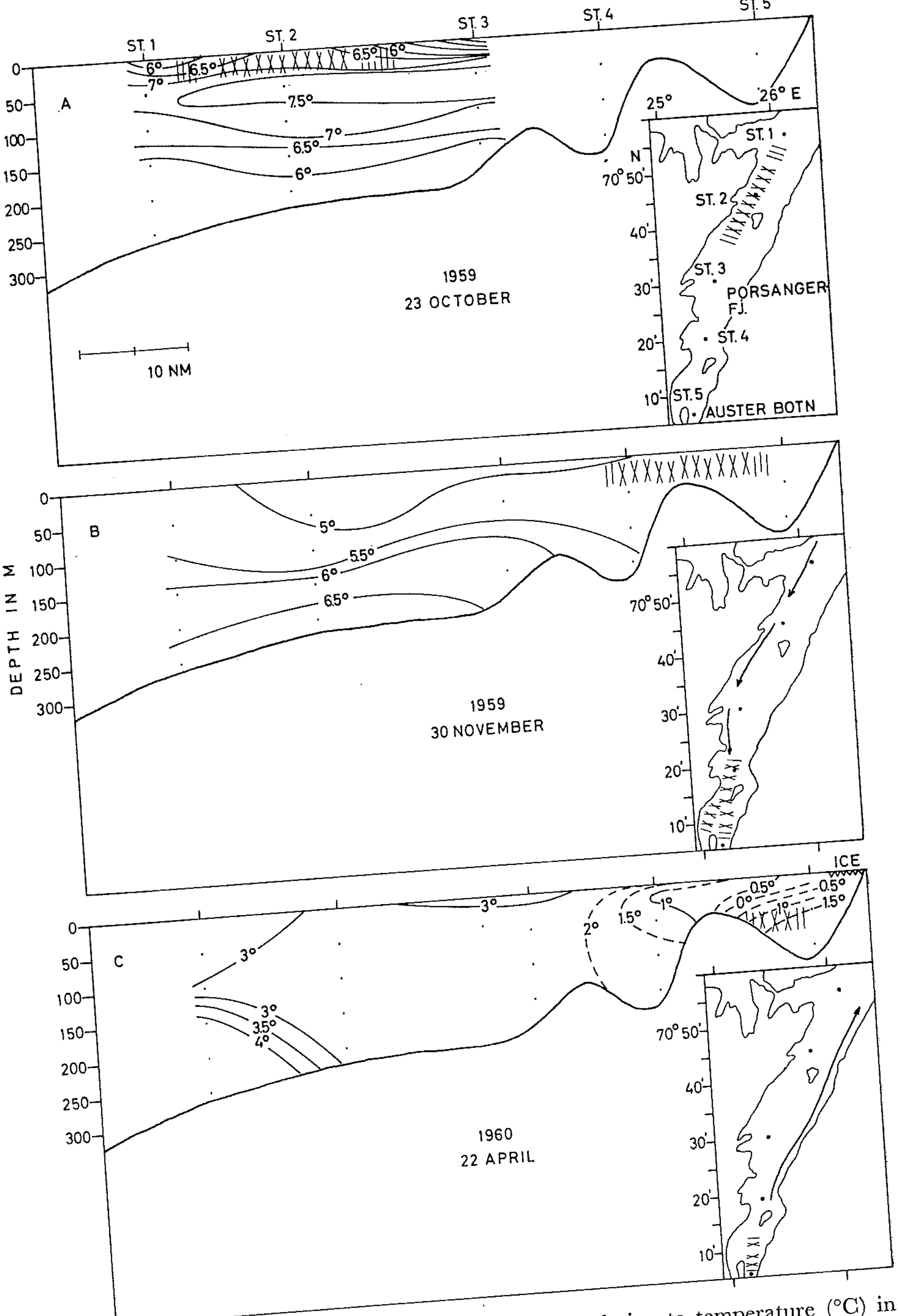

Fig. 16. Distribution of herring (1959 year-class) in relation to temperature (°C) in Porsangerfjord during the immigration and wintering period 1959–1960. Legend as in Fig. 14A.

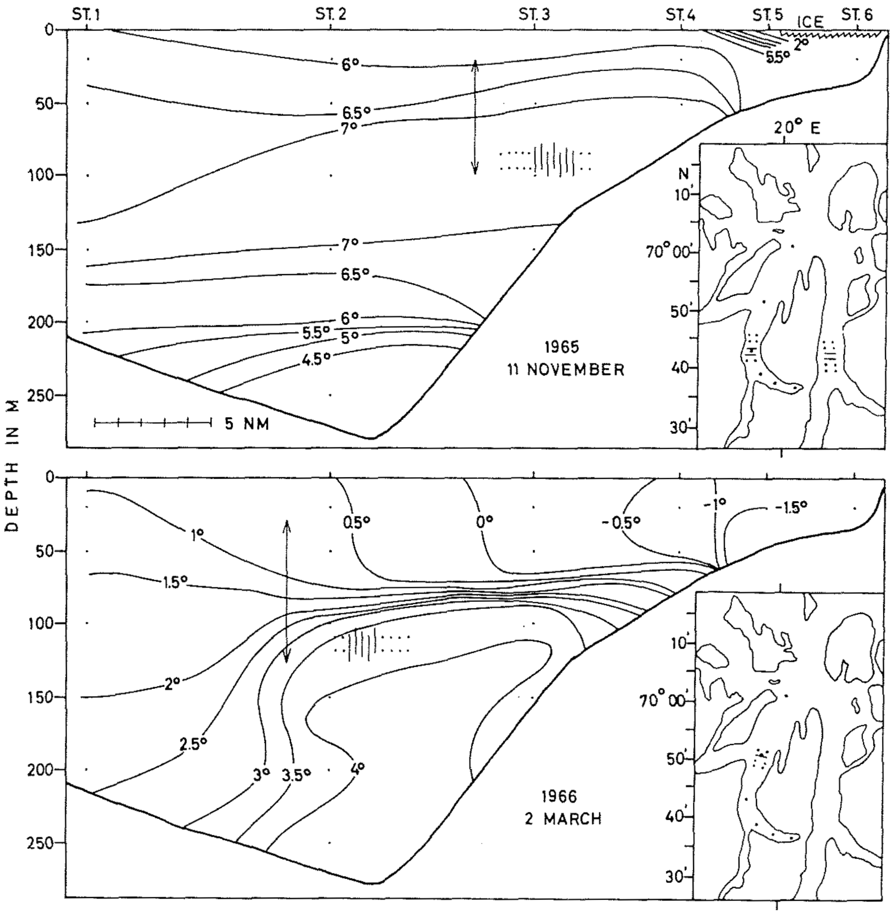

Fig. 17. Distribution of herring (1965 year-class) in relation to temperature (°C) in Ullsfjord during the wintering period 1965–1966. Double pointed arrows denote vertical extension of the distribution. Legend as in Fig. 14A.

vertical migration increased. From late afternoon to the following morning the herring were found close to the surface, i.e. above 50 m depth, whereas during the day the herring remained in the intermediate warm water layer at depths varying from 50 to 120 m. The emigration started in March when this layer disappeared, and the herring usually migrated from water of lower to higher temperature. In Porsangerfjord the herring stayed in cold water, probably near the bottom in water of temperature below 0 °C, throughout the winter until May when the herring ascended and gradually started migrating from the fjord.

The fishery on 0-group herring starts with the immigration and is continued throughout the wintering period. The concentrations of 0-group herring migrating into the fjords appeared to be most dense in

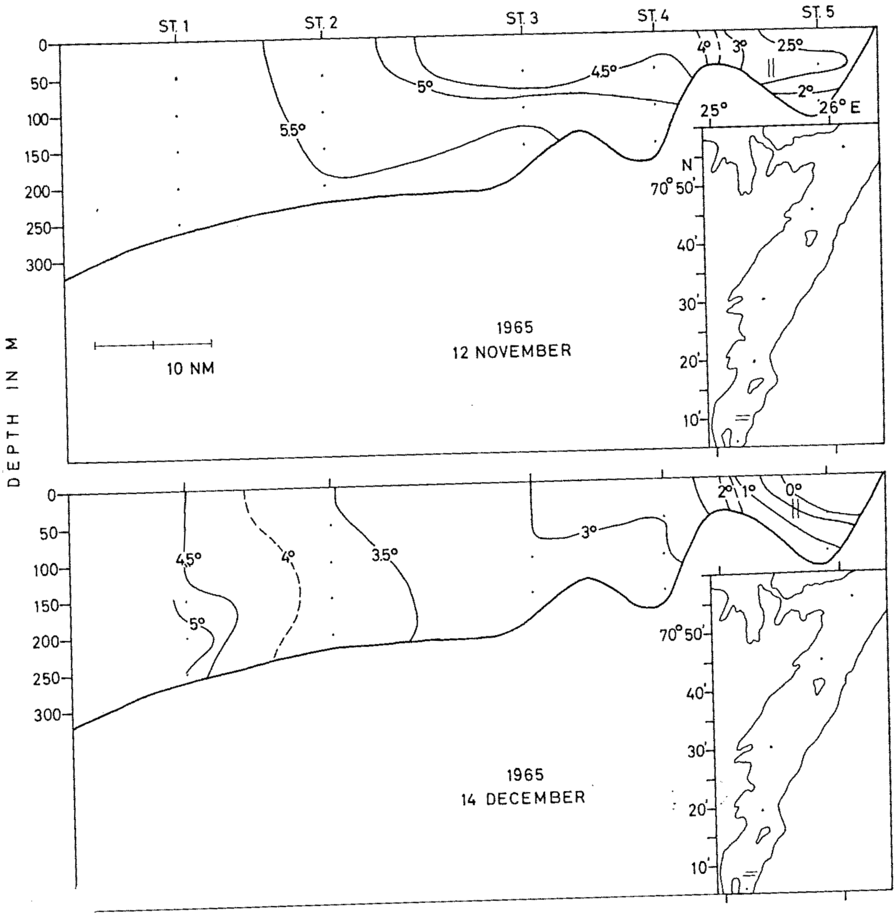

Fig. 18. Distribution of herring (1965 year-class) in relation to temperature (°C) in Porsangerfjord in November–December 1965. Legend as in Fig. 14A.

years when rich year-classes occurred, but other factors will also have an influence on the proportion of 0-group herring migrating into the fjords, e.g. the drift and distribution pattern during the larval and post-larval stages. In 1959–1960, 1960–1961 and 1961–1962 a productive small-herring fishery took place, whereas in the other years in question the fishery was rather poor, especially in 1965–1966.

Adolescent herring

The distribution and migration of the 1959 year-class during 1960 is illustrated in Fig. 19A. During winter and spring the year-class was recorded as I-group in the fjords and offshore from the banks of eastern Finnmark into the northern, central and southern parts of the Barents Sea. In Sep-

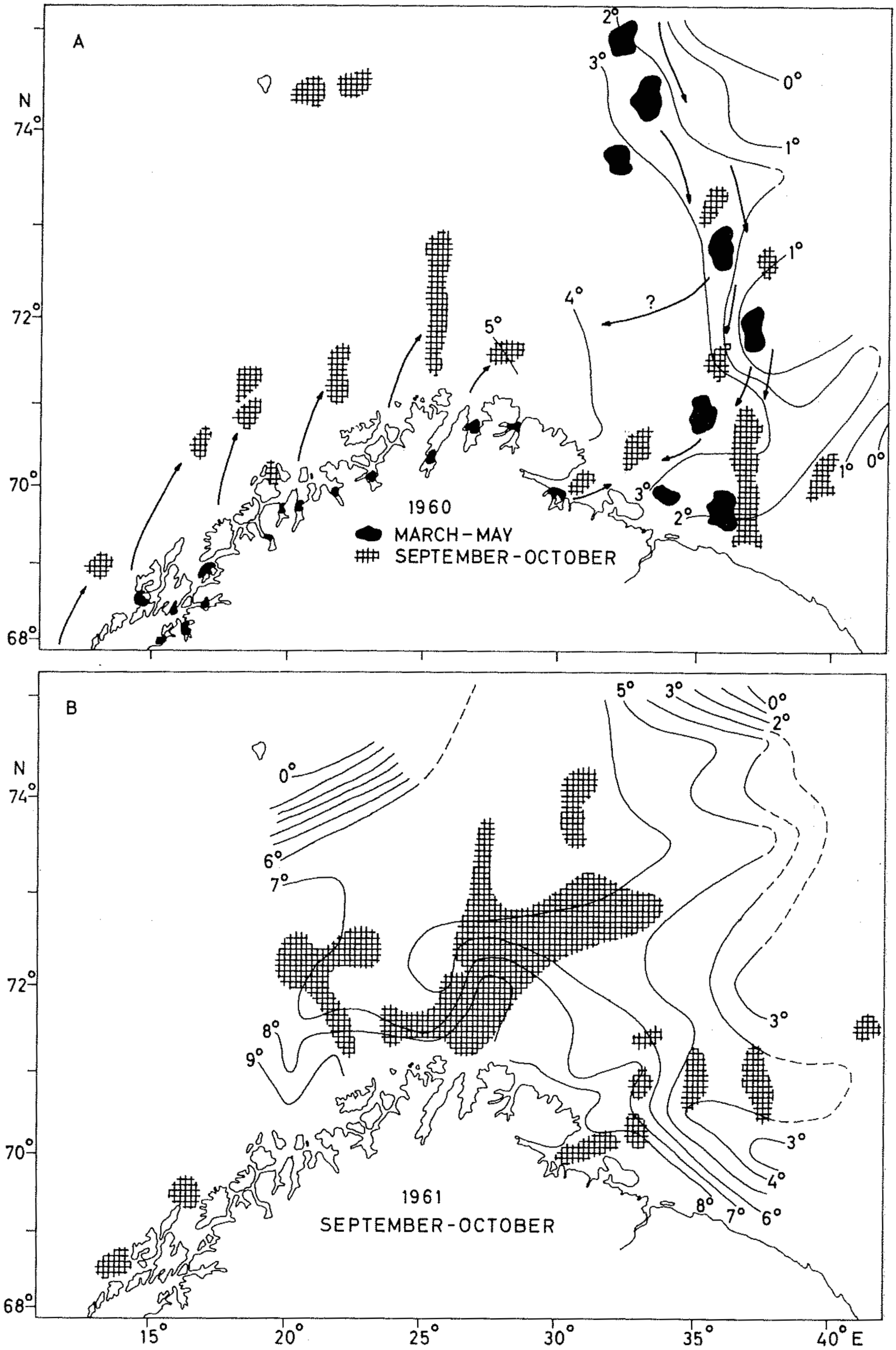

Fig. 19. Distribution of adolescent herring, mainly of the 1959 year-class in relation to temperature (°C) at 50 m depth, (A) in 1960 and (B) 1961. Temperatures in (A) refer to April—May and arrows denote the main migration routes of herring during the summer of 1960.

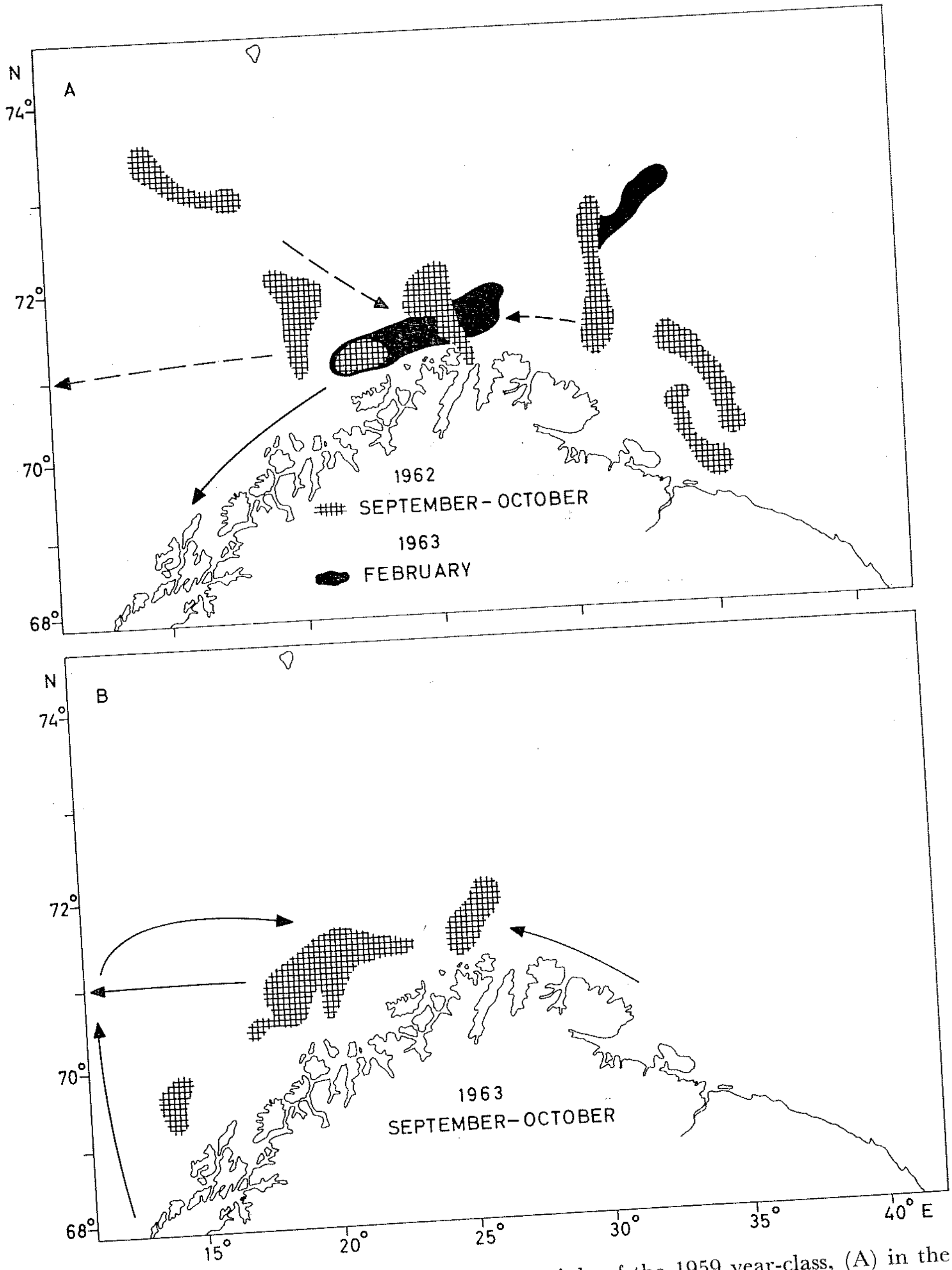

Fig. 20. Distribution of adolescent herring, mainly of the 1959 year-class, (A) in the autumn and winter of 1962 and 1963 and (B) in the autumn of 1963. Arrows indicate migration routes, broken ones summer and autumn 1962 to winter 1963, the fully drawn ones spring and summer 1963.

tember–October of 1960 the main concentrations as I-group were recorded from the North Cape Bank and eastward into the central and southern parts of the Barents Sea. During the summer of 1960 the open sea concentrations of this year-class gradually moved southward along the front between the cold and warmer water in the area from the Central Bank towards the Thor Iversen Bank. At the same time its members, which had wintered in the fjords of northern Norway, migrated from the coast. Members of this year-class also occurred on the banks around Bear Island in the autumn of 1960. Some of these herring could have wintered in this area, and others probably had migrated from the region south of Hope Island, although the majority of the herring observed south of Hope Island in the previous autumn presumably migrated southwards over the Central Bank and Thor Iversen Bank. In the winter and spring of 1961 the 1959 year-class was found in almost the same areas although the distribution was more restricted to the central and southern parts of the Barents Sea.

In the autumn of 1961 (Fig. 19B) the 1960 year-class had mixed with that of the 1959, and it was not possible to distinguish exactly between the distribution of these year-classes. However, the 1959 year-class, which was then in its third year of life (II-group), had moved farther west although it was also found in the central and southern parts of the Barents Sea. During the winter of 1962 the 1959 year-class was still observed off the coast of Finnmark and in the southern part of the Barents Sea (areas 03 and 02). The following summer dense concentrations in which the 1959 year-class predominated, were observed off Finnmark in areas 03 and 10 (Table 1).

In the autumn of 1962 (Fig. 20A) large concentrations mainly of the 1959 year-class were recorded off Torsvåg (areas 04 and 12), while other concentrations were also observed farther east. During the summer of 1962 members of the 1959 year-class migrated westwards into the Norwegian Sea, but most of the herring remained in the areas off Torsvåg. From the autumn of 1962 to February 1963 herring mainly of the 1959 year-class concentrated off western Finnmark. Some of these herring became mature and migrated later in the winter of 1963 towards Lofoten for spawning (Devold 1968). In the autumn of 1963 (Fig. 20B) most of the 1959 year-class had left the central parts of the Barents Sea and the Finnmark coast and had concentrated off Torsvåg together with herring which spawned at Lofoten in 1963.

The 1960 year-class dominated among the herring recorded off eastern Finnmark in spring and summer 1963 (Table 1). The 1963 and 1964 year-classes remained off eastern Finnmark during the entire adolescent phase (up to the end of 1968), and no westward migration could be discovered during this period (Table 1).

Table 1. Age composition (in %) of adolescent herring caught with purse seine (PS) and pelagic trawl (PT) in some of the main fishing areas in 1961–1968.

Date		Area	Gear	No.	Year-class				
					1959	1960	1961	1963	1964
1961	11–22.9	03 and 12	PS	215	90.7	9.3			
	20.9	03 and 10	PS	97	29.9	70.1			
1962	28.2–7.3	03 and 02	PT	102	41.2	58.8			
	1.7–2.8	03 and 10	PS	973	90.6	9.4	—		
	13.9	03	PT	76	57.9	42.1	—		
	14–18.9	04 and 12	PT and PS	112	77.7	21.4	0.9		
1963	6.2	04	PT	49	67.3	28.6	4.1		
	2.2–5.4	03 and 13	PT	255	27.5	60.4	12.1		
	4.6–25.7	03	PS	358	7.5	81.3	11.2		
	1.10–28.11	04	PT and PS	725	43.2	42.2	14.6		
1965	30–31.8	03	PT and PS	302	—	—	—	41.7	58.3
1966	4–24.8	03	PT and PS	305	—	—	—	44.3	55.7
1967	11.8	03	PS	50	—	—	—	36.0	64.0
1968	8.4–8.5	03	PS	537	—	—	—	41.9	58.1

Almost all the adolescent herring found along the coast were recorded outside the entrances to the fjords. The main fat-herring fishery, therefore, took place offshore and most intensively off eastern Finnmark (area 03) and off Vesterålen and Lofoten (area 05). However, almost no fishing took place on the dense offshore concentrations recorded in the autumn of 1962 and 1963 between Torsvåg and North Cape (areas 04 and 12). During the period 1965–1968 a productive fat-herring fishery occurred off eastern Finnmark on the 1963 and 1964 year-classes which were concentrated within a relatively limited area.

LENGTH AND GROWTH STUDIES

The present investigations have shown that herring, which have wintered in the fjords during the late 0-group and early I-group stages, move into the open sea and join those which have spent their first year of life there. With increasing age more extensive migrations occur, extending into the central and western parts of the Norwegian Sea. To investigate the effect of growth on the timing of migration from the nursery areas the length and growth in different areas are compared.

Length distributions of 0-group herring are given in Table III. An analysis of variance showed in most cases significant differences in lengths of 0-group herring between areas along the coast (Table IV). However, the differences between the northernmost areas 05, 04 and 03 were not consistently significant. Mean lengths of 0-group herring in different areas

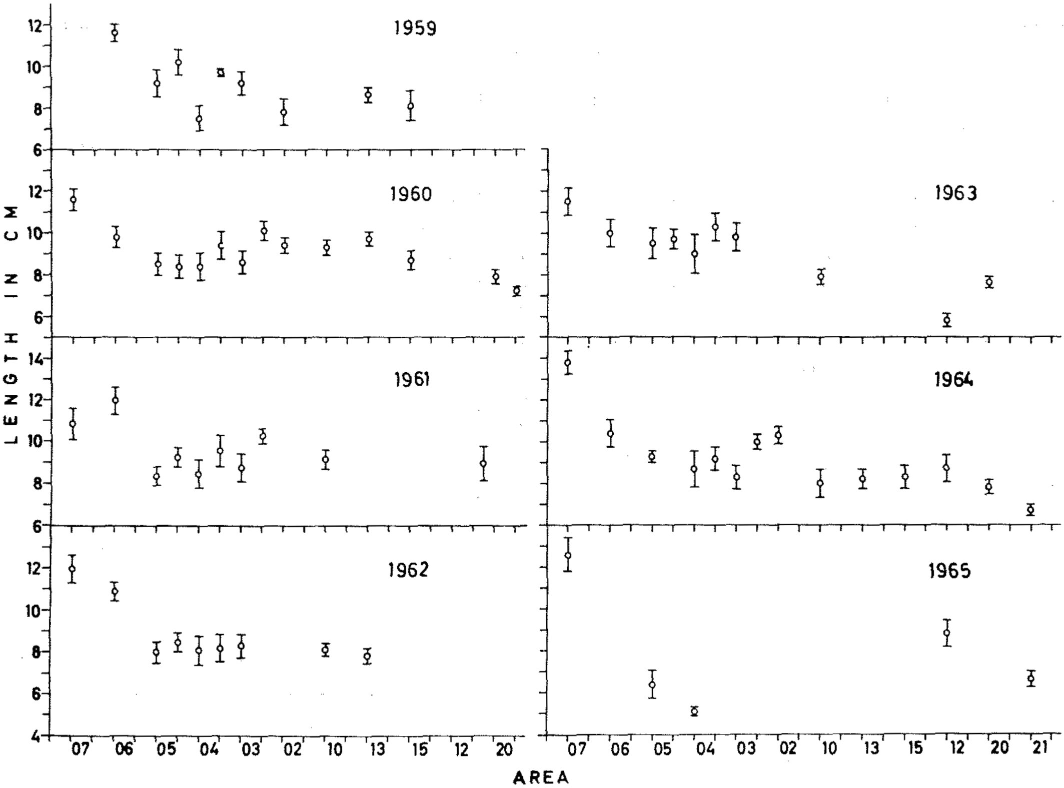

Fig. 21. Mean length of 0-group herring of the 1959–1965 year-classes in different areas. The vertical bars show the standard deviation. Samples collected with IKMT are omitted in the figure.

are listed in Table V and illustrated in Fig. 21. The mean lengths were larger for 0-group herring caught south of Lofoten (in areas 07 and 06) than for those caught north of this region. Herring collected in coastal and offshore waters north of Lofoten had variable mean lengths, but no clear decreasing trend in length was found from south to north.

Length distributions of adolescent herring of the 1959 year-class collected after the main growth seasons are shown in Fig. 22. Decreasing lengths were found from south to north. Both fast and slow growing herring were caught off Torsvåg (in areas 04 and 12). The length distribution of $3\frac{1}{2}$-year-old herring caught off Iceland (areas 56, 57, 58, 59) shows that these herring had grown more rapidly than herring of the same year-class occurring off Torsvåg at the same time. The appearance of slow growing herring off Torsvåg in the autumn of 1962 ($3\frac{1}{2}$-year-old) gave evidence of an immigration of the 1959 year-class from the eastern part of the Finnmark coast and from the Barents Sea (Fig. 22C and E).

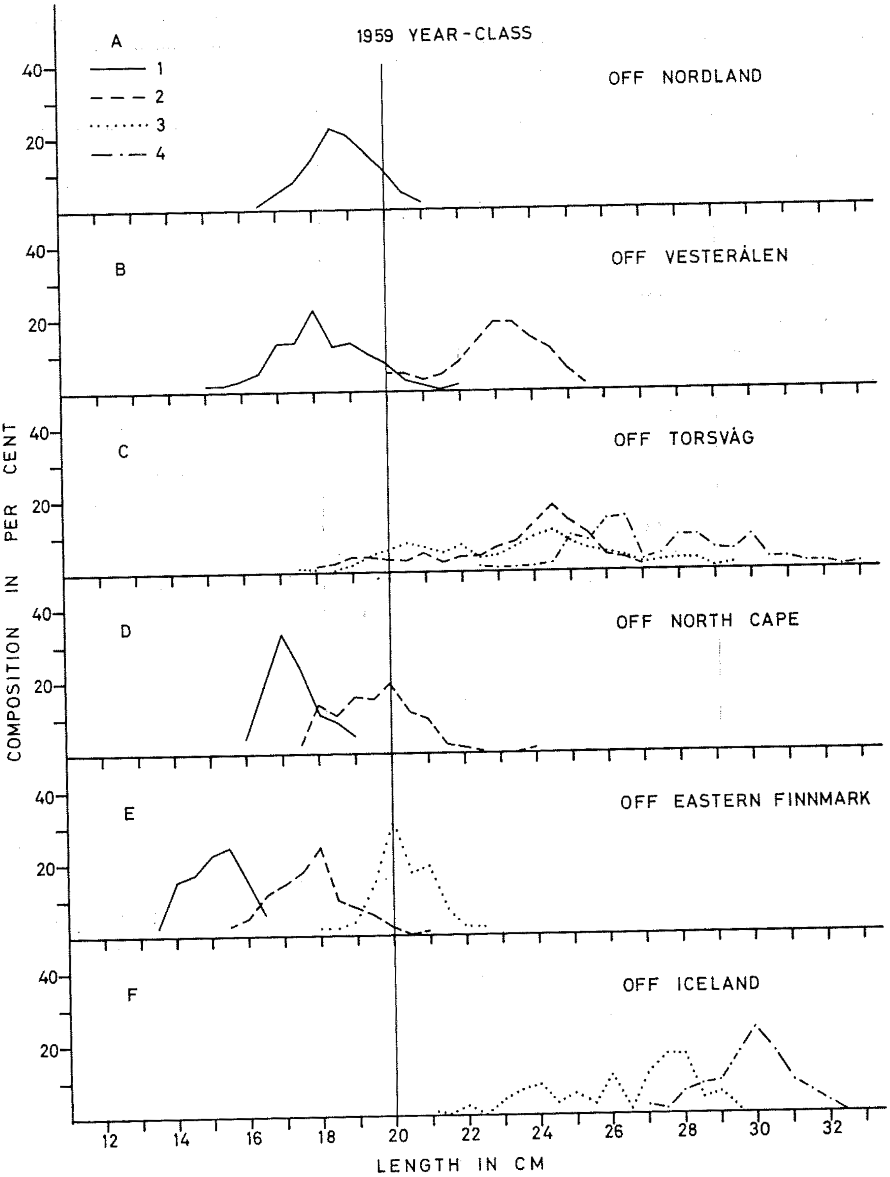

Fig. 22. Length distribution of adolescent herring of the 1959 year-class in different regions. Legend:

(1) $1\frac{1}{2}$-year-old, (A) No. = 401, (B) No. = 88, (D) No. = 49, (E) No. = 54;
(2) $2\frac{1}{2}$-year-old, (B) No. = 130, (C) No. = 176, (D) No. = 89, (E) No. = 108;
(3) $3\frac{1}{2}$-year-old, (C) No. = 244, (E) No. = 60, (F) No. = 75;
(4) $4\frac{1}{2}$-year-old, (C) No. = 142, (F) No. = 102.

Table 2. Composition (in %) of southern (S) and northern (N) growth types of the 1959 and 1961 year-classes in different regions during 1961–1967. Data on the herring off Iceland are from JAKOBSSON (1964, 1965, 1966, 1967).

Year	Region	1959 year-class				1961 year-class			
		No.	N	S	Un-certain	No.	N	S	Un-certain
1961	Off eastern Finnmark	99	88.9	—	11.1				
	Off Torsvåg	100	47.0	24.0	29.0				
1962	Off eastern Finnmark	728	96.2	0.1	3.7				
	Off Torsvåg	95	91.6	—	8.4				
	Off Iceland	407	56.5	43.5	—				
1963	Off eastern Finnmark	27	100.0	—	—	40	95.0	—	5.0
	Off Torsvåg	309	83.2	14.9	1.9	71	31.0	47.9	21.1
	Off Iceland	722	54.8	45.2	—	8	—	100.0	—
1964	Off Iceland	1630	65.3	34.5	0.2	122	24.6	70.5	4.9
1965	Off Møre	1045	64.9	29.5	5.6	300	2.3	33.3	64.4
	Off Lofoten	632	82.8	12.8	4.4	51	7.8	90.2	2.0
	Off Iceland	2130	69.9	30.1	—	241	32.4	66.0	1.6
1966	Off Møre	2101	76.5	20.6	2.9	378	13.2	81.8	5.0
	Off Lofoten	457	85.8	12.9	1.3	84	27.4	66.7	5.9
1967	Off Møre	1354	80.7	17.3	2.0	374	22.7	71.4	5.9

Also, the relative abundance between the fast growing southern (S) and the slow growing northern (N) growth types (LEA 1929) in different regions indicates that the fastest growing members of a year-class started their westward migration towards the feeding areas in the Norwegian Sea earlier than those with a slower growth (Table 2). The 1961 year-class, which had a higher proportion of S-type herring than the year-class of 1959, showed up in catches off Iceland already in 1963 when they were 2½-year-old.

Further knowledge of the migration pattern during the adolescent and maturing phases has been obtained from studies of annual length increments, $t_n = (l_n - l_{n-1})$. For this purpose scales from the herring of the 1959 year-class were analysed to investigate some of the characteristics of herring participating in the westward migration from the Barents Sea and the migration from the coast of northern Norway. The mean annual length increments are listed in Table VI, and the frequency distributions are illustrated in Fig. 23.

In the autumn of 1961 the main concentrations of adolescent herring were found off northern Norway, from the Vesterålen region and eastward towards the Skolpen Bank. The t_1 and t_2 distributions of herring

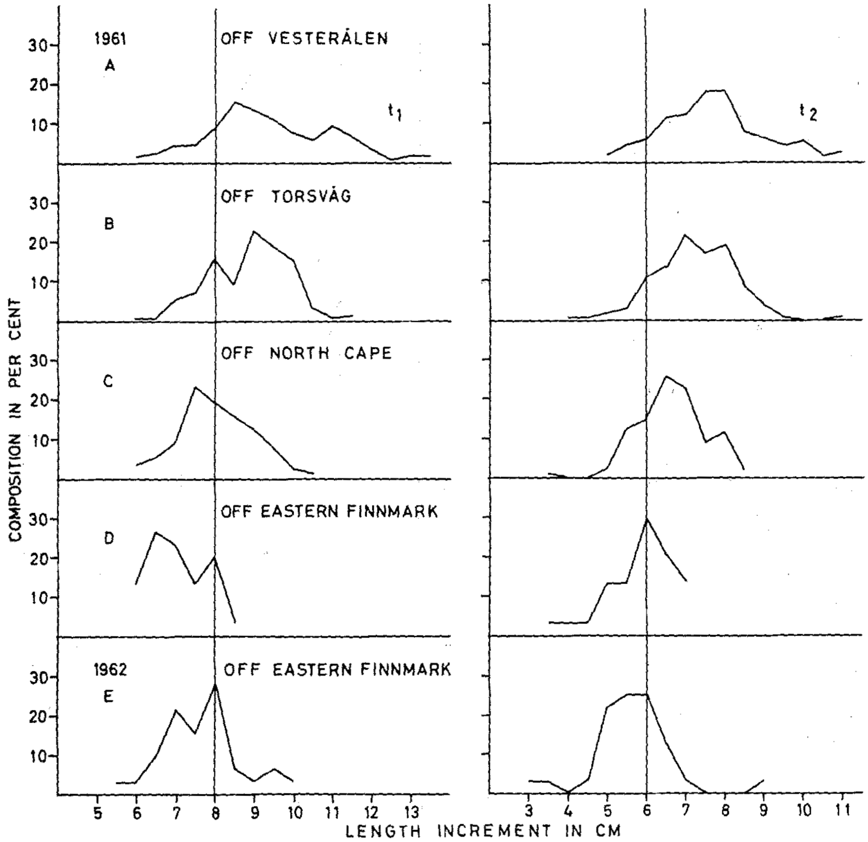

Fig. 23. Annual length increments of the first (t_1) and the second (t_2) year of life of adolescent herring of the 1959 year-class collected in the autumn and winter of 1961 and 1962.

caught in the westernmost region (Fig. 23A) show somewhat larger length increments than those off eastern Finnmark in areas 03, 02 and 10 (Fig. 23D), whereas herring collected off North Cape in area 12 and off Torsvåg show intermediate t_1 and t_2 values (Fig. 23B and C).

As indicated in Table 2 herring of the 1959 year-class appeared on the fishing grounds off Iceland during the summer of 1962. The t_1 and t_2 distributions (Fig. 24A) resemble those found off the Norwegian coast the year before (Fig. 23A), and indicate an extensive migration across the Norwegian Sea of the faster growing herring. Herring with a growth pattern similar to that found off eastern Finnmark in 1961 did not appear off Iceland in 1962.

A comparison of the t_1, t_2 and t_3 distributions of herring caught in September 1962 off Torsvåg (Fig. 24B) with those found in July farther east (Fig. 24C) suggests that herring located off Finnmark in the summer

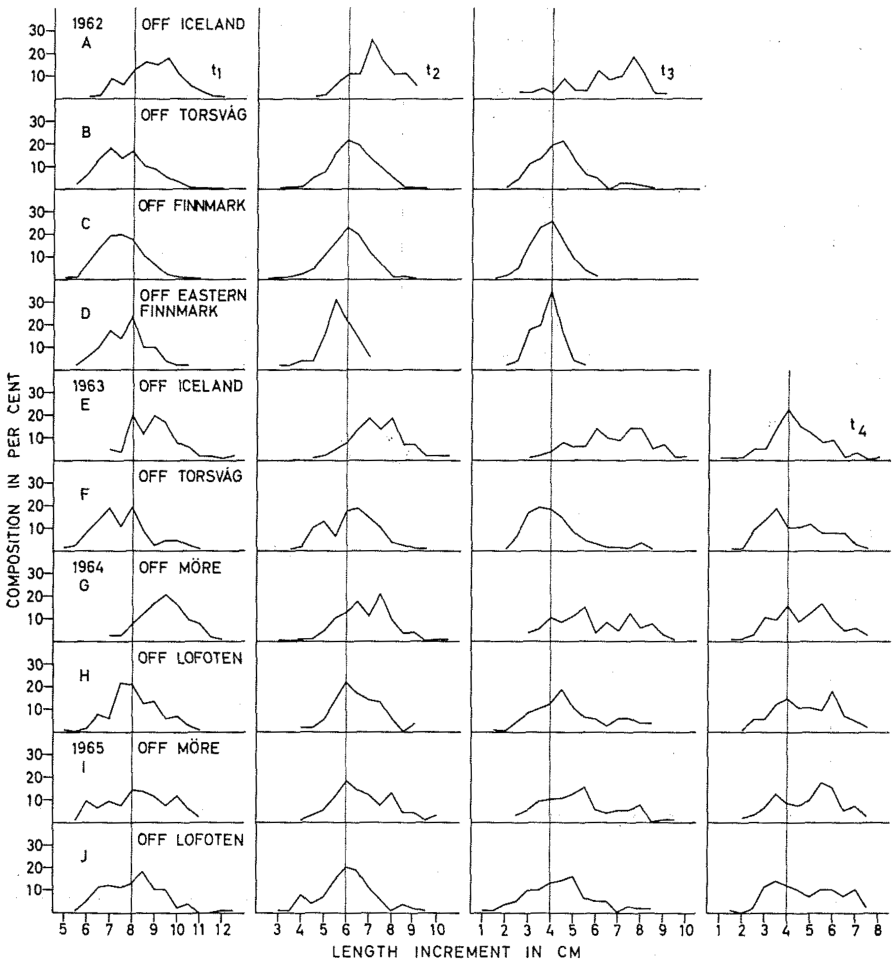

Fig. 24. Annual length increments of the first (t_1), second (t_2), third (t_3) and fourth (t_4) year of life of adolescent and adult herring of the 1959 year-class collected in 1962–1965, (A) to (F) during late summer and autumn, (G) to (J) during winter.

of 1962 migrated westward during the following months and appeared off Torsvåg in September of the same year. The length increments of herring found off Iceland in the summer of 1963 were significantly larger than those for herring caught off Torsvåg in September of the year before and in 1963 (Fig. 24B, E and F). This suggests that a westward migration into the Norwegian Sea did not take place to the same extent in 1963 as in 1962. The t_1, t_2 and t_3 distributions of herring caught off Lofoten in the winter of 1964 were similar to those found off Torsvåg in the autumn of 1962 (Fig. 24H and B), and partly also to those found off Torsvåg in 1963 (Fig. 24H and F). Herring caught off Møre in the winter of 1964 showed almost the same length increment distributions as those caught off Iceland in 1962 and 1963 (Fig. 24G, A and E). The distribution of the annual length increments also was different for herring caught off Møre and herring caught off Lofoten during the winter herring season in 1965, although this difference, especially between the t_1 distributions, was not as pronounced as in 1964 (Fig. 24I and J, G and H).

The results of the length and growth studies show that the migration from the nursery areas is largely size determined, a feature which again probably is related to environmental conditions during the adolescent phase. The westward migration of herring spending their first year of life in the Barents Sea and off the eastern Finnmark coast was somewhat delayed, although the length distribution of the 0-group herring may be similar to that of 0-group herring spending their life farther west and south along the coast (areas 04 and 05). When the herring in these latter areas and in area 06 migrated from the coast early in the I-group stage, they joined the faster growing herring from the nursery areas in the open sea. These herring entered the feeding area in the Norwegian Sea earlier than the slower growing herring from the coastal areas and the Barents Sea.

Slower growing herring of the 1959–1961 year-classes gradually aggregated at the entrance of the Barents Sea, i.e. off Torsvåg in areas 04 and 12, during the summer of 1961, 1962 and 1963. These herring originated mainly from the fjords of Finnmark and the central and eastern parts of the Barents Sea, but also faster growing herring from the coastal areas farther south migrated to the accumulation area off Torsvåg. The fastest growing herring in this area gradually segregated from the population and migrated westwards to the central part of the Norwegian Sea and the areas off Iceland. However, some of the more slow growing herring remained in the eastern part of the Norwegian Sea throughout the summer of 1962 and 1963.

ANALYSIS OF TAG RETURNS

The migrations of herring tagged off northern Norway in 1961 and 1962 are shown in Fig. 25, and migrations of herring tagged in 1963 in Fig. 26. Both in 1961 and 1962 most of the tagged herring belonged to the 1959 year-class, in autumn 1963 the major part belonged to the year-classes of 1959 and 1960 (Table 3). Tagged herring from these experiments were recovered off Lofoten–Vesterålen and in waters off Iceland the following year. Herring tagged in 1962 and in autumn 1963 were found in catches on the spawning grounds off Møre two years after tagging, whereas herring from the tagging in 1961 did not

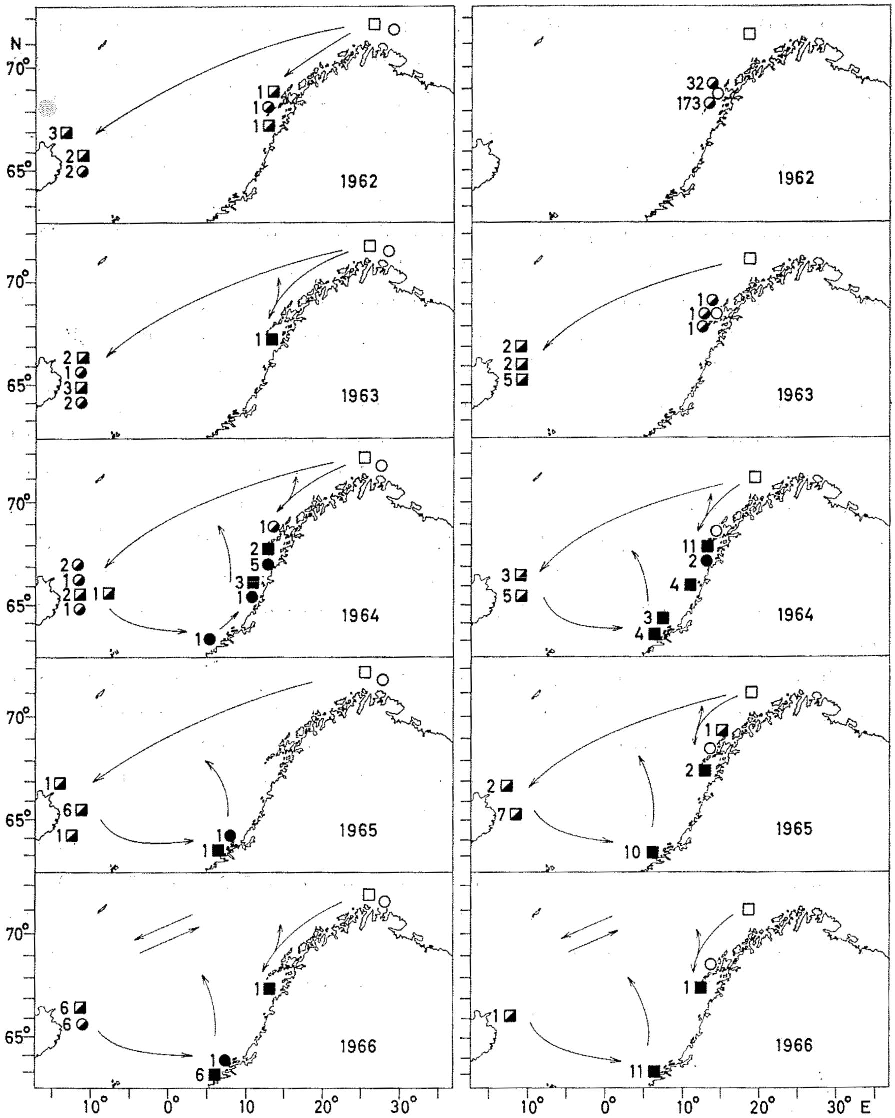

Fig. 25. Migration of herring tagged in 1961 (left column) and 1962 (right column). Open symbols indicate the tagging localities. Tags recovered during the summer fishing seasons 1962–1966 are given by half-filled symbols, recoveries during the Norwegian winter herring seasons 1963–1966, by filled symbols. The number of tags recovered is listed in the figure. Arrows indicate migration routes during the respective years.

reach these spawning grounds until three years after they were released. However, they showed up after two years in catches on the spawning grounds off Lofoten. None of the herring tagged off Varangerfjord in June 1963 has as yet (1968) been recaptured on the spawning grounds off

Table 3. Age composition (in %) of catches from which herring were taken for tagging.

Date		Tagging locality	No.	Year-class 1959	1960	1961
1961	12.3	Off North Cape	83	97.6	2.4	—
	22.9	Off North Cape, NE	74	94.6	5.4	—
1962	18.9	Off Torsvåg	99	83.8	12.1	4.1
	21.9	Off Vesterålen	100	1.0	3.0	96.0
1963	5.6	Off Varangerfjord	96	—	90.6	9.4
	10.6	Off Varangerfjord	99	18.2	73.7	8.1
	19.6	Off Varangerfjord	99	—	18.2	81.8
	25.6	Off Vesterålen	92	13.0	81.5	5.5
	1.10	Off Torsvåg	197	67.0	21.3	11.7

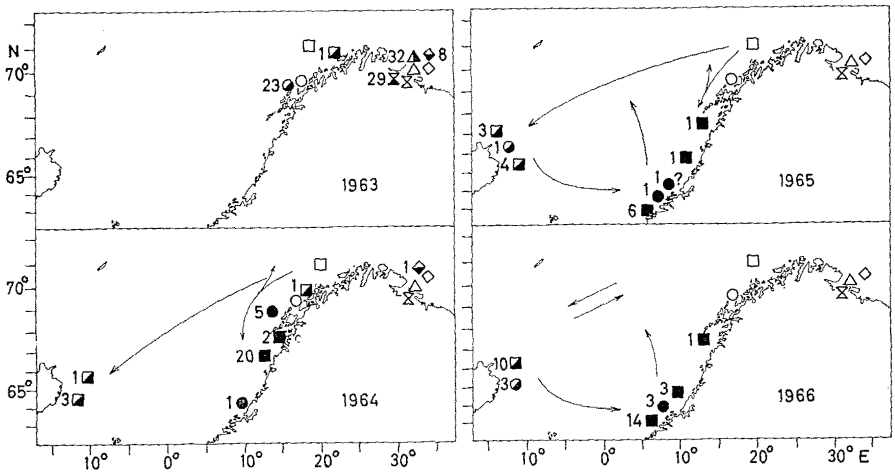

Fig. 26. Migration of herring tagged in 1963. Open symbols indicate the tagging localities. Tags recovered during the summer fishing seasons 1963–1966 are given by half-filled symbols, recoveries during the Norwegian winter herring seasons 1964–1966, by filled symbols. The number of tags recovered is listed in the figure. Arrows indicate migration routes during the respective years.

Møre or at Lofoten, but herring of the 1959 year-class tagged in autumn 1960 off eastern Finnmark (Table II) were recaptured at Lofoten in 1964 and 1966 and off Iceland in 1965.

These results indicate that recruits to the spawning grounds in the Møre region migrated via the feeding areas off Iceland through the traditional wintering area northwest of the Faroe Islands, whereas herring spawning off Lofoten remained in the northeastern part of the Norwegian Sea and moved to the Lofoten shelf from an area located off the coast of northern Norway. A more detailed description of the migration routes for this northern component spawning off Lofoten during the period 1963–1966 has been given by DEVOLD (1968) and JAKOBSSON (1968). They found that during the summer of 1966 the northern component joined the main component spawning off the Møre–Trøndelag coast, and that in 1967 and 1968 no major spawning took place off Lofoten.

It is concluded from the present investigations that herring, which in the 0-group stage were distributed far north and east off northern Norway, as adults migrated to the spawning grounds off Møre. However, this migration phase lasted longer for the herring from the northern nursery areas than for those growing up farther south. Herring from the southernmost nursery areas usually had higher growth rates and reached maturity earlier than did those spending their first years of life in the northern, central and southern parts of the Barents Sea. Accordingly, herring from these nursery areas might appear as recruit spawners from one to four years later than those from areas farther south. Taking into account the mortality during the migration phase, herring from the Barents Sea will be considerably more reduced in numbers before they reach the spawning grounds off Møre than those spending the 0-group stage along the coast south of Lofoten.

ABUNDANCE

ESTIMATES FROM ACOUSTIC SURVEYS

The distribution of 0-group herring together with the density of the echo recordings (the echo abundance) have been used to study the variation in abundance from one year to another. The surveys did not cover all the fjords. In order to obtain an estimate of abundance valid for the total distribution in inshore waters, the ratio between the area covered by the 0-group herring and the surface area in fjords which were investigated, also was applied to the fjords which had not been surveyed. In area 05 ratios for Hadselfjord and Vestfjord were used, in area 04 mainly ratios for Ullsfjord and Lyngenfjord, and in area 03 ratios for Porsangerfjord, Laksefjord, Tanafjord and Varangerfjord (Fig. 13). The total geographical distribution of scattered and dense concentrations in areas north of 67 °N was estimated for the surveys illustrated in Figs. 4–10. The estimated areas of distribution are listed in Table 4.

Fishing experiments with purse seine (two in 1960 and five in 1963) in scattering layers above 30 m depth at night were carried out to establish a conversion factor between scattered and dense echo recordings (Fig. 27). The ratio between the catches in litres taken in scattering layers (0–30 m depth) with density 1 to 2 (scattered) and density 3 to 4 (dense) was about

Table 4. Area of distribution (in square nautical miles) of scattered and dense 0-group herring concentrations and indices of echo abundance for 0-group herring in offshore and inshore areas in the autumn of 1959–1965.

Year-class	Offshore			Inshore			Total		
	Scat-tered	Dense	Abund-ance index	Scat-tered	Dense	Abund-ance index	Scat-tered	Dense	Aund-ance index
1959	62250	25318	315430	2520	784	10360	64770	26102	325790
1960	70144	7017	140314	3599	344	7039	73743	7361	147353
1961	23044	852	31564	3034	293	5964	26078	1145	37528
1962	12249	—	12249	1203	132	2523	13452	132	14772
1963	28312	2023	48542	2989	204	5029	31301	2227	53571
1964	58700	1263	71330	2845	78	3625	61545	1341	74955
1965	8400	—	8400	739	—	739	9139	—	9139

1:10. Indices of total echo abundance, therefore, were estimated by multiplying dense recordings by a factor of 10 (Table 4). The vertical extension of the scattering layers was not taken into account in these estimates.

The abundance indices for the total 0-group stock are by far the highest for the 1959 and 1960 year-classes, followed by those of 1964, 1963 and 1961. The estimates for the 1962 and especially for the 1965 year-classes are by far the lowest.

Estimates of the abundance of 0-group herring in the open sea (offshore) compared with that recorded in the fjords (inshore) have also been made for each year-class (Table 4). Not all of the 0-group herring observed along the coast migrated into the fjords. This was indicated by the low frequency of returns of 0-group herring tagged just outside the coast or at the entrances to the fjords, e.g. off Vesterålen in 1959 (Table 6). None of the 0-group herring tagged in 1960 off Bear Island and off eastern Finnmark has been recaptured in inshore areas. To separate the offshore from the inshore population, half of the area with recordings outside the border line drawn in Fig. 13 between Røst and North Cape was classified as offshore and the other half classified as inshore. Herring observed outside the fjords off eastern Finnmark are assumed not to migrate into the fjords and are included in the offshore distribution.

From Table 4 it appears that a relatively small part of the total 0-group population was distributed in the fjords in the autumn of 1959, 1960, 1963, 1964 and 1965 (3–10%). However, in 1961 and 1962 a somewhat higher percentage (15–20%) of the total 0-group population was found inshore. The results indicate that the proportion of 0-group herring entering the fjords is inversely related to the total abundance of the

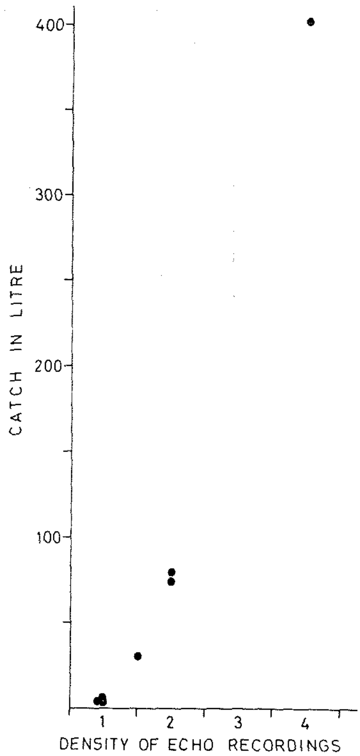

Fig. 27. Relationship between the density of the scattering layer recorded by echo sounder and the catch of the sound scatterers sampled with purse seine. The catches consisted almost entirely of 0-group herring.

0-group stock. In years when the herring are mainly restricted to the coastal belt, a relatively higher percentage of the population is found inshore.

CATCH AND CATCH PER UNIT EFFORT

Catch and effort statistics from the small- and fat-herring fishery can also be used to analyse the variations in year-class strength. The total catch of small- and fat-herring landed during the period 1930–1968 (Fig. 28), shows that considerable fluctuations have occurred. The most important small-herring fishery occurs in the fjords from late autumn to early spring, with the late autumn period being the most important. The period in the early spring coincides with the migration from the fjords. The fat-herring are usually caught at the entrances or outside the fjords, and the fishery starts in early summer and has its peak in the summer or early autumn.

In the Norwegian catch statistics herring weighing ≤ 50 g, corresponding to a total length up to 18–20 cm, are grouped as small-herring

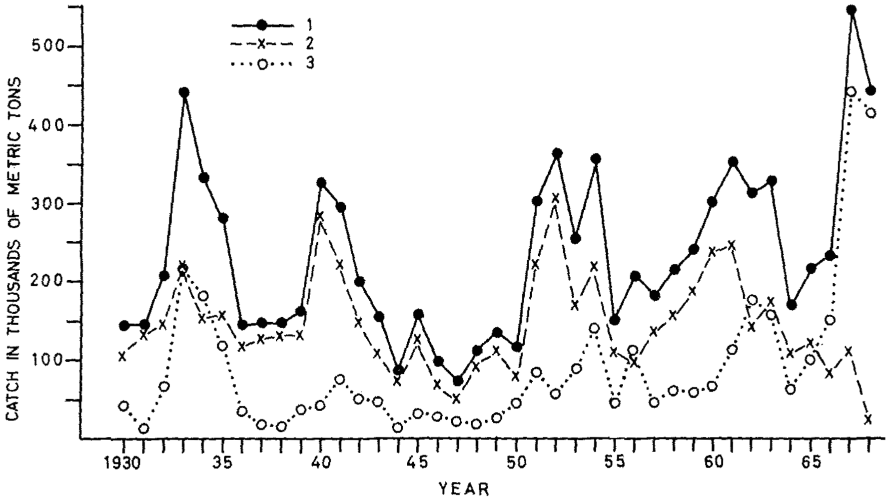

Fig. 28. Norwegian and Soviet catches of young and adolescent herring in 1930–1968, (1) total catch, (2) small-herring and (3) fat-herring.

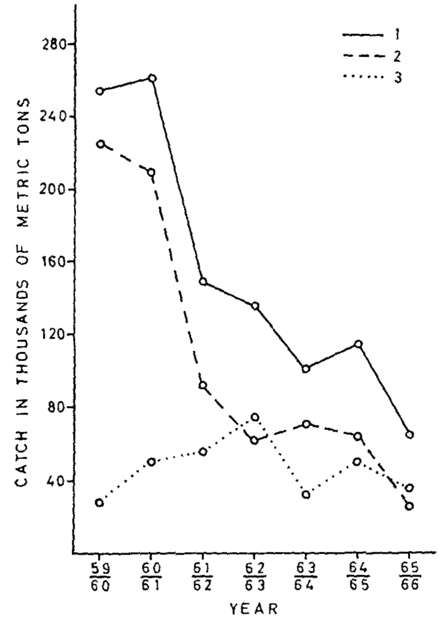

Fig. 29. Catches of small-herring landed from 1959–1960 to 1965–1966, (1) total catch, (2) 0- and I-group and (3) I- and II-group herring. Catches landed in 1959–1960 are due to the 1959 and 1958 year-classes, respectively, in 1960–1961 to the 1960 and 1959 year-classes, etc.

and fish weighing $\geq$51 g are listed as fat-herring. The small-herring subject to fishing in the autumn are mainly 0-group fish. During the following summer when these are in the I-group stage, the fastest growing herring appear in the fat-herring catches. This is especially true in areas 07, 06 and 05. The I-group herring in the northernmost areas 04 and 03, and those with lower growth rates in areas 07, 06 and 05 are still found in the small-herring catches throughout the second year until the summer of the third year of life when they, as II-group herring, gradually appear in the fat-herring catches. With a new 0-group entering the fishery every autumn, three different year-classes are represented in the small-herring catches during a calendar year. However, during the period from 1 September to 31 August the next year the catches consist mostly of two year-classes. The catches were separated on year-class by analysing the samples collected by the inspectors at the various reduction plants along the coast (Fig. 29). During 1959–1966, the 1959 and 1960 year-classes yielded the highest catches followed by the year-classes of 1961, 1963, 1964, 1962 and 1965.

Since the small-herring are mixed with the fat-herring in the catches, it is difficult to collect samples which give a representative age composition of the fat-herring landed. However, small-herring were avoided in the samples by excluding herring weighing ≤ 50 g, corresponding to lengths less than 18–20 cm. Fig. 30 shows the age composition of fat-herring in the different areas. Most of the samples were taken during the summer and autumn. Samples collected in areas 07 and 06 during the first half of the year (1 April to 31 May) were grouped separately, and in these samples I-group fish were excluded. These herring, usually called "forfangstsild", are a mixture of young recruit spawners and fat-herring. During the period 1959–1968 the yield of the fat-herring fishery was highest in 1961–1963, when the 1959 and 1960 year-classes dominated and in 1966–1968 when the year-classes of 1963 and 1964 were dominant, with a maximum yield in 1968. Herring older than five years were only rarely found in the fat-herring catches, except during the "forfangstsild" season.

In Table 5 catches of fat-herring are separated on year-class and area. The 1964 year-class has yielded the highest catch followed by those of 1959, 1963, 1960, 1961 and 1962. An evaluation of the 1965 year-class is omitted because catch data still are incomplete. The ranking of year-classes by catch is different from that found in the small-herring catches and the exploitation rate of the 1963 and 1964 year-classes obviously has increased. A further discussion of this feature will be given in a later section.

Almost all the catches of small- and fat-herring are taken with purse seine, and the fishing fleet which is equipped with echo sounder and sonar, usually moves from one fjord to another searching for herring. Prior to 1964 the purse seine was shot from two dorries, but from 1964 onwards the power block was introduced and the purse seine, which was then shot from the vessel, was gradually made deeper. Accordingly, the

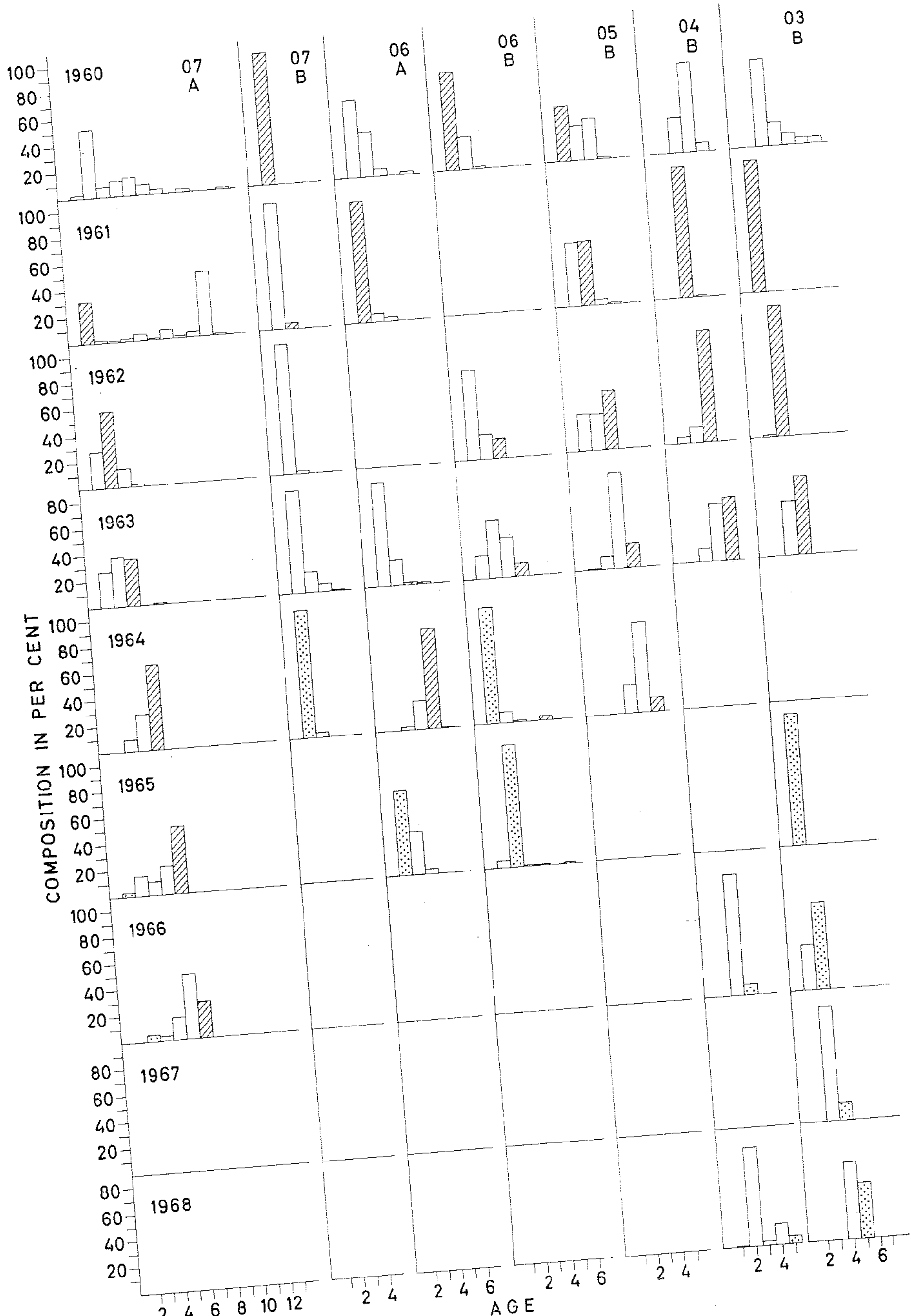

Fig. 30. Age composition (in %) of fat-herring in different areas in 1960–1968, (A) during April–May and (B) during June–December.

Table 5. Yield (in thousands of metric tons) of the 1959–1964 year-classes according to area during the Norwegian fat-herring fishery in 1960–1968.

Year-class	Area 07	06	05	04	03	Total
1959	49.558	35.127	65.583	4.108	119.676	274.052
1960	26.652	18.253	97.039	1.571	7.520	151.035
1961	15.660	29.682	25.571	0.368	—	71.281
1962	9.706	8.323	0.273	—	—	18.302
1963*	8.160	22.793	45.123	2.407	189.361	267.844
1964*		0.448	116.890	18.424	268.213	403.975

* Data still incomplete.

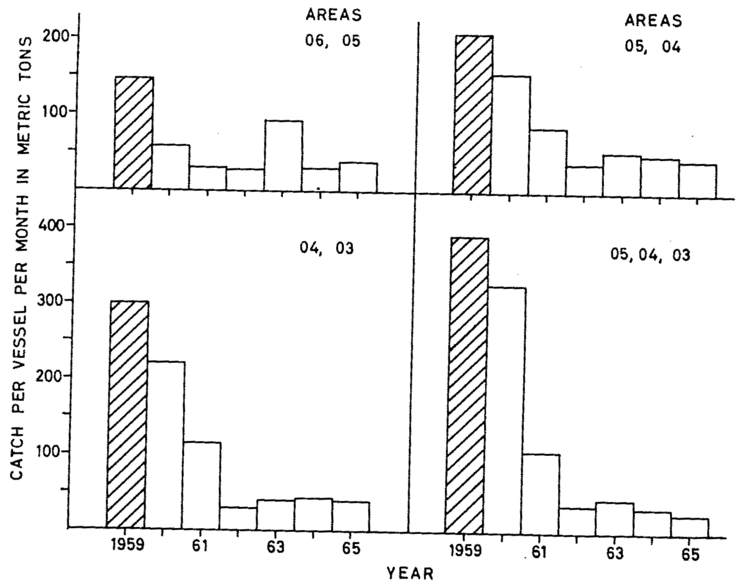

Fig. 31. Average catch of 0-group herring per vessel per month during the autumn fishery (October–December) in 1959–1965.

fleet was more efficient in 1965–1968 than during the previous period when the efficiency was considered to be fairly constant. The more modern sonar equipment introduced during the period 1964–1967 also added to the increase in efficiency of the fleet.

The fat-herring fishery, especially off the Finnmark coast, mainly takes place in the open sea or at the entrances to the large fjords. For this reason and because the availability of fat-herring varies greatly, the abundance estimates for fat-herring are more variable than those for 0-group herring. The abundance estimates for fat-herring, therefore, have been omitted here. One of the chief problems encountered when dealing with effort statistics from purse seine catches concerns the integration of searching time in the unit of fishing effort. Information concerning the time spent on the fishing grounds or number of shots with and without catch is not available. However, the average catch per vessel operating is likely to give a reasonably reliable indication of the abundance of herring in the different districts.

The average catch of 0-group herring per vessel per month during the autumn fishery from October to December in the different areas is illustrated in Fig. 31. The abundance estimates for areas 05, 04 and 03 combined are higher than those for areas 04 and 03, and 05 and 04 in 1959 and 1960. The reason for the average catch per vessel being higher for areas 05, 04 and 03 combined is due to the larger and more efficient vessels operating in all the three areas. Those operating in areas 04 and 03, 05 and 04 or 06 and 05 are smaller vessels, and the abundance indices for these areas are comparable. The catches per vessel were highest in 1959 followed by 1960 and 1961. In 1962 and 1965 the catches per vessel were lowest in most of the areas.

ESTIMATES FROM TAG RETURNS

Abundance estimates from tag returns are mainly based on taggings of 0-group herring in the Ullsfjord region. For tagging experiments at other localities (Table II) the number of recaptures is too low to permit abundance estimates. Only tags recovered in plants which were equipped with tested magnets have been dealt with quantitatively, and experiments giving less than ten recaptures are excluded in Table 6. The frequencies of returns from 0-group taggings in the fjords were relatively low in 1959–1960, 1960–1961, 1961–1962 and 1963–1964, indicating high abundances of the 1959, 1960, 1963 and 1961 year-classes compared with those of 1962 and 1964. In the autumn of 1965 no 0-group herring were tagged.

Herring catches from different fishing localities were sometimes mixed at the reduction plants before the processing started, and therefore the location of some recaptures could not be determined with certainty. In spite of this limitation the present material indicates that almost all returns during the first months after release were derived from the fjord complex where the tagging took place. This feature was clearest for tagging experiments carried out inside the entrances to the fjords and confirms the findings from acoustic surveys that 0-group herring entering the fjords in autumn stay there the following winter.

A summary of the estimates of year-class strengths at the 0-group stage obtained by the three different methods applied is given in Table 7.

Table 6. Recaptures from taggings of 0-group herring (1959–1964 year-classes) three to seven months after release and catches of the same year-classes processed at reduction plants. The catches are from the region of recapture.

Date of tagging		Region of recapture	No. of effectively tagged herring	Effective quantity processed (in tons)	Time from tagging to capture (in months)	No. of recaptures	Percentage recaptures per 100 tons (inverse value in brackets)
1959	2.10	Vesterålen	853	1283	4	10	0.09 (10.94)
	8.10	Hamarfj.–Ullsfj.–Lyngenfj.	1706	12167	5	237	0.11 (8.76)
	19.10	Varangerfj.	512	11370	7	63	0.11 (9.24)
1960	3.10	Hamarfj.–Ullsfj.–Lyngenfj.	1706	30534	6	253	0.05 (20.59)
	21.10	Varangerfj.	853	10812	6	156	0.17 (5.91)
1961	28.9	Hamarfj.–Ullsfj.–Lyngenfj.	1706	4970	3	187	0.22 (4.53)
1962	21.9	Hadselfj.–Vesterålen	1109	45	3	52	10.42 (0.10)
	27.9	Malangen	512	196	3	58	5.78 (0.17)
	28.9	Hamarfj.–Ullsfj.–Lyngenfj.	1024	1737	3	203	1.14 (0.88)
1963	27.9	Hamarfj.–Ullsfj.–Lyngenfj.	1706	2795	4	51	0.11 (9.35)
1964	29.9	Hamarfj.–Ullsfj.–Lyngenfj.	1706	212	3	128	3.54 (0.28)

Table 7. Summary showing the results of the abundance estimates of 0-group herring for the 1959–1965 year-classes.

Year-class	Echo abundance index $\times 10^{-3}$		Catch per vessel (in tons) in areas 05, 04, 03 combined	Mean inverse value of percentage recaptures per 100 tons
	Total	Inshore		
1959	325.8	10.4	391.6	9.65
1960	147.4	7.0	325.9	13.25
1961	37.5	6.0	105.0	4.53
1962	14.8	2.5	35.4	0.38
1963	53.6	5.0	44.8	9.35
1964	75.0	3.6	33.6	0.28
1965	9.1	0.7	25.5	—

The results are only comparable for the inshore part of the 0-group population. The inshore abundance estimates obtained from acoustic surveys and those obtained from catch per vessel show the same ranking of the respective year-classes except for those of 1962 and 1964. However, the discrepancy in the values of the abundance estimates is pronounced for some of the year-classes, especially those of 1962, 1963 and 1964. Because taggings were made in few localities, the abundance estimates obtained from these experiments do not give representative values for year-class strength of the inshore 0-group population.

The estimates of the total 0-group stock obtained from the acoustic surveys indicate that the 1959 year-class was about twice as abundant as the 1960 year-class and this again about twice as abundant as that of 1964. The difference between the 1961 and 1963 year-classes probably was small although the latter year-class was somewhat more abundant. The 1962 and 1965 year-classes definitely were the poorest ones.

MORTALITY

Mortality estimates of herring during the late 0-group and early I-group stages in some Norwegian fjords can be obtained from data on catch per unit of effort and from taggings. The total instantaneous mortality coefficient ($Z = F+M$) for the 1959 and 1960 year-classes was estimated according to the equation of BEVERTON and HOLT (1957)

$$N_t = N_0 e^{-(F+M)t} \tag{1}$$

where N_0 is the number of fish at the time t_0 and N_t the number of fish at the time t. F and M are the instantaneous fishing and natural mortality coefficients, respectively.

The catch per unit of effort is taken to be proportional to N_0 at the time t_0 and N_t at the time t. During the migration into the fjords the herring are found in many small shoals, and the availability usually is lower than in the wintering period. Because of this the catch per vessel was relatively low in October, and November had to be chosen as the commencement of the fishing season in 1959 and December in 1960. By plotting the logarithms of monthly catches per vessel for November to April in 1959–1960 and for December to April in 1960–1961 and calculating the regression lines to the points, the monthly apparent total mortality ($Z = F+X$) could be estimated (Fig. 32) where F is the monthly fishing mortality and X is a combination of natural mortality and the effect of emigration.

The estimates are given in Table 8, and the basic material used for estimating the catch per vessel is given in Table VII. The values for Z is considerably greater than those obtained for adult herring in the late 1950s and in the 1960s (DRAGESUND and JAKOBSSON 1963, ANON. 1969). The monthly instantaneous mortality coefficients are of the same magni-

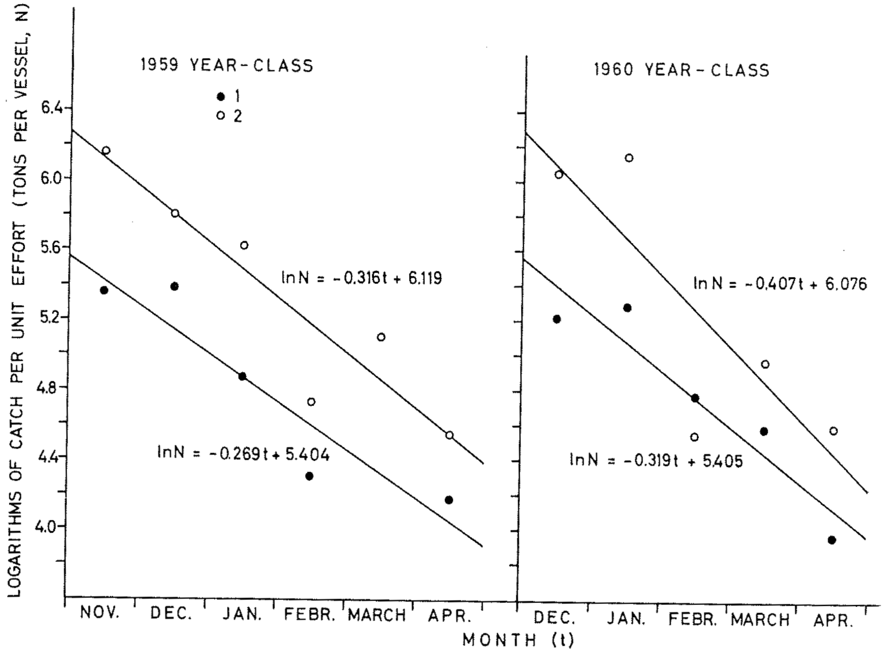

Fig. 32. Calculated regression lines fitted to months and logarithms of catch per vessel, (1) areas 05 and 04, (2) areas 05, 04 and 03.

tude as those of the annual instantaneous mortality coefficients of adult herring.

The exploitation rate (E) defined as

$$E = \frac{F}{F+M} \tag{2}$$

can also be estimated approximately from tag returns by the expression

$$E = \frac{n_r}{N_0 - N_t} = \frac{F}{F+X} \tag{3}$$

where n_r is the estimated number of tagged herring recaptured during the period from t_0 to t, N_0 the number of effectively tagged herring present at the time t_0 and

$$N_t = N_0 e^{-Z(t-t_0)} \tag{4}$$

the number of tagged herring present at the time t. The Z values (F+X) obtained for areas 05, 04 and 03 (Table 8) were used to calculate N_t, and the estimated values for E and Z were used to solve equation (3) for F. The values for N_0, N_t and n_r are listed in Table 9. The estimates

Table 8. Estimates of monthly instantaneous total mortality coefficient (Z) during the late 0-group and early I-group stages covering the period from November to the following April.

Year-class	Area	Z
1959	05 and 04	0.28
	05, 04 and 03	0.32
1960	05 and 04	0.32
	05, 04 and 03	0.41

Table 9. Estimates of number of effectively tagged 0-group herring present (N_0) at the time t_0, number of tagged herring present (N_t) at the time t and number of herring recaptured (n_r) during the period from t_0 to t.

Year-class	Vesterålen			Ullsfjord-Lyngenfjord			Varangerfjord		
	N_0	N_t	n_r	N_0	N_t	n_r	N_0	N_t	n_r
1959	853	237	37	1706	344	382	512	55	84
1960	—	—	—	1706	146	312	853	73	216

Table 10. Estimates of the exploitation rate (E) during the late 0-group and early I-group stages and the monthly instantaneous mortality coefficients F and X, covering the period from November to the following April.

Year-class	Region	E	F	X
1959	Vesterålen	0.060	0.019	0.301
	Hamarfjord–Ullsfjord–Lyngenfjord	0.280	0.090	0.230
	Varangerfjord	0.184	0.059	0.261
1960	Hamarfjord–Ullsfjord–Lyngenfjord	0.200	0.082	0.328
	Varangerfjord	0.277	0.114	0.296

of E, F and X for herring during the late 0-group and early I-group stages from November to April in some of the fjords of northern Norway are given in Table 10.

Another approach for estimating the fishing mortality during the 0- and I-group stages can be obtained from the ratio between catch and stock size of herring wintering in the Ullsfjord region. The stock size was estimated from tag returns by a modification of the Petersen method (Aasen *et al.* 1961, Dragesund and Haraldsvik 1968). The number of tags returned each month during the period from November to April at factories equipped with tested magnets were plotted against the effective quantity processed at the same factories in that month (Fig. 33), and the regression lines were calculated. The stock size was estimated by multi-

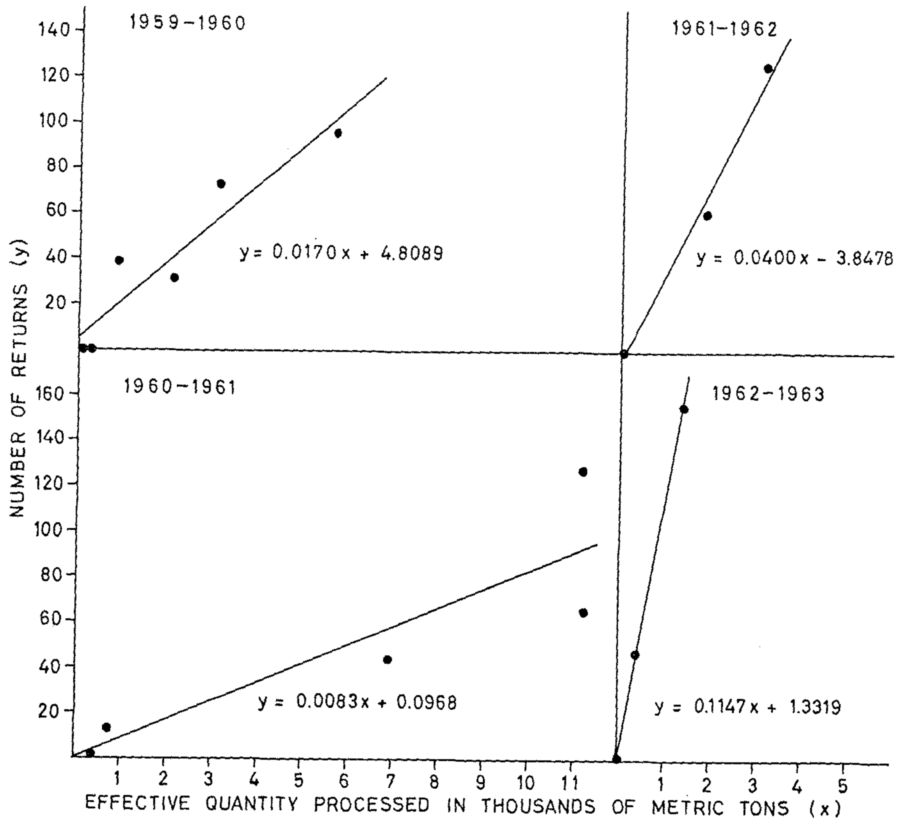

Fig. 33. Calculated regression lines fitted to the monthly catch of 0- and I-group herring processed at factories equipped with magnets and the monthly number of returns.

plying the number of effectively tagged herring present at the beginning of the period by the ratio of the effective quantity processed and the number of returns. This ratio was obtained from Fig. 33.

F was estimated according to the equation of BEVERTON and HOLT (1957)

$$\frac{C}{S} = \frac{F}{Z} (1—e^{-Zt}) \tag{5}$$

where C is the catch of herring in numbers and S the stock size in numbers. The Z values for areas 05, 04 and 03 given in Table 8 for the 1959 and 1960 year-classes were used to solve equation (5) for F. To estimate F for the year-classes of 1961 and 1962 the mean of the Z values was used. The results are listed in Table 11.

Although the values for F listed in Tables 10 and 11 are slightly different, they are considerably higher than those obtained from tagging

Table 11. Catch (C), estimated stock size (S) of 0- and I-group herring and estimated monthly instantaneous mortality coefficient (F) during the late 0-group and early I-group stages in the Ullsfjord region for the 1959–1962 year-classes.

Year-class	C		S		F
	Tons	No.	Tons	No.	
1959	19500	279×10^7	91700	1310×10^7	0.085
1960	37600	537×10^7	204700	2924×10^7	0.082
1961	6400	91×10^7	41300	590×10^7	0.085
1962	2900	41×10^7	8800	126×10^7	0.181

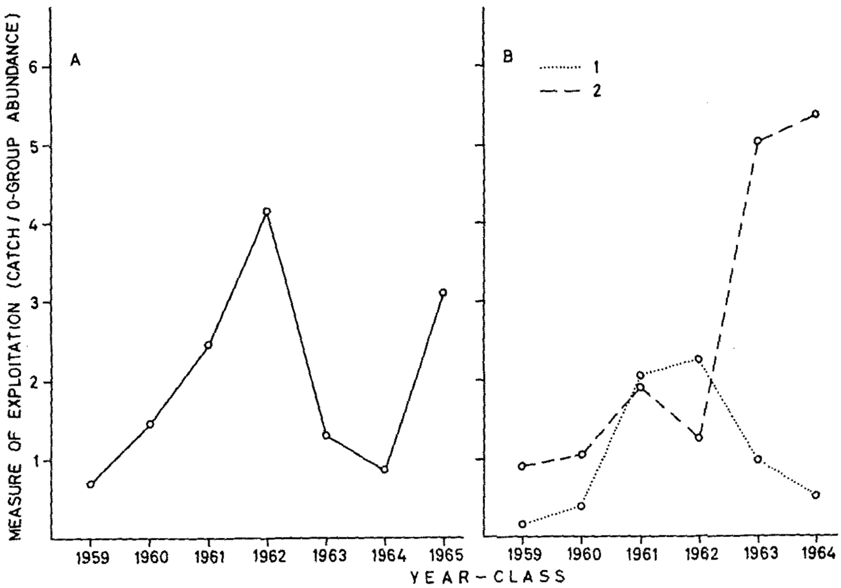

Fig. 34. Measure of exploitation, (A) during the late 0-group and early I-group stages indicated by the ratio of catch in tons/0-group echo abundance for the year-classes 1959–1965 and (B) at later stages for the year-classes 1959–1964, (1) as catch in tons of I- and II-group herring/total 0-group echo abundance and (2) as catch of fat-herring in tons/total 0-group echo abundance.

experiments during the adult stage (Dragesund and Jakobsson 1963, Anon. 1969). The monthly instantaneous fishing mortality coefficients during the late 0-group and early I-group stages are somewhat lower than those of the annual instantaneous mortality coefficients of the adult herring. However, the natural mortality was high for 0- and I-group herring, and accordingly the exploitation rate was lower than for the adult herring in the mid-1960s (Anon. 1969).

Another measure of the exploitation is obtained by taking the ratio between the total catch at different stages of the year-classes 1959–1965 and the total echo abundance index (Fig. 34). It is clearly demonstrated that poor year-classes were more heavily exploited than the rich ones during the late 0-group and early I-group stages (Fig. 34A). Also during the late I-group and early II-group stages the poor year-classes were more heavily fished than the richer ones (Fig. 34B).

The yield of the fat-herring fishery increased considerably from 1965 to 1968. This resulted in an increase of the exploitation of the 1963 and 1964 year-classes by five to six times compared with that of the 1959 and 1960 year-classes. The high exploitation of the 1963 and 1964 year-classes, which appeared to be fairly abundant during the 0-group stage, has most likely resulted in a considerable reduction of these year-classes before they entered the adult stock.

DISCUSSION

DISTRIBUTION OF 0-GROUP HERRING IN RELATION TO SPAWNING GROUNDS OF THE PARENT STOCK

During 1959–1965 the main spawning centre was located off Møre, i.e. on the shelf between Stad and Grip (DRAGESUND 1970). In 1959–1961 the majority of the ripe herring tended to concentrate farther south than in 1962–1965, when the centre of the spawning was located between Ona and Grip. In the southernmost region (area 08) spawning was negligible except in 1959, when spawning was observed as far south as Bokn. The second important spawning district was located off Halten–Sklinna. Within this region the location of spawning did not change. Except in 1960 (YUDANOV 1962) mass spawning at Lofoten was not recorded during 1959–1962, whereas herring spawned regularly in that area in 1963–1965. During 1959–1965 Norwegian herring also spawned on the Faroe plateau (YUDANOV 1962, 1964, 1966).

The origin of 0-group herring recorded off northern Norway is difficult to determine. The drift pattern of the larvae from the Faroe spawning grounds is not known, but the international 0-group fish surveys carried out in the Barents Sea and in the northeastern part of the Norwegian Sea in 1966 and 1967 (ANON. 1966, 1967) suggested that the majority of the 0-group fish recorded in the Barents Sea were derived from spawning grounds along the Norwegian coast. Also, the larval survey in 1959 (WIBORG 1959) showed that herring larvae were scarce off the continental shelf in the eastern part of the Norwegian Sea. It is concluded, therefore, that the major part of the herring observed along the coast of northern Norway and in the Barents Sea were hatched off the Norwegian coast between Stad and Grip, off Halten–Sklinna and in 1963–1965 also at the Lofoten spawning grounds.

It also may be concluded that larvae hatched off Møre–Trøndelag drifted far into the Barents Sea. This was indicated by the 0-group distribution in 1959 when no major spawning took place in the Lofoten region. Moreover, in 1959–1961 the 0-group herring were more abundant off Troms and Finnmark (areas 04 and 03) than farther south in areas 06 and 05 (Fig. 31), confirming the hypothesis of a long northward transport of larvae from the spawning grounds off Møre (DRAGESUND 1970). This indicates that the northward extension of concentrations of 0-group herring does not depend only on the location of spawning, but also on the conditions for transport of larvae from the spawning grounds.

GROWTH AND MIGRATION IN RELATION TO MECHANISM OF RECRUITMENT

The 0-group herring within areas 05, 04 and 03 had fairly uniform lengths. This was to be expected since larvae hatched on the spawning grounds off Møre–Trøndelag are transported northwards in the same water masses and live under rather similar environmental conditions during their first five–six months of life. However, larvae which accumulate at the entrances to the fjords in areas 07 and 06 (off Møre–Trøndelag and the southern part of Nordland) and later enter the fjords in these areas, will live in warmer water and will have a faster growth than those transported farther north.

Herring located off eastern Finnmark were found to have a markedly slower growth during the adolescent phase than those found farther west and south along the coast (Figs. 22 and 23). Herring of the 1959 year-class which stayed in the southern part of the coastal waters of northern Norway (areas 06 and 05) during the 0-group stage, migrated northwards during the second and third years of life, i.e. in 1960 and 1961, and joined the fastest growing herring farther north in an accumulation area off Torsvåg (Figs. 19, 23A and B). These herring started their westward migration into the Norwegian Sea some time during late 1961 or early 1962 and showed up on the feeding grounds off Iceland as early as in the summer of 1962. Herring with slightly smaller annual length increments (1959 year-class) remained in the accumulation area off Torsvåg during the summer and autumn of 1962.

Off Finnmark, slowly growing herring of the 1959 year-class reached an age of three–four years before they disappeared from the fat-herring catches and migrated westward to the accumulation area off Torsvåg from where they later joined the spawning stock. A similar migration pattern was found for the 1960 and 1961 year-classes. Thus, the higher growth rate of herring in the southern part of the coast of northern Norway led to an earlier migration to and from the accumulation area off Torsvåg than for herring spending their nursery period farther north and east in coastal and offshore waters off northern Norway. Accordingly, fat-herring in areas 06 and 05 were younger than those off Finnmark (area 03), and in the catches south of Vesterålen fat-herring older than three years were scarce, except during the "forfangstsild" season in April–May.

The 1963 and 1964 year-classes showed a different migration pattern compared with those of 1959–1961. During the entire fat-herring stage, i.e. up to an age of four–five years, the 1963 and 1964 year-classes were mainly recorded off eastern Finnmark. Migrations over short distances were observed back and forth between the eastern part of the Finnmark coast and the Murman coast, and in contrast to the 1959–1961 year-classes those of 1963 and 1964 did not concentrate in any detectable shoals off western Finnmark or off Troms during the second to fourth years of life. Their migration from the nursery areas off eastern Finnmark was at least one year delayed compared with the migrations of the 1959–1961 year-classes.

Variations in the occurrence of fat-herring in coastal waters off northern Norway have been discussed by LEA (1929), and variations off the Murman coast by GLEBOV (1938). According to LEA the large fat-herring (oceanic herring) occur in offshore waters where the herring adopt an oceanic mode of life. Lea concluded that large yields of fat-herring in the fjords were caused by an immigration of oceanic herring. Such immigrations were sporadic and might occur when the oceanic herring were driven towards the coast by unknown causes. GLEBOV distinguished between two types of immigrations to the fjords, one in May–July consisting mainly of I- and II-group herring, and the other consisting of mainly III- and IV-group herring approaching the coast during the autumn from August onwards. GLEBOV also found that the immigration was irregular and not always associated with strong year-classes, but was related to hydrographic conditions in coastal and offshore waters. The migration into the fjords was most frequent in years with pronounced horizontal temperature gradients. In the summer the immigration of I- and II-group herring took place when the temperature gradient increased from the open sea into the fjords, whereas in the autumn an immigration of III- and IV-group herring occurred when the temperature gradient decreased from the open sea and into the fjords.

The present investigations showed that the migration of 0-group herring into the fjords was regular and occurred almost at the same time every autumn. It cannot be stated whether the mechanism of the migration from the open sea into the fjords is a response to environmental conditions followed by an orientated active migration or if it is a passive migration resulting from drift (HARDEN JONES 1968). In Porsangerfjord the herring moved from water masses of higher to lower temperature, whereas in Ullsfjord this feature was not so clear. No distinct immigration of fat-herring (oceanic herring) to the fjords was recorded. In the years when great concentrations accumulated off northern Norway, mainly in 1961–1963, the fat-herring did not enter the fjords on their migrations from the nursery areas into the Norwegian Sea. With the material at hand no further interpretation can be given of the sporadic immigrations of fat-herring to the fjords of northern Norway. However, in years when the fat-herring stock is large, numerous shoals often occur close to the coast, and it is likely that such shoals may move into the fjords.

When studying the growth of herring, LEA (1929) observed that winter rings of scales from young and adolescent herring caught in northern Norway were more distinct (N-type) than winter rings of herring scales from the coastal area farther south (S-type). RUNNSTRØM (1936) has given further information on the geographical distribution of the two types. On the Finnmark coast, 100% of the young herring had the northern scale type. In the intermediate region, between Finnmark and the coast of Møre, the N- and S-types were mixed. On the southwest coast about 90% of the young herring had rings of the S-type. From this evidence RUNNSTRØM concluded that the northern type of winter rings is formed in coastal waters off northern Norway and that the southern type is formed at the southern part of the west coast, thus supporting LEA's theory. According to LEA more diffuse winter rings (oceanic rings) are formed during the adolescent period of transition from immature to mature herring when the herring have moved into the central part of the Norwegian Sea. However, DEVOLD (1963) suggested that the distinct winter rings (N-type) are formed when the young herring live under arctic and subarctic conditions in the Barents Sea. The more diffuse oceanic rings are formed after the westward migration into areas with boreal conditions.

This hypothesis seems to be in agreement with the distribution of 0-group herring of the 1959 and 1961 year-classes and the characteristics of their winter rings. In 1961 relatively few 0-group herring were found in the northern and eastern parts of the Barents Sea, and eventually only a small percentage of the year-class was found to have N-type winter rings. In 1959 the major part of the 0-group stock was distributed in the Barents Sea and on the shelf between Bear Island and West-Spitsbergen. In accordance with this, high percentage of distinct N-type winter rings were found for the 1959 year-class.

According to ØSTVEDT (1958) the relative abundance of N- and S-types in the spawning shoals seemed to be related to year-class strength, high frequencies of N-type herring being correlated with rich year-classes.

The major part of the 1959 year-class had N-type winter rings, whereas the 1961 year-class showed a lower percentage of this growth type both in the adolescent and adult shoals (Table 2). The correlation between rich year-classes and relatively high frequencies of N-type herring may therefore be explained as a result of strong northward transport and high abundance during the larval and postlarval stages.

OTTESTAD (1934) argued that only part of the fat-herring occurring off northern Norway might later migrate to the spawning grounds off southern Norway (area 08) and the winter herring district off Møre. The majority of fat-herring after becoming mature probably spawned farther north off Lofoten and Vesterålen. According to LEA (1929) the duration of the oceanic stage varies with the individual history of the herring. Some individuals mature after one year, others after two or three years. Each year the maturing herring, which will spawn the following spring, split off from the stock of oceanic herring. In the years 1962–1964 adolescent herring, predominately of the 1959 and 1960 year-classes, were located off Torsvåg during the autumn. Some of these herring matured and migrated to the Lofoten spawning grounds for the first time in 1963 (DEVOLD 1968), whereas others migrated westwards to the feeding areas off Iceland (JAKOBSSON 1968).

Herring approaching the Lofoten region for spawning in 1963–1966 stayed off northern Norway and in the Barents Sea during the young and adolescent phases. This component, which was separated from the main stock of adult herring both during spawning and on the wintering grounds, did not appear on the Lofoten spawning grounds in the winter of 1967 and 1968 (DEVOLD 1968). In the summer and the autumn of 1966 the two groups had mixed and formed one stock with a spawning migration towards the Møre coast. After this admixture adolescent herring in waters off Troms and Finnmark and in the Barents Sea therefore will appear on the spawning grounds off Møre somewhat later than those from the nursery areas farther south.

SELIVERSTOVA (1968) tried to estimate the abundance of the 1950 year-class which stayed in the Barents Sea during the adolescent phase and to determine the recruitment from the Barents Sea to the adult stock of the 1950 year-class in the Norwegian Sea. A relatively small percentage (1–3%) was found in the adult stock when the year-class was four to five years old, but the percentage increased to about 13–14% at an age of seven and eight years.

No other specific recruitment pattern or mechanism can be discovered from the present data, but it can be concluded that variations in growth may influence the migration pattern and the duration of the adolescent phase. Growth, on the other hand, is determined by the distribution during the 0-group stage and the 0-group distribution consequently plays an important role in recruitment mechanism. The year by year northward displacement of the main spawning centre, with a corresponding northward displacement of the 0-group population may have been the primary cause for the extended duration of the adolescent phase of the herring of the 1963 and 1964 year-classes.

ABUNDANCE OF 0-GROUP HERRING COMPARED WITH YEAR-CLASS STRENGTH IN THE ADOLESCENT AND ADULT STOCKS

The abundance estimates of 0-group herring show great variations from one year to another. The 1959 and 1960 year-classes were particularly numerous during the 0-group stage. These year-classes also were abundant throughout the adolescent phase and showed up as rich year-classes in the adult stock both on the feeding and spawning grounds (DEVOLD 1968, DRAGESUND 1970). Similarly, year-classes with low abundance during the 0-group stage, such as that of 1962, appeared to be weak during all the subsequent stages. The 1961, 1963 and 1964 year-classes were considerably more abundant as 0-group herring than those of 1962 and 1965, though clearly less abundant than those of 1959 and 1960.

In Fig. 35 the echo abundance of 0-group herring for the 1959–1962 year-classes is plotted against year-class strength in the adult stock. The values for adult year-class strength (at six years of age) are those obtained from tagging experiments and combined acoustic surveys and underwater photography (ANON. 1969). A very close correlation is found between the two independent estimates of year-class strength, and it is concluded, therefore, that the abundance indices of 0-group herring obtained from the acoustic surveys give a fairly good estimate of year-class strength.

An indication of the relative strengths of the 1959–1965 year-classes in the adolescent and adult stocks can also be obtained from their frequencies in samples collected in different fisheries. These frequencies are compared with estimates of 0-group abundances in Table 12. Samples collected during the different seasons in 1963–1968 clearly demonstrated that the 1959 year-class predominated over the year-class of 1960. In 1964 and 1965 none of the 1962 year-class and only a relatively small part of the 1960 and 1961 year-classes had reached maturity, and consequently the relative strength of the 1959 year-class as indicated by the age distribution was overestimated compared with those of 1960 and 1961. In 1966–1968 the strengths of the 1960 and 1961 year-classes probably were overestimated in relation to the 1959 year-class as mortality had reduced the latter to a greater extent. The age compositions in Table 12 indicate that the relative strength of the 1959 year-class during the adolescent and adult phases was about twice that of 1960 and at least six times that

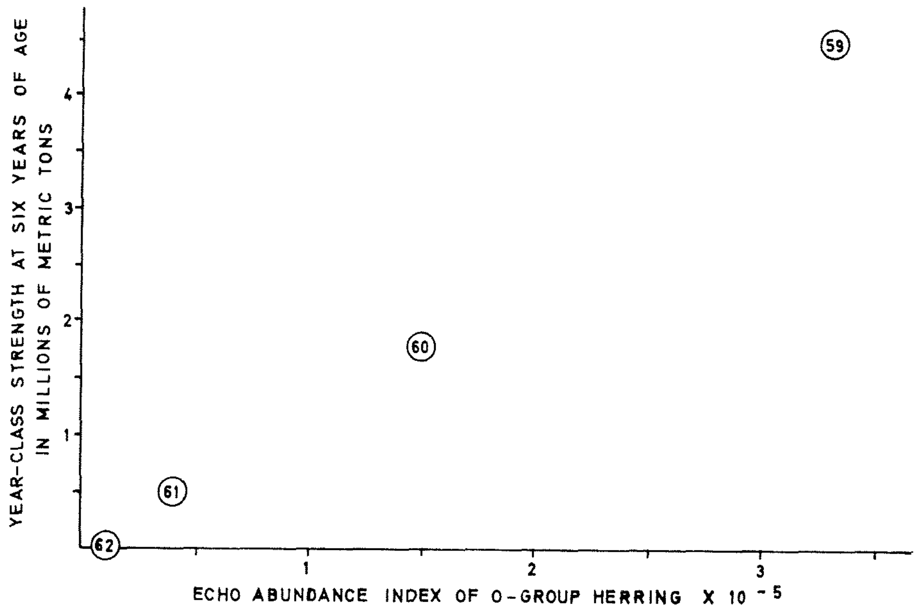

Fig. 35. Relationship between year-class strength at the 0-group stage and at six years of the 1959–1962 year-classes.

of 1961. This conclusion agrees fairly well with the estimates of 0-group abundance obtained from the acoustic surveys (Table 12).

In 1965–1968 none of the 1959–1962 year-classes was found in the fat-herring catches off Finnmark, and it is concluded, therefore, that the majority of these year-classes had migrated from the Barents Sea and the coastal areas off northern Norway. In these years the 1963 and 1964 year-classes dominated in catches off Finnmark (Table 12). Up to 1968 the 1963 and 1964 year-classes had not joined the stock on the spawning grounds in significant numbers. However, in the fat-herring catches (1966–1968) they occurred in about the same ratio as during the 0-group stage. Due to the long adolescent phase the abundance of these herring will be considerably reduced when they reach the adult stage. In addition to the high exploitation of the 1963 and 1964 year-classes, this probably is the primary cause for the absence of these year-classes in the spawning stock in 1968.

EFFECT OF THE NORWEGIAN SMALL- AND FAT-HERRING FISHERIES ON RECRUITMENT TO THE ADULT STOCK

The stock size of adult Norwegian herring increased markedly from 1963 to 1965, primarily because of recruits of the rich year-classes of 1959 and 1960. From 1966 to 1968 a rapid decrease in stock size took place

Table 12. Echo abundance estimates of 0-group herring and age composition of adolescent and adult herring of the 1959–1965 year-classes in different regions in 1963–1968.

Year	Month	Region	Year-class 1959	1960	1961	1962	1963	1964	1965	Others
			Total 0-group echo abundance $\times 10^{-3}$							
1959–1965	Sept.–Oct.	Off northern Norway	325.8	147.4	37.5	14.8	53.6	75.0	9.1	—
			Age composition in %							
1963	Febr.	Ingøy Trench	67.3	28.6	4.1	—				—
	March–April	Off Lofoten	90.9	8.6	—	—				0.5
	June–July	Off eastern Finnmark	7.5	81.3	11.2	—				—
	July–Aug.	Off Iceland	22.9	2.3	0.3	—				74.5
	Oct.–Nov.	Off Torsvåg	43.0	42.1	14.6	—				0.3
1964	Febr.	Off Møre	51.5	4.0	—	—	—			44.5
		Off Lofoten	88.4	10.1	0.6	—	—			0.9
	July–Aug.	Off Iceland	46.8	10.1	4.0	0.1	—			39.0
	Aug.–Sept.	Area 37	70.6	21.2	7.9	—	—			0.3
1965	Febr.–March	Off Møre	62.7	10.7	3.2	—	—	—		23.4
		Off Lofoten	74.1	19.6	5.8	—	—	—		0.5
	July–Aug.	Off Iceland	42.3	12.7	5.8	0.4	1.5	—		37.3
	Aug.	Off Finnmark	—	—	—	—	64.4	35.6		—
1966	Febr.–March	Off Møre	53.4	27.7	10.3	0.1	—	—	—	8.5
		Off Lofoten	51.6	39.1	8.0	0.3	—	—	—	1.0
	July–Aug.	Off Iceland	49.8	18.7	7.9	0.8	2.7	—	—	20.1
	Aug.	Off Finnmark	—	—	—	—	29.6	52.5	17.9	--
1967	Febr.–March	Off Møre	48.8	32.1	13.4	0.4	0.5	—	—	4.8
	June–Aug.	Off Finnmark	—	—	—	—	33.9	66.1	—	—
	July–Aug.	Off Iceland	50.3	31.8	11.6	1.1	1.2	0.1	—	3.9
1968	Febr.–March	Off Møre	46.9	34.2	13.8	1.7	0.7	—	—	2.7
	April–May	Off Finnmark	—	—	—	—	41.9	58.1	—	—
		Off Iceland	47.2	31.4	13.0	2.1	2.4	0.2	0.1	3.6

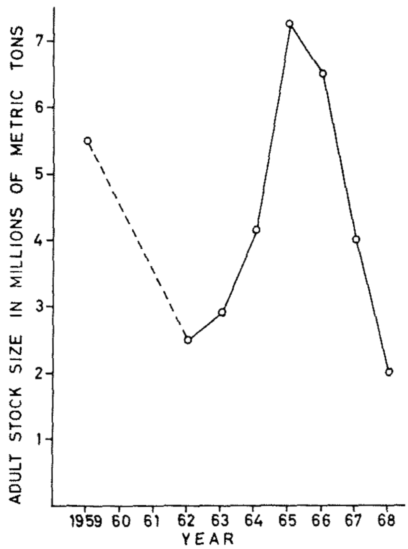

Fig. 36. Stock size of adult Norwegian herring in 1959–1968 (ANON. 1969).

(Fig. 36). During this period the stock should have been recruited from the 1962–1964 year-classes. Although the exploitation during the late 0-group and early I-group stages was nearly the same for these year-classes as for those of 1959–1961 (Fig. 34), they did not show up in significant numbers in the adult stock. The ratios of the yield of the separate year-classes of 1959–1965 in the small-herring fisheries and the echo abundance of 0-group herring (inshore) show that the exploitation of 0- and I-group herring in the fjords generally has fluctuated in accordance with the abundance of herring (Fig. 37). It is concluded, therefore, that the variations in recruitment to the adult stock during the 1960s cannot be attributed to the fishery on 0- and I-group herring.

FEDOROV, TRUSKANOV and YUDANOV (1963) pointed out that for adults the ratio between the strengths of weak and strong year-classes on the basis of catches was 1/8–1/14, while the ratio of the same year-classes in the small-herring catches was only 1/2–1/3. They take this to support their claim that the fishery on small-herring was an important factor determining recruitment during the late 1950s and early 1960s. MARTI (1959), dealing with year-classes prior to those of 1959–1965, held the opinion that year-classes which were heavily fished as young, gave relatively smaller catches as adults than those which were lightly fished prior to recuitment to the adult stock.

Fig. 38 shows the ratios between year-class strength of the 1959–1963 year-classes at the 0-group stage and at six years. Adult year-class strength for that of 1963 is based on a spawning stock size in 1969 of 1.3 million tons. This stock size was estimated from data in the report of the Atlanto-

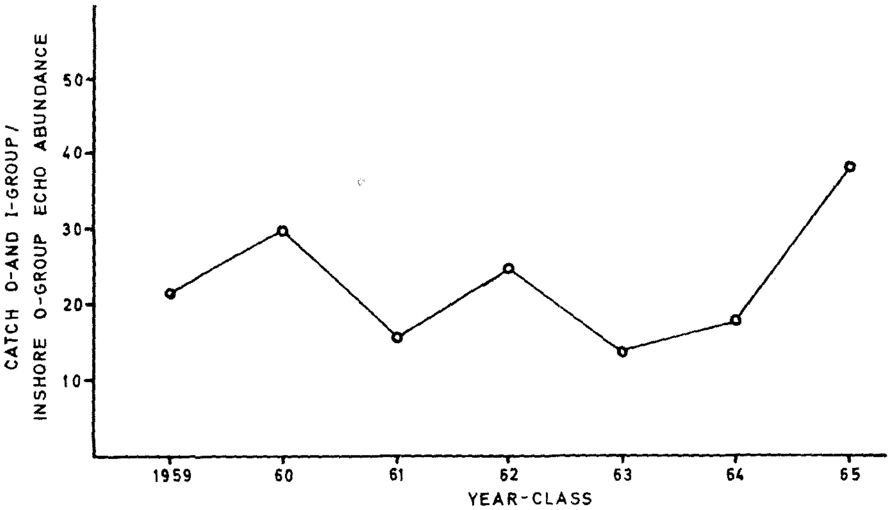

Fig. 37. Ratio between catch (in tons) of 0- and I-group herring in Norwegian fjords and inshore echo abundance of 0-group herring of the 1959–1965 year-classes.

Scandian Herring Working Group (ANON. 1969) applying a total annual mortality coefficient of Z = 0.44. For the 1964 and 1965 year-classes no adult abundance indices can be given.

There is no marked difference in the ratios between year-class strengths in the 0-group and the adult stocks of the 1959–1961 year-classes. However, the ratios of the 1962 and especially the 1963 year-classes were relatively higher. This indicates that these year-classes have been more reduced in numbers during the young and adolescent phases than the 1959–1961 year-classes. The exploitation of the 1962 year-class was higher during the 0- and I-group stages than that of 1963 (Fig. 34). The same was the case for the 1961 year-class compared with that of 1963, but the effect of this could not be measured in the adult stock. It is difficult, therefore, to verify whether the relative abundance of poor year-classes decreased markedly compared with the rich ones because of exploitation during the late 0-group and early I-group stages in the Norwegian fjords. However, the high natural mortality rate during these stages and the relatively low percentage of the 0-group stock present in the fjords suggest that the small-herring fishery was not a determining factor for the total mortality of year-classes up to 1965 before they were recruited into the adult stock.

The exploitation of the 1963 and 1964 year-classes during the fat-herring stage was five to six times higher than for the 1959 and 1960 year-classes, and this is assumed to have reduced the number of recruits of the 1963–1964 year-classes markedly. Since the fat-herring are exploited in

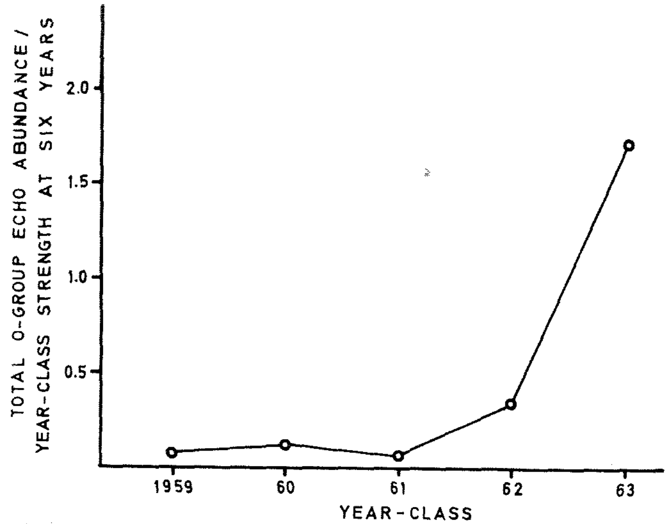

Fig. 38. Ratio between total 0-group echo abundance and year-class strength at six years (in tons) of the 1959–1963 year-classes.

offshore waters and natural mortality is most likely considerably lower than for 0- and I-group herring, the fat-herring fishery may be expected to have a relatively greater effect on recruitment to the adult stock than the small-herring fishery on 0- and I-group herring in the Norwegian fjords. No exact estimate can be made of the impact of the Norwegian small- and fat-herring fisheries on subsequent recruitment to the adult stock for the year-classes of 1959–1965. However, tentative estimates have been made for the strong year-class of 1959 and the weaker year-class of 1963 to study the possible reduction of year-class strength at six years caused by the fishery on young and adolescent herring using alternative values of natural mortalities.

The catches of 0- to III-group herring by month and district are listed in Tables VIII and IX. The catches were converted to numbers and reduced according to the equation

$$N_t = N_0 e^{-Mt} \qquad (6)$$

where N_0 is the number of herring at the time t_0 and N_t at the time t. M is the instantaneous natural mortality coefficient.

Little is known about natural mortality of young and adolescent herring except for the late 0- and early I-group stages (Table 10). Because data on loss of tags are uncertain and the emigration of herring may have affected the estimates, fishing mortality is most likely underestimated. Consequently, the natural mortality may have been overestimated, and therefore the lowest monthly apparent natural mortality ($X = 0.23$) was used for the wintering period (October to April) of 0- and I-group herring in the fjords. This value corresponds to an annual M_1 of 2.76 (Table 13).

It may be assumed that natural mortality is considerably reduced after the second growth season when most of the herring have nearly doubled their lengths (Table VI). Swimming speeds increase with the lengths. BLAXTER and DICKSON (1959) found that captive herring ranging from 1–25 cm swam at speeds (for distances at least ten times their body length) of 3–175 cm/sec. Herring 20–25 cm long could swim at nearly maximum speed for 1100 lengths. It is likely, therefore, that the predator effect will decrease with length and that the natural mortality is inversely related to length. When the herring have moved from the coast and the central parts of the Barents Sea, they have relatively few predators, and in the late adolescent phase the annual natural mortality may be of the same magnitude as in the adult phase, i.e. $M = 0.16$ (ANON. 1965).

Tentatively, the monthly instantaneous natural mortality coefficient during the late I- and early II-group stages has been graded down to one fourth, one half and three quarters of that in the late 0- and early I-group stages, i.e. to 0.0575, 0.115 and 0.173, respectively, corresponding to annual instantaneous mortality coefficients (M_2) of 0.69, 1.38 and 2.07 (Table 13). These three alternative M_2 values were used to calculate the reduction from May in the I-group stage to April in the II-group stage. For the period from May in the II-group stage to 1 January in the VI-group stage the annual instantaneous mortality coefficients (M_3, M_4, M_5, M_6) are assumed to be equal, and two different values (0.16 and 0.24) were used. The estimated number of herring at the VI-group stage (by 1 January) was converted to tons by applying average weights of 217 and 232 g for herring from nursery areas in Troms–Finnmark and Møre–Trøndelag–Nordland, respectively (W_1, Table 13).

In order to evaluate the loss due to fishing on 0- to III-group herring, catches at subsequent stages (up to age six by 1 January) were estimated. The catches in numbers for the 1959 and 1963 year-classes in the adult fisheries are taken from the report of the Atlanto-Scandian Herring Working Group (ANON. 1969). The yield from the pre-recruit fisheries (fat-herring and "forfangstsild") in Norwegian coastal waters after age of three years (by April) are given in Tables X and XI. The total catches were reduced according to the alternative M_3, M_4, M_5, M_6 values listed in Table 13 and converted to tons (W_2). The loss due to catches of young and adolescent herring can be found from the expression

$$\frac{W_1}{W_1 + W_2 + S_6} 100 \qquad (7)$$

Table 13. Estimates of percentage loss to year-class strength at six years due to the catches of young and adolescent herring of the 1959 and 1963 year-classes. Catches and year-class strengths are given in thousands of metric tons.

Year-class	Alternative values of annual natural mortality M_1	M_2	$M_3 \ldots M_6$	Loss due to catches of 0- to III-group W_1	III- to V-group W_2	Year-class strength at six years S_6	Percentage loss $\frac{W_1 \cdot 100}{W_1+W_2+S_6}$	Loss due to catches of 0- to I-group w_1	Percentage loss $\frac{w_1 \cdot 100}{W_1+W_2+S_6}$	Loss due to catches of I- to II-group w_2	Percentage loss $\frac{w_2 \cdot 100}{W_1+W_2+S_6}$	Loss due to catches of II- to III-group w_3	Percentage loss $\frac{w_3 \cdot 100}{W_1+W_2+S_6}$
1959	2.76	0.69	0.16	1345	809	4501	20.2	682	10.2	402	6.0	261	3.9
	2.76	1.38	0.16	873	809	4501	14.1	342	5.5	270	4.4	261	4.2
	2.76	2.07	0.16	622	809	4501	10.5	172	2.9	189	3.2	261	4.4
	2.76	0.69	0.24	1006	728	4501	16.1	508	8.1	300	4.8	198	3.2
	2.76	1.38	0.24	654	728	4501	11.1	255	4.3	201	3.4	198	3.4
	2.76	2.07	0.24	467	728	4501	8.2	128	2.2	141	2.5	198	3.5
1963	2.76	0.69	0.16	529	537	31	48.2	111	10.1	101	9.2	317	28.9
	2.76	1.38	0.16	442	537	31	43.8	55	5.4	70	6.9	317	31.4
	2.76	2.07	0.16	394	537	31	41.0	27	2.8	50	5.2	317	33.0
	2.76	0.69	0.24	397	473	31	44.1	82	9.1	75	8.3	240	26.6
	2.76	1.38	0.24	333	473	31	39.8	41	4.9	52	6.2	240	28.7
	2.76	2.07	0.24	298	473	31	37.2	21	2.6	37	4.6	240	29.9

where S_6 is the estimated size in tons of the year-class at six years assuming full recruitment at this age.

The estimates show that the catches of 0- to III-group herring may have reduced the 1959 year-class at six years by 8.2–20.2% and the 1963 year-class by 37.2–48.2%. This again shows that the exploitation of the 1963 year-class during the young and adolescent phases was considerably higher than for the 1959 year-class, and taking into account the subsequent catches (up to age six) nearly all the herring of the 1963 year-class were caught before recruitment into the adult stock.

The effect of fishing on the different age groups can be analysed by splitting the loss (W_1) on 0- and I-group (w_1), I- and II-group (w_2) and II- and III-group (w_3) herring (Table 13). The loss due to catches of 0- and I-group herring may have reduced the 1959 and 1963 year-classes by 2.2–10.2%. Taking into account that the fjord population of the 1959 year-class was only about 3% of the 0-group population and about 10% of the 1963 year-class, it may be assumed that the higher estimates in Table 13 represent an overestimate of the loss due to fishing on 0- and I-group herring.

Further calculations have been made to estimate the yields which might have been obtained from the loss due to the catches of 0- to III-group herring if exploitation had started by 1 January at six years of age and continued throughout the lifespan up to an age of eighteen years. The number of fish by 1 January at six years of age is denoted by N_6. When estimating N_6 the two highest and lowest values of M_2 were excluded. The number by 1 January the following year (N_7) can be estimated from the expression

$$N_7 = N_6 e^{-Z} \tag{8}$$

where $Z = (F + M)$ is the total annual instantaneous mortality coefficient.

The catch in numbers from age six to seven is given by

$$C_6 = \frac{F}{F+M}(N_6 - N_7) = \frac{F}{F+M} N_6 (1 - e^{-(F+M)}) \tag{9}$$

and from age seven to eight by

$$C_7 = \frac{F}{F+M} N_7 (1 - e^{-(F+M)})$$

etc. to

$$C_{18} = \frac{F}{F+M} N_{18} (1 - e^{-(F+M)})$$

It has been assumed that

$$E = \frac{F}{F+M} \text{ and } Z = (F+M)$$

do not change for age groups from six to eighteen years. Average values of exploitation rate ($E = 0.64$) and total annual instantaneous mortality coefficient ($Z = 0.44$) for the 1959–1961 year-classes, which were obtained from the report of the Atlanto-Scandian Herring Working Group (ANON. 1969), have therefore been used in the estimates (Table XII). The annual catches in numbers have been converted to tons and compared with the actual catches of 0- to III-group herring (Table 14). The estimates show that about the same yield in weight would have been obtained already at the end of the third year of exploitation (starting the fishery at six years of age), and the total yield over the life-span (from six to eighteen years) would have been considerably higher.

The tentative estimates are based on too few exact observations on natural mortality during the young and adolescent phases, and unknown factors may change the results completely. Nevertheless, they indicate that the fishery for young and adolescent herring may effect the subsequent recruitment to the adult stock considerably. The high exploitation of the 1963 year-class during the fat-herring stage thus probably resulted in a marked reduction of this year-class before it entered the adult stock.

Table 14. Catches of 0- to III-group herring of the 1959 and 1963 year-classes, and estimates of yield which might have been obtained by refraining from these catches and by starting the exploitation at six years of age. The catches are given in thousands of metric tons. See Table XII for further information.

Year-class	Category	Catch	Estimated yield		
			Year	Alternative 1	Alternative 2
1959	0- and I-group	176	1965	203	152
	I- and II-group	109	1966	141	105
	II- and III-group	93	1967	110	82
	0- to III-group	378	1965–1967	454	339
			1968–1977	215	162
			1965–1977	669	501
1963	0- and I-group	45	1969	102	78
	I- and II-group	36	1970	71	54
	II- and III-group	114	1971	55	42
	0- to III-group	195	1969–1971	228	174
			1972–1981	108	83
			1969–1981	336	257

Both the small- and fat-herring fisheries fluctuate according to variations in year-class strength, but other biological factors, such as distribution, growth and migration also influence the yield of these fisheries. The decline in the catches of Norwegian winter herring in the late 1950s and early 1960s, the increase in the mid-1960s and the decrease in 1967–1968 were primarily associated with variations in year-class strength and not with the Norwegian small-herring fishery in the fjords. However, an extension of the 0-group herring fishery to the open sea, and a high exploitation rate of fat-herring will result in an appreciable reduction in the subsequent abundance in the adult stock. Environmental factors presumably play a major role in determining the reproductive success of the stock (DRAGESUND 1970). However, with the spawning stock size at a relatively low level an intensified fishery may endanger the prospects for future reproduction of the stock of Norwegian herring. Any increase in the fishing rate should be avoided, and a reduction of the fisheries on young and adolescent herring should be considered to improve the abundance of adult herring.

SUMMARY

1. The distribution of young and adolescent herring in coastal and offshore waters of northern Norway has been investigated for the 1959–1965 year-classes by combined acoustic surveys and fishing experiments.

2. In the autumn (August–October) 0-group herring occur pelagically in the upper 50 m of water together with the 0-group of several other species, such as cod, haddock, redfish, capelin and others. This complicates the charting and identification of the sound scatterers, but detailed studies of the echo recordings and frequent sampling in the scattering layer made it possible to determine the distribution of 0-group herring.

3. In 1959, 1960, 1964 and to some extent in 1963 and 1965, 0-group herring had an oceanic distribution, and only a minor part of the 0-group population entered the fjords of northern Norway. In 1961 and 1962 the distribution was more restricted to the coastal areas, and a greater proportion of the total 0-group population was present in the fjords. Herring entering the fjords at the 0-group stage in the autumn emigrate during the I-group stage from March to May.

4. Herring in the northern and eastern Barents Sea had slower growth rates and consequently a longer phase of migration to the spawning areas than did those distributed farther south and west. Herring from nursery grounds in the Barents Sea, therefore, are considerably more reduced in numbers before they reach the spawning grounds off Møre than those

which have spent their 0-group stage in the southern nursery areas in Norwegian coastal waters. The growth rate, therefore, may influence the migration pattern and the duration of the adolescent phase. Growth on the other hand is determined by the distribution during the 0-group stage, and the 0-group distribution consequently plays an important role in recruitment mechanism.

5. Abundance estimates of 0-group herring were obtained from three independent sources, i.e. acoustic surveys, catch and effort statistics and tagging experiments. The 1959 year-class, but also that of 1960, were numerous during the 0-group stage and remained abundant throughout the adolescent phase and in the adult stock. Year-classes of low abundance at the 0-group stage, such as the 1962 year-class, remained weak throughout the subsequent stages. The 1963 year-class, which was fairly abundant as 0-group, did not show up in significant numbers in the adult stock in 1968 and 1969. The 1964 and 1965 year-classes have not been studied in their adult phase because they had not attained maturity when the material was compiled. The year-classes of 1963 and 1964 showed about the same relative strengths during the adolescent phase as at the 0-group stage.

6. Mortality estimates obtained from catch and effort data and tagging experiments indicate that the fishing mortality of 0- and I-group herring in Norwegian fjords was relatively high, but because natural mortality was much higher, the exploitation rate was relatively low. Taking into account that the fjord population is only part of the total 0-group population, it is concluded that the fishing mortality generated by the 0- and I-group fishery in Norwegian fjords was too small to be the primary cause of the failure of recruitment to the adult stock.

7. A considerable increase in the exploitation of fat-herring, i.e. I- to IV-group herring took place from 1965 to 1968. The increase in exploitation during the adolescent phase of the 1963 and 1964 year-classes compared with those of the 1959–1961, and a long duration of the migration of the former year-classes from the nursery areas to the spawning grounds may explain why the year-classes of 1963 and 1964 tended to be relatively weak in the adult stock.

8. With the relatively low level of the spawning stock size an intensified fishery on the Norwegian herring should be avoided. An extension of the small- and fat-herring fisheries into the open sea may result in an appreciable reduction in the subsequent abundance in the adult stock, and a reduction of the fishery on young and adolescent herring should be considered to improve the abundance of adult herring.

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TABLES

Table I. Records of fishing experiments with pelagic trawl (PT), purse seine (PS), bottom trawl (BT) and Isaacs–Kidd ten foot mid water trawl (IKMT) for identification of echo traces during the surveys in 1959–1965.

Area	Date	Gear	No. of hauls, shots or samples	No. of fish per nautical mile towed or per purse seine shot				
				Year-class of herring				Other species
	1959			1959	1958	1957	1956	
06	27.9	PT	1	611	—	—	—	Not identified
05	30.9–2.10	PS	3	18438	—	—	—	Not identified
	6.10	PT	1	213	—	—	—	Not identified
04	9.10	PT	1	8520	—	—	—	Not identified
	8.10	PS	1	685000	—	—	—	Not identified
03	18–20.10	PS	3	35032	—	—	—	Not identified
	22.10	PS	1	A few hl				
	20.10	PS	1	Ca. 100 hl, mainly of 1957, 1958 year-classes				
02 and 10	15–16.10	Stomach content	2	8	—	—	—	Not identified
13	8.10	Stomach content	1	15	—	—	—	Not identified
15	12.10	Stomach content	1	24	—	—	—	Not identified
20	3.9	Stomach content	1	10	—	—	—	Not identified
	3.9–20.10	Stomach content	2	Many/some	—	—	—	Not identified
	20.10	BT with cover	1	200	—	—	—	Not identified
21	9–16.10	BT with cover	4	8	—	—	—	Not identified
	9.10	Stomach content	3	Some	—	—	—	Not identified
25	10.10	Stomach content	1	Some	—	—	—	Not identified
	12.10	BT with cover	1	1	—	—	—	Not identified
23	10.10	Und. wat. photogr.	1	Identified as 0-gr. herring, 1959 year-class				

Table I (*continued*)

1960				1960	1959	1958	1957	
05	28.9–2.10	IKMT	8	45	—	—	—	12
	29.9–2.10	PT	2	15	—	—	—	1
	29.9	PS	1	266	—	—	—	8
04	2–23.10	IKMT	4	4	—	—	—	—
	2–23.10	PT	2	2649	3	—	—	6
	3–24.10	PS	3	298259	80	—	—	—
03	10.10	IKMT	1	7	—	—	—	1
	21–22.10	PT	2	824	A few	—	—	—
	19–21.10	PS	3	1064	2	—	—	17
03 and 10	13.9–11.10	IKMT	4	11	—	—	—	14
02 and 10	13.9–14.10	PS	3	Ca. 1300	46	—	—	54
04 and 12	23.9–8.10	IKMT	4	1	1	—	—	3
12	8.10	PT	1	—	2326	24	24	1
13	15.9–13.10	IKMT	3	2	—	—	—	2
	13.10	PT	1	25	11	—	—	49
15 and 23	16.9–12.10	IKMT	4	7	—	—	—	523
15	12.10	PT	1	13	—	—	—	53
20	21.9–8.10	IKMT	8	139	1	—	—	4
	22.9–5.10	PT	3	371	—	—	—	28
	7.10	PS	1	Ca. 40000	—	—	—	—

Table I (*continued*)

Area	Date	Gear	No. of hauls, shots or samples	No. of fish per nautical mile towed or per purse seine shot				
				Year-class of herring				Other species
1961				1961	1960	1959	1958	
05	4.9	IKMT	1	2	—	—	—	39
	3–28.9	PT	6	82	—	—	—	5
	6–27.9	PS	2	26540	60	—	—	—
04	23–26.9	PT	7	83	1	—	—	26
	25.9	PS	1	4808	—	—	—	—
03	21–23.9	PT	5	70	1	1	—	13
	20.9	PS	1	7370	1211	519	—	—
03 and 10	17–20.9	PT	5	19	1	1	—	44
03	22.9	PS	2	15	2	25762	—	—
04 and 12	9–12.9	PT	2	4	1	—	—	23
12	11–12.9	PS	2	3	34	1008	—	—
11	23.11	PT	1	—	4	4	—	—
13	1.8–20.11	PT	2	Ca. 80 l mixture of I- and II-group herring 1959–1960 year-classes and 0-group cod and haddock.				
20	9.9	PS	1	3	—	—	—	721
1962				1962	1961	1960	1959	
05	21–23.9	PT	3	40023	5	—	—	1
	21–27.9	PS	4	577066	25705	803	268	—
04	17.9	PT	2	1630	17	—	—	49
	28–29.9	PS	3	15188	700	2	—	—
03	13.9	IKMT	1	2	—	—	—	—
	13.9	PT	2	22	29	147	107	—
03 and 10	5–7.9	IKMT	2	4	—	—	—	1
	6.9–5.11	PT	7	135	82	253	198	—
04 and 12	12.9–16.11	PT	3	1	1	4	5	5
	18–29.9	PS	2	—	1326	3583	25023	—
13	8.9	PT	1	166	—	—	—	14

Table I (*continued*)

1963				1963	1962	1961	1960	
05	3.10	IKMT	1	1	—	—	—	1
	4.10	PT	1	280	—	—	—	—
	4.10	PS	1	13424	—	—	—	—
04	2.10	IKMT	1	1	—	—	—	35
	30.9–6.10	PT	2	96	—	3	14	—
	27.9–1.10	PS	6	35024	—	865	1575	—
03	30.8–17.9	IKMT	4	11	—	—	—	14
	18–20.9	PT	2	552	—	—	—	2
10	20–21.9	IKMT	2	3	—	—	—	30
	20.9	PT	1	39	—	—	—	2 litres
13	11.9	IKMT	1	18	—	—	—	33
14	4.9	IKMT	1	3	—	—	—	5
20	11.9	IKMT	1	8	—	—	—	11
	24.9	PT	1	126	—	—	—	6
1964				**1964**	**1963**	**1962**	**1961**	
05	12.8–1.10	PT	2	2362	1	—	—	3
04	10.9	IKMT	1	2	—	—	—	—
	10–28.9	PT	2	10769	—	—	—	1
	29.9	PS	2	16870	—	—	—	1
03	15–21.9	PT	2	204	15	—	—	129
	16–25.9	PS	2	10939	340	—	—	20
10	15.9	IKMT	1	2	—	—	—	65
02 and 10	13–14.9	PT	4	169	1	—	—	—
12	11.9	IKMT	1	2	—	—	—	24

Table I (*continued*)

Area	Date	Gear	No. of hauls, shots or samples	No. of fish per nautical mile towed or per purse seine shot				
				Year-class of herring				Other species
	1964			1964	1963	1962	1961	
04 and 12	10.8–26.9	PT	9	312	1	—	—	—
13	13.9	IKMT	1	5	—	—	—	3
	11–23.9	PT	3	95	—	—	—	—
15	23.9	PT	1	20	—	—	—	404
20	8.9	IKMT	1	4	—	—	—	161
	2–23.9	PT	2	14	—	—	—	222
21	23.7–6.9	PT	5	130	—	—	—	—
37	31.8–1.9	PT	2	—	—	—	—	24
	1965			1965	1964	1963	1962	
05	25–27.8	PT	3	38	—	—	—	—
04	30.8	PT	2	192	—	—	—	4
03	31.8	PT	2	—	1697	2128	—	3
12	9–14.9	PT	2	16	—	—	—	257
21	10–11.9	PT	2	25	—	—	—	862

Table II. Tagging experiments with internal steel tags on young and adolescent herring in coastal and offshore waters of northern Norway in 1959–1964.

Date		Position	Category of herring	No. of herring tagged
1959	1.10	N 67° 50′, E 14° 10′	0-group	600
	2.10	N 68° 40′, E 12° 45′	0-group	1000
	8.10	N 70° 10′, E 19° 30′	0-group	2000
	19.10	N 69° 50′, E 30° 30′	0-group	600
1960	3.10	N 70° 10′, E 19° 30′	0-group	2000
	7.10	N 74° 30′, E 19° 30′	0 group	2000
	14.10	N 70° 20′, E 36° 30′	0-group	1500
	14.10	N 69° 20′, E 37° 20′	I-group	1000
	21.10	N 70° 03′, E 29° 50′	0-group	1000
	23.10	N 70° 50′, E 26° 00′	0-group	300
1961	6. 9	N 69° 20′, E 17° 00′	0-group	1000
	20. 9	N 69° 50′, E 30° 30′	0-group	1000
	20. 9	N 69° 50′, E 30° 30′	I-group	200
	25. 9	N 70° 10′, E 19° 30′	0-group	2000
	27. 9	N 69° 35′, E 17° 25′	0-group	500
	12. 9	N 71° 35′, E 25° 35′	Fat-herring	950
	22. 9	N 71° 35′, E 27° 45′	Fat-herring	500
1962	21. 9	N 68° 30′, E 15° 00′	0-group	1300
	25. 9	N 67° 10′, E 13° 50′	0-group	600
	27. 9	N 69° 18′, E 18° 40′	0-group	600
	28. 9	N 69° 35′, E 19° 40′	0-group	1200
	18. 9	N 71° 40′, E 19° 35′	Fat-herring	1900
	21. 9	N 68° 30′, E 15° 00′	Fat-herring	800
1963	27. 9	N 69° 35′, E 19° 40′	0-group	2000
	4.10	N 68° 30′, E 15° 00′	0-group	1000
	17. 6	N 69° 50′, E 30° 30′	I-group	300
	19. 6	N 70° 15′, E 34° 00′	I-group	900
	5. 6	N 70° 10′, E 32° 30′	Fat-herring	600
	10. 6	N 70° 10′, E 32° 30′	Fat-herring	400
	19. 6	N 70° 15′, E 34° 00′	Fat-herring	100
	25. 6	N 69° 10′, E 16° 30′	Fat-herring	400
	1.10	N 71° 10′, E 20° 00′	Fat-herring	1000
1964	16. 9	N 70° 03′, E 29° 50′	0-group	1000
	25. 9	N 70° 50′, E 26° 00′	0-group	1000
	29. 9	N 69° 35′, E 19° 35′	0-group	2000

Table III. Length distribution (in cm) of 0-group herring of the 1959–

Year-class	Area	Date	Gear	No.	6.0	6.5	7.0	7.5	8.0	8.5
1959	05	1.10	PS	648						6
		2.10	PS	456						
		16.11	PS	608			18	33	37	54
	04	8.10	PS	685				3	9	33
		19.10	PS	793			8	26	78	130
		19.10	PS	661		3	—	23	52	76
		30.10	PS	613		2	12	18	42	70
		10.11	PS	617	1	—	3	—	5	11
		17.11	PS	764				9	19	87
		20.11	PS	570			1	3	12	45
		20.11	PS	833		1	3	22	59	129
		21.11	PS	712		3	18	38	55	108
		21.11	PS	838				18	55	118
		22.11	PS	577				5	7	52
		23.11	PS	459					2	5
		23.11	PS	789				9	35	106
		23.11	PS	649			4	6	25	64
		23.11	PS	729			26	103	159	150
		24.11	PS	772				4	18	47
		2.12	PS	868			3	19	54	89
		2.12	PS	886			10	26	59	108
		8.12	PS	723			9	15	29	53
		8.12	PS	824			22	51	76	117
	03	18.10	PS	1176				8	318	427
		19.10	PS	1384			24	210	431	277
		20.10	PS	725			19	22	23	43
		22.10	PS	814					12	95
		26.10	PS	774			1	3	16	71
		23.11	PS	531			4	23	52	76
		24.11	PS	583			12	32	65	88
		24.11	PS	836			26	57	104	117
		27.11	PS	885			5	33	157	200
		1.12	PS	880			1	48	151	193
		1.12	PS	956			16	101	180	176

1965 year-classes caught with purse seine (PS) and pelagic trawl (PT).

9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0
182	245	147	45	15	5	3				
9	18	46	64	102	108	68	33	7	—	1
61	65	82	46	80	47	32	34	19		
109	173	161	103	53	34	5	2			
114	104	71	84	94	52	30	2			
82	59	65	65	98	81	41	13	2	1	
99	70	68	67	78	55	27	5			
41	64	106	97	122	78	64	16	9		
168	174	181	72	31	14	8	—	—	1	
86	109	109	62	73	41					
239	180	114	46	29	7	3	—	1		
153	110	89	47	53	29	9				
228	195	140	45	24	10	4	1			
124	157	116	49	52	14	1				
25	42	65	75	79	80	68	13	5		
176	167	128	71	50	26	17	3	1		
108	148	151	61	47	21	11	1	1	1	
120	66	49	26	18	7	3	2			
128	147	194	80	87	36	27	3	1		
177	178	179	75	56	28	9	1			
177	172	148	88	65	19	11	3			
91	108	112	92	90	69	31	20	4		
145	111	96	50	65	48	34	8	—	1	
258	96	50	14	5						
189	116	73	40	18	6					
113	168	128	102	67	26	14				
196	220	176	82	23	10					
158	187	143	101	44	25	11	5	6	3	
133	83	77	35	24	12	4	4	3	1	
113	84	97	43	29	9	4	5	2		
149	122	138	57	32	18	10	3	2	1	
189	121	85	37	27	13	4	5	7	2	
179	124	83	34	34	12	11	4	5	1	
174	130	92	37	21	9	12	3	2	3	

Table III (*continued*)

Year-class	Area	Date	Gear	No.	5.5	6.0	6.5	7.0	7.5	8.0	8.5
1960	07	12.11	PS	100							
		14.11	PS	100							
		18.11	PS	100							
	05	29.9	PS	266				9	48	62	51
		20.10	PS	100		1	5	25	19	16	14
		20.10	PS	1050			24	106	269	202	159
		30.10	PS	63					1	12	18
	04	3.10	PS	126							
		23.10	PS	100				20	22	22	18
		24.10	PS	97				1	2	16	17
		24.10	PS	100					3	7	14
		7.11	PS	1091				45	250	275	193
		16.11	PS	200				8	22	35	41
		28.11	PS	100			1	6	6	8	16
		29.11	PS	100					3	7	8
		6.12	PS	100				1	2	1	7
		14.12	PS	100				3	14	11	12
	03	19.10	PS	131						8	23
		21.10	PS	71							
		21.10	PS	100							
1961	07	31.1.62	PS	100							6
		23.1.62	PS	100							
	06	16.12	PS	234							
		15.1.62	PS	90						1	—
	05	4.9	PS	99					4	23	28
		6.9	PS	100						5	22
		27.9	PS	99							2
	04	25.9	PS	100							
		25.10	PS	100						4	10
		22.11	PS	95	1	4	9	11	14	13	7
	03	20.9	PS	100							2
		22.9	PS	30							

9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
2	8	9	14	22	16	18	6	2	2	1		
		2	7	9	16	20	18	15	9	3	1	
	1	3	16	15	21	22	12	6	1	3		
37	25	21	11	2								
6	3	3	3	4	1							
122	55	45	32	19	8	8	1					
13	5	9	4	1								
3	7	22	43	35	11	3	1	1				
12	4	1	1									
24	13	8	6	6	4							
18	24	14	7	6	5	1	1					
113	55	60	36	34	20	10						
29	18	18	9	9	7	3	—	—	1			
15	11	14	14	7	2							
13	7	8	14	20	13	4	3					
7	16	32	23	11								
13	13	3	8	12	8	2	1					
43	38	10	6	2	1							
		5	20	26	19	—	—	—	1			
3	12	39	27	13	6							
22	26	18	13	7	6	1	1					
		3	12	17	21	12	6	9	13	6	1	
	1	22	27	17	18	33	59	29	13	7	4	4
3	4	6	1	9	7	17	15	17	7	3		
29	10	4	1									
54	14	3	2									
6	18	19	24	19	10	1						
	8	24	32	26	9	1						
21	17	18	7	9	5	5	2	—	2			
6	10	10	4	3	3							
7	13	30	24	14	6	4						
2	4	6	11	4	2	1						

Table III *(continued)*

Year-class	Area	Date	Gear	No.	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
1962	07	10.11	PS	100										
		20.11	PS	100										
		10.12	PS	318										
		12.12	PS	290										
		16.1.63	PS	100										1
		24.1.63	PS	100										
	05	21.9	PS	200					1	3	20	30	35	35
		25.9	PS	162						1	25	70	47	14
		27.9	PS	200				4	7	14	32	48	46	27
	04	28.9	PS	210				18	63	87	25	8	3	1
		29.9	PS	224				3	5	6	17	20	30	40
		29.9	PS	186				5	7	10	22	22	28	21
	05	17.9	PT	55		1	8	13	16	4	5	6	1	1
		21.9	PT	102					3	4	6	11	22	33
		23.9	PT	102				2	6	13	30	29	14	4
		22.10	PT	101					1	3	15	26	30	18
	04	17.9	PT	100		1	3	16	20	24	18	14	3	—
		17.9	PT	109		4	19	42	31	9	3	—	—	1
		2.10	PT	102			1	4	5	15	19	21	16	8
		2.10	PT	99				3	3	11	14	11	11	11
		3.10	PT	103	1	1	2	14	18	23	14	8	8	6
		3.10	PT	64		1	5	15	11	7	4	5	11	4
		11.10	PT	100				4	6	5	9	15	17	9
		25.10	PT	100				1	1	9	17	15	15	17
		26.10	PT	104						1	1	6	14	16
		30.10	PT	100					3	9	7	17	19	14
		31.10	PT	100			1	4	21	18	26	11	11	4
		8.11	PT	100						4	9	14	16	24
		22.11	PT	101				3	5	8	10	12	13	13
		23.11	PT	107			2	—	6	10	11	19	18	22
		5.12	PT	103				2	5	10	19	20	13	13
	03	7.9	PT	54					3	5	6	12	25	2
		13.9	PT	52					1	2	4	9	21	11
		5.10	PT	101				3	9	22	34	14	10	6
		5.10	PT	101			1	1	7	25	27	23	12	3
		5.10	PT	87						2	1	4	15	29
		8.10	PT	22				1	—	2	9	4	4	2
		2.11	PT	80				1	5	8	19	9	21	11
		3.11	PT	19							4	4	2	4
		1.12	PT	81							1	2	6	7

9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0
4	17	17	14	6	4	4	17	11	4	2			
	2	4	6	14	19	13	17	11	10	3	1		
		6	14	19	35	54	73	60	38	11	3	3	2
	5	9	27	33	37	42	47	48	28	10	3	1	
2	3	2	7	6	15	17	24	12	9	2			
		4	13	13	13	27	16	8	2	2	1	1	
27	22	19	7	1									
1	1	1	2										
13	7	1	1										
2	2	1											
38	42	21	2										
25	28	16	1	1									
17	5	1											
2	2												
8													
—	1												
4	4	4	1										
15	11	7	2										
4	2	1	1										
1													
15	9	7	4										
10	8	3	4										
18	20	20	8										
13	8	6	3	1									
1	1	2											
16	11	1	4	1									
13	9	7	5	1	1	1							
10	6	1	2										
6	4	4	4	2	1								
1													
4													
2	1												
1	1												
25	6	5											
3	3												
3	2												
21	18	13	5	5	2	1							

Table III *(continued)*

Year-class	Area	Date	Gear	No.	4.5	5.0	5.5	6.0	6.5	7.0	7.5
1963	05	5.9	PT	30						1	6
		4.10	PT	100							
		16.11	PT	101			1	5	4	6	11
	04	9.9	PT	100				1	—	5	7
		9.9	PT	84						2	7
		9.9	PT	109						3	6
		10.9	PT	101	1	38	40	17	3	—	1
		20.9	PT	106		1	14	42	21	12	12
		20.9	PT	75		4	3	11	7	2	3
		25.9	PT	34							
		26.9	PT	101					6	6	4
		12.10	PT	11							
		30.10	PT	50						3	2
		8.11	PT	102					2	11	9
		14.11	PT	97							
		15.11	PT	100					1	5	3
		20.11	PT	100					7	5	12
		4.12	PT	103				1	3	10	12
	03	18.9	PT	100							
		18.9	PT	51			3	4	4	4	2
		20.9	PT	100							
		15.10	PT	65					3	9	11
		11.12	PT	101						1	4

8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
13	4	2	3	1							
	1	5	16	35	19	11	7	3	3		
22	14	11	8	9	2	3	3	1	1		
18	14	21	15	14	3	2					
8	11	27	15	11	2	1					
18	18	34	23	6	1						
—	1										
2	1	—	—	—	1						
5	11	9	8	4	4	2	2				
			1	3	12	12	3	3			
4	5	7	13	14	19	15	5	2	1		
		1	—	1	1	3	4	1			
5	2	5	4	8	5	6	6	2	1	1	
9	7	8	12	23	10	7	3	1			
	3	2	9	9	13	28	18	11	3	1	
1	5	13	15	21	16	13	5	2			
12	13	11	12	11	7	5	3	2			
10	9	6	6	10	11	11	7	5	1	1	
		6	29	30	28	7					
2	3	11	6	7	4	1					
10	22	24	27	15	2						
5	—	1	—	2	8	9	7	6	3	1	
2	3	4	14	20	19	18	8	5	2	1	

Table III (*continued*)

Year-class	Area	Date	Gear	No.	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
1964	04	9.9	PT	100				2	10	24	19	14
		10.9	PT	100			1	4	28	31	19	9
		21.9	PT	100					3	8	31	36
		21.9	PT	101				1	8	13	25	26
		27.9	PT	96				1	—	6	23	26
		28.9	PT	100					1	5	16	60
		9.10	PT	101	1	—	—	—	—	1	1	7
		9.10	PT	65								
		22.10	PT	52	1	6	1	1	2	7	10	14
		10.11	PT	53								
		12.11	PT	34							1	2
		18.11	PT	100			1	1	2	17	39	17
		18.11	PT	100					2	11	20	26
		18.11	PT	100							3	5
		20.11	PT	103								14
		10.12	PT	101			1	1	—	5	9	13
		11.12	PT	12								
		18.12	PT	100								2
	03	15.9	PT	100						6	23	26
		15.9	PT	100						7	25	17
		18.9	PT	101							5	26
		18.9	PT	101			1	2	7	20	23	21
		21–22.9	PT	100							4	6
		19.11	PT	22			1	—	—	—	—	3
		9.12	PT	102						2	14	32
	02	21.9	PT	29								
	10	13.9	PT	103					4	3	1	1
		14.9	PT	102				2	16	43	27	10
	13	11.9	PT	60						1	5	12
		22.9	PT	100					2	13	14	20
		23.9	PT	68					1	4	7	11
	12	9.9	PT	53					2	3	5	7
		10.9	PT	101							1	1
		23.9	PT	100			1	3	3	5	7	14
		24.9	PT	108					2	3	7	20
		26.9	PT	100				3	10	17	18	19

8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
13	9	5	2	1	1						
4	2	1	—	—	1						
13	5	1	2	1							
13	8	5	1	1							
15	16	2	6	—	—	1					
17	1										
16	16	15	8	12	10	11	2	1			
1	1	2	1	7	10	20	13	9	1		
5	2	2	1								
	2	3	1	4	12	15	12	3	1		
3	1	1	4	4	3	8	4	3			
9	11	3									
16	14	3	4	3	1						
5	9	20	25	17	2	4	5	3	2		
20	16	14	5	12	8	6	7	—	1		
14	16	8	6	4	1	6	5	4	4	4	
					1	2	2	4	1	1	1
3	—	3	3	12	19	23	19	8	4	4	
14	7	8	9	3	4						
13	9	13	8	3	4	1					
41	15	7	4	2	1						
17	6	2	2								
14	24	12	21	10	5	3	1				
4	6	5	3								
24	8	7	4	2	3	2	1	1	1	1	
1	1	2	6	8	6	3	2				
4	26	32	19	8	4	1					
2	1	1									
29	13										
27	6	9	4	3	2						
15	12	8	2	3	4	—	—	1			
14	7	6	4	3	2						
1	7	15	27	24	22	3					
13	3	11	15	14	6	3	2				
29	13	12	10	8	3	1					
20	6	3	2	1	1						

Table IV. Analysis of variance of the data in Table III.

Area	Gear	Source of variation	Sums of squares	Degrees of freedom	Variance of estimate	F	Probability
					1959 year-class		
05, 04 and 03	PS	Between areas	10631.302	2	5315.651 (s^2_B)		
		Within areas	122725.400	25615	4.791 (s^2_W)		
		Between samples	19181.219	31	618.749 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	103544.181	25584	4.047 (s^2_w)		
		Total	133356.702	25617		$\frac{s^2_B}{s^2_b}$	<0.05
					1960 year-class		
05, 04 and 03	PS	Between areas	3024.802	2	1512.401 (s^2_B)		
		Within areas	21462.832	3892	5.515 (s^2_W)		
		Between samples	4563.484	14	325.963 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	16899.348	3878	4.358 (s^2_w)		
		Total	24487.634	3894		$\frac{s^2_B}{s^2_b}$	<0.05
07, 05, 04 and 03	PS	Between areas	12068.346	3	4022.782 (s^2_B)		
		Within areas	22768.419	4191	5.433 (s^2_W)		
		Between samples	4761.771	16	297.611 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	18006.648	4175	4.312 (s^2_w)		
		Total	34836.765	4194		$\frac{s^2_B}{s^2_b}$	<0.05
					1961 year-class		
05, 04 and 03	PS	Between areas	341.263	2	170.632 (s^2_B)		
		Within areas	3852.209	720	5.350 (s^2_W)		
		Between samples	1589.416	5	317.883 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	2262.793	715	3.165 (s^2_w)		
		Total	4193.472	722		$\frac{s^2_B}{s^2_b}$	>0.05

					1961 year-class		
07, 06, 05, 04 and 03	PS	Between areas	5563.961	4	1390.990 (s^2_B)		
		Within areas	7530.480	1242	6.063 (s^2_W)		
		Between samples	2486.318	7	355.188 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	5044.162	1235	4.084 (s^2_w)		
		Total	13094.441	1246		$\frac{s^2_b}{s^2_B}$	>0.05
					1962 year-class		
05 and 04	PS	Between areas	75.579	1	75.579 (s^2_B)		
		Within areas	6567.199	1180	5.565 (s^2_W)		
		Between samples	2373.214	4	593.304 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	4193.985	1176	3.566 (s^2_w)		
		Total	6642.778	1181		$\frac{s^2_B}{s^2_b}$	>0.05
05, 04 and 03	PT	Between areas	130.997	2	65.499 (s^2_B)		
		Within areas	16210.148	2446	6.627 (s^2_W)		
		Between samples	6826.211	25	273.048 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	9383.937	2421	3.876 (s^2_w)		
		Total	16341.145	2448		$\frac{s^2_B}{s^2_b}$	>0.05
07, 05 and 04	PS	Between areas	38258.607	2	19129.303 (s^2_B)		
		Within areas	11960.318	2187	5.469 (s^2_W)		
		Between samples	2908.844	9	323.205 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	9051.474	2178	4.156 (s^2_w)		
		Total	50218.925	2189		$\frac{s^2_B}{s^2_b}$	<0.05

Table IV (*continued*)

Area	Gear	Source of variation	Sums of squares	Degrees of freedom	Variance of estimate	F	Probability
					1963 year-class		
05, 04 and 03	PT	Between areas	858.072	2	429.036 (s^2_B)		
		Within areas	22565.678	1918	11.765 (s^2_W)		
		Between samples	11912.946	20	595.647 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	10652.732	1898	5.613 (s^2_w)		
		Total	23423.750	1920		$\frac{s^2_B}{s^2_b}$	>0.05
					1964 year-class		
04 and 03	PT	Between areas	205.966	1	205.966 (s^2_B)		
		Within areas	21332.571	2142	9.959 (s^2_W)		
		Between samples	12011.093	23	522.221 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	9321.478	2119	4.399 (s^2_w)		
		Total	21538.537	2143		$\frac{s^2_B}{s^2_b}$	>0.05
04, 03, 02, 10, 13 and 12	PT	Between areas	400.601	4	100.150 (s^2_B)		
		Within areas	27509.570	3063	8.981 (s^2_W)		
		Between samples	14636.416	31	472.142 (s^2_b)	$\frac{s^2_b}{s^2_w}$	<0.05
		Within samples	12873.154	3032	4.246 (s^2_w)		
		Total	27910.171	3067		$\frac{s^2_B}{s^2_b}$	>0.05

Table V. Mean length of 0-group herring of the 1959–1965 year-classes caught with pelagic trawl (PT), purse seine (PS) and Isaacs–Kidd ten foot midwater trawl (IKMT).

Year-class	Date of sampling	Area	Gear	No. of samples	No. of fish	Mean length in cm.	Standard deviation	Standard error
1959	28.9	06	PT	1	101	11.6	0.86	0.09
	6.10	05	PT	1	102	9.2	1.28	0.13
	1.10–16.11	05	PS	3	300	10.2	1.15	0.07
	13.10–27.11	04	PT	5	441	7.5	1.23	0.06
	8.10–2.12	04	PS	20	1993	9.7	0.35	0.01
	18.10–1.12	03	PS	11	1104	9.2	1.04	0.03
	16.10	02	Stomach content	1	9	7.8	1.25	0.42
	8.10	13	Stomach content	1	15	8.6	0.71	0.18
	12.10	15	Stomach content	2	24	8.1	1.42	0.29
1960	12–18.11	07	PS	3	300	11.6	1.04	0.06
	18–29.11	06	PS	2	106	9.8	1.01	0.10
	29.9–2.10	05	PT	2	56	8.5	1.04	0.14
	28–29.9	05	IKMT	5	359	7.3	0.70	0.04
	29.9–30.10	05	PS	4	362	8.4	1.08	0.06
	2.10–30.11	04	PT	5	217	8.4	1.28	0.09
	3.10–14.12	04	PS	10	1001	9.4	1.29	0.04
	10.10–11.11	03	PT	4	371	8.6	1.08	0.06
	19–21.10	03	PS	3	273	10.1	0.93	0.06
	14.10	02	PS	1	100	9.4	0.77	0.08
	13.10	10	PS	1	100	9.3	0.70	0.09
	13.10	13	PT	1	59	9.7	0.62	0.08
	12.10	15	PT	1	53	8.7	0.89	0.12
	22.9–5.10	20	PT	3	301	7.9	0.65	0.04
	21.9–8.10	20	IKMT	4	285	7.5	0.80	0.05
	7.10	20	PS	1	100	7.2	0.42	0.04

Table V (*continued*)

Year-class	Date of sampling	Area	Gear	No. of samples	No. of fish	Mean length in cm.	Standard deviation	Standard error
1961	13–23.1.62	07	PS	2	200	10.9	1.47	0.10
	16.12.61–15.1.62	06	PS	2	190	12.0	1.26	0.09
	4–27.9	05	PT	4	329	8.4	0.87	0.05
	4–27.9	05	PS	3	298	9.3	0.94	0.03
	24.9–21.11	04	PT	13	1229	8.5	1.34	0.04
	25.9–22.11	04	PS	3	295	9.6	1.46	0.08
	21.9–10.12	03	PT	8	726	8.8	1.33	0.05
	20–22.9	03	PS	2	130	10.3	0.75	0.07
	17–20.9	10	PT	4	101	9.2	0.90	0.09
	9–10.9	12 and 20	PT and PS	2	10	9.0	1.62	0.51
1962	10.11.62–16.1.63	07	PS	2	200	12.0	1.36	0.10
	21.12	06	PS	1	98	10.9	0.87	0.09
	17.9–22.10	05	PT	4	360	8.0	1.03	0.05
	21–27.9	05	PS	3	308	8.5	0.95	0.05
	17.9–5.12	04	PT	15	1492	8.1	1.40	0.04
	28–29.9	04	PS	3	302	8.2	1.37	0.08
	7.9–1.12	03	PT	9	597	8.3	1.12	0.05
	7.9	10	PT	2	108	8.1	0.59	0.06
	8.9	13	PT	1	99	7.8	0.75	0.08
1963	24.10–10.12	07	PS	3	302	11.5	1.27	0.07
	15.12	06	PT	1	99	10.0	1.29	0.13
	5.9–16.11	05	PT	3	231	9.5	1.44	0.09
	4.10	05	PS	1	100	9.7	0.96	0.10
	9.9–4.12	04	PT	15	1273	9.0	1.87	0.05

1963	27.9–13.11	04	PS	3	301	10.3	1.34	0.08
	18.9–11.12	03	PT	5	417	9.8	1.34	0.07
	20.9	10	PT	1	79	7.9	0.75	0.08
	5.8	12	PT	1	102	5.8	0.65	0.06
	24.9	20	PT	1	100	7.6	0.51	0.05
1964	7.12	07	PS	1	101	13.8	1.11	0.11
	30.10–3.12	06	PS	2	200	10.4	1.28	0.09
	1.10	05	PT	1	100	9.3	0.52	0.05
	9.9–18.12	04	PT	18	1518	8.7	1.73	0.04
	29.9	04	PS	2	200	9.2	1.06	0.07
	15.9–29.12	03	PT	7	626	8.3	1.11	0.05
	16–25.9	03	PS	2	200	10.0	0.72	0.05
	21.9	02	PT	1	29	10.3	0.82	0.15
	13–14.9	10	PT	2	205	8.0	1.34	0.09
	11–23.9	13	PT	3	228	8.2	0.95	0.06
	23.9	15	PT	1	20	8.3	1.05	0.23
	9–26.9	12	PT	5	462	8.7	1.34	0.06
	2.9	20	PT	1	46	7.8	0.64	0.09
	4–6.9	21	PT	2	40	6.7	0.57	0.09
1965	14.10–16.11	07	PS	3	298	12.6	1.62	0.09
	25–27.8	05	PT	2	161	6.4	1.35	0.11
	30.8	04	PT	2	258	5.1	0.39	0.02
	9–14.9	12	PT	2	47	8.8	1.24	0.18
	10–11.9	21	PT	2	96	6.6	0.76	0.08

Table VI. Mean annual length increments ($\bar{t}$ in cm) of herring (1959 year-class) collected in different regions in 1961–1965, s = standard deviation and $s/\sqrt{n}$ = standard error.

Region	Date		n	$\bar{t}_1$	s_1	$s_1/\sqrt{n}$	$\bar{t}_2$	s_2	$s_2/\sqrt{n}$	$\bar{t}_3$	s_3	$s_3/\sqrt{n}$	$\bar{t}_4$	s_4	$s_4/\sqrt{n}$
Off Vesterålen	1961	24.8–6.9	116	9.44	1.62	0.15	7.71	1.34	0.12						
Off Torsvåg		12–22.9	166	8.88	1.00	0.08	7.21	1.01	0.08						
Off North Cape		11–22.9	89	8.03	0.97	0.10	6.63	0.86	0.09						
Off eastern Finnmark		20.9	30	7.05	0.72	0.13	5.83	0.89	0.16						
Off eastern Finnmark	1962	18.2–6.3	32	7.64	1.00	0.18	5.63	1.02	0.18						
Off Iceland		21.7–14.9	100	8.82	1.30	0.13	7.11	1.01	0.10						
Off Torsvåg		18–29.9	237	7.69	1.20	0.08	6.22	0.98	0.06	4.38	1.19	0.08			
Off Finnmark		1.7–2.8	391	7.53	0.96	0.05	5.99	0.98	0.05	3.86	0.80	0.04			
Off eastern Finnmark		13.9–5.11	51	7.74	1.08	0.15	5.57	0.83	0.12	3.77	0.70	0.10			
Off Iceland	1963	29.7–14.8	102	9.16	1.41	0.14	7.39	1.18	0.12	6.66	1.54	0.15	4.40	1.21	0.12
Off Torsvåg		1–30.10	130	7.58	1.24	0.11	6.21	1.15	0.10	4.18	1.31	0.11	4.33	1.33	0.12
Off Møre	1964	17–20.2	107	9.46	1.15	0.11	6.84	1.19	0.12	5.92	1.68	0.16	4.75	1.33	0.13
Off Lofoten		2–4.3	106	8.17	1.10	0.11	6.46	1.02	0.10	4.94	1.64	0.16	4.81	1.31	0.13
Off Møre	1965	15.2	96	8.30	1.41	0.14	6.79	1.31	0.13	5.32	1.59	0.16	4.99	1.41	0.14
Off Lofoten		18–20.2	99	8.10	1.32	0.13	6.06	1.20	0.12	4.47	1.53	0.15	4.87	1.51	0.15

Table VII. Catch of 0- and I-group herring of the 1959 and 1960 year-classes landed by purse seiners in different areas.

Year-class	Month	Area	Catch in tons	No. of vessels
1959	November	05 and 04	6178	29
	December	05 and 04	5699	26
	January	05 and 04	2466	19
	February	05 and 04	887	12
	March	05 and 04	4	1
	April	05 and 04	262	4
	November	05, 04 and 03	6636	14
	December	05, 04 and 03	4330	13
	January	05, 04 and 03	4403	16
	February	05, 04 and 03	685	6
	March	05, 04 and 03	1647	10
	April	05, 04 and 03	1041	11
1960	December	05 and 04	7556	41
	January	05 and 04	6742	34
	February	05 and 04	2256	19
	March	05 and 04	689	7
	April	05 and 04	264	5
	December	05, 04 and 03	9728	23
	January	05, 04 and 03	11647	25
	February	05, 04 and 03	1612	17
	March	05, 04 and 03	580	4
	April	05, 04 and 03	1786	18

Table VIII. Catch and average weight of young and adolescent herring (1959 year-class) according to month and district.

Month	Møre and Romsdal, Trøndelag		Nordland		Troms		Finnmark	
	Catch in tons	Weight in g	Catch in tons	Weight in g	Catch in tons	Weight in g	Catch in tons	Weight in g
				0- and I-group				
October	11979	11	13982	9	1963	7	2310	5
November	14579	11	19275	9	5289	7	20108	5
December	303	11	10123	9	10946	7	14527	5
January	313	11	3595	9	10072	7	15173	5
February	—	—	237	9	3155	7	1567	5
March	44	13	59	9	487	7	9072	5
April	1373	16	458	11	424	9	4487	6
				I- and II-group				
May	9693	22	2744	15	3395	13	4797	7
June	7045	32	1962	23	399	18	2816	9
July	1280	43	1148	34	716	24	8698	11
August	8986	57	764	46	59	34	1447	16
September	3667	63	1088	48	3	40	—	—
October	2552	66	3987	49	146	43	—	—
November	3437	67	1990	49	1309	44	3795	21
December	1324	67	495	49	1401	44	8075	21
January	937	67	2141	49	1453	44	7616	21
February	56	67	776	49	556	44	1898	21
March	1	68	104	49	109	44	1137	21
April	345	73	296	50	270	44	2052	22
				II- and III-group				
May	3429	82	309	53	573	45	947	24
June	3523	91	395	63	749	47	14702	29
July	1798	101	176	77	368	57	35997	34
August	1800	112	4421	93	309	76	38	41
September	526	123	3263	98	69	90	50	47
October	759	132	6393	99	1682	96	18	51
November	749	138	2943	100	1013	99	46	53
December	961	140	1444	100	514	100	13	54
January	161	140	1621	100	340	100	—	—
February	15	140	254	100	37	100	—	—
March	22	140	28	100	—	—	—	—
April	60	140	5	100	—	—	—	—

Table IX. Catch and average weight of young and adolescent herring (1963 year-class) according to month and district.

Month	Møre and Romsdal, Trøndelag		Nordland		Troms		Finnmark	
	Catch in tons	Weight in g	Catch in tons	Weight in g	Catch in tons	Weight in g	Catch in tons	Weight in g
				0- and I-group				
October	6220	11	1673	9	1316	7	449	5
November	4248	11	11031	9	9051	7	1770	5
December	1303	11	1606	9	374	7	386	5
January	563	11	4018	9	261	7	7	5
February	—	—	—	—	—	—	—	—
March	—	—	—	—	—	—	—	—
April	—	—	161	11	—	—	—	—
				I- and II-group				
May	1199	22	934	15	1039	13	506	7
June	2103	32	1120	23	837	18	235	9
July	1300	43	583	34	204	24	8	11
August	1071	57	726	46	11	34	—	—
September	854	63	1374	48	3	40	—	—
October	1120	66	4552	49	322	43	—	—
November	1429	67	3868	49	856	44	1409	21
December	524	67	834	49	261	44	2814	21
January	173	67	338	49	171	44	2663	21
February	35	67	—	—	—	—	—	—
March	222	68	—	—	—	—	—	—
April	259	73	44	50	1	44	—	—
				II- and III-group				
May	6664	82	1486	53	1019	45	615	24
June	1898	91	1482	63	711	47	5315	29
July	1787	101	4714	77	1150	57	38480	34
August	1716	112	7934	93	832	76	19154	41
September	718	123	3535	98	2664	90	5953	47
October	1106	132	1162	99	108	96	1346	51
November	563	138	825	100	11	99	363	53
December	219	140	162	100	—	—	23	54
January	—	—	—	—	—	—	—	—
February	—	—	—	—	—	—	—	—
March	—	—	—	—	—	—	—	—
April	47	140	2	100	—	—	—	—

Table X. Catch and average weight of young and adolescent herring (1959 year-class) according to month and district.

Month	Møre and Romsdal, Trøndelag		Nordland		Troms		Finnmark	
	Catch in tons	Weight in g	Catch in tons	Weight in g	Catch in tons	Weight in g	Catch in tons	Weight in g
				III- and IV-group				
May	57	141	357	100	—	—	—	—
June	57	143	2439	101	141	101	8059	55
July	21	147	232	103	227	102	58948	56
August	27	157	9955	108	235	104	3543	62
September	11	172	7852	113	1173	107	—	—
October	11	199	9606	123	954	112	—	—
November	60	199	2974	131	391	117	—	—
December	14	199	1858	131	8	117	—	—
January	—	—	904	131	—	—	—	—
February	—	—	303	131	—	—	—	—
March	—	—	149	131	—	—	—	—
April	8	199	859	131	—	—	—	—
				IV- and V-group				
May	45	199	999	140	13	123	—	—
June	99	200	643	155	6312	135	7426	85
July	74	200	6277	180	1506	160	9245	90
August	113	200	3751	200	13	180	275	100
September	48	200	238	200	22	200	11	120
October	43	200	356	200	655	200	1121	140
November	39	200	332	200	—	—	60	140
December	19	200	20	200	18	200	—	—
January	3	200	12	200	—	—	44	140
February	—	—	—	—	—	—	—	—
March	—	—	—	—	—	—	—	—
April	249	200	2951	200	—	—	—	—
				V-group				
May	—	—	33	200	7	200	—	—
June	—	—	49	200	4	200	—	—
July	—	—	67	200	1	200	—	—
August	—	—	79	200	2	200	—	—
September	—	—	—	—	—	—	—	—
October	—	—	—	—	—	—	—	—
November	—	—	—	—	—	—	—	—
December	45	225	305	200	155	200	—	—

Table XI. Catch and average weight of young and adolescent herring (1963 year-class) according to month and district.

Month	Møre and Romsdal, Trøndelag*		Nordland*		Troms		Finnmark	
	Catch in tons	Weight in g	Catch in tons	Weight in g	Catch in tons	Weight in g	Catch in tons	Weight in g
				III- and IV-group				
May	195	141	8	100	—	—	660	54
June	97	143	29	101	—	—	9972	55
July	24	147	37	103	1	102	34656	56
August	26	157	18	108	8	104	27557	62
September	14	172	16	113	3	107	16943	72
October	16	199	27	123	12	112	6	79
November	24	199	7	131	—	—	—	—
December	5	199	—	—	—	—	—	—
January	—	—	—	—	26	117	12	81
February	—	—	—	—	—	—	—	—
March	—	—	—	—	—	—	—	—
April	—	—	—	—	—	—	19778	81
				IV- and V-group				
May					2	123	3046	83
June					22	135	7998	85
July					6	160	10312	90
August					11	180	8655	100
September					431	200	1426	120
October					520	200	606	140
November					207	200	323	140
December					20	200	105	140
January					—	—	—	—
February					—	—	—	—
March					—	—	—	—
April					—	—	—	—
				V-group				
May					—	—	8380	140
June					—	—	41900	140
July					—	—	41900	140
August					6	200	29330	140
September					30	200	—	—
October					30	200	—	—
November					—	—	—	—
December					—	—	—	—

* Data incomplete.

Table XII. Estimated annual yields which might have been obtained from the 1959 and 1963 year-classes by refraining from fishing 0- to III-group herring, and by starting the exploitation at six years of age (calculated from 1 January). $M_1 = 2.76$, $M_2 = 1.38$ and two alternative values of $M_3 = M_4 = M_5 = M_6$, i.e. 0.16 and 0.24 have been used to estimate N_6. Average values of $E = 0.64$ and $Z = 0.44$ are used for the period of exploitation (ANON. 1969).

Year	Average weight in g	Alternative 1			Alternative 2		
		No. by 1 Jan. $\times 10^{-6}$ N_n	Catch in no. $\times 10^{-6}$ C_n	Catch in thousands of metric tons	No. by 1 Jan. $\times 10^{-6}$ N_n	Catch in no. $\times 10^{-6}$ C_n	Catch in thousands of metric tons
1965	225	3959	902	203	2970	677	152
1966	242	2550	581	141	1912	436	105
1967	293	1642	374	110	1232	281	82
1968	302	1058	241	73	793	181	55
1969	317	681	155	49	511	116	37
1970	321	439	100	32	329	75	24
1971	334	282	64	21	212	51	17
1972	341	182	41	14	136	31	11
1973	364	117	27	10	88	20	7
1974	388	75	17	7	57	13	5
1975	388	49	11	4	36	8	3
1976	388	31	7	3	23	5	2
1977	388	20	5	2	15	3	1
Total		11085	2525	669	8314	1897	501
1969	225	1998	455	102	1514	345	78
1970	242	1287	293	71	975	222	54
1971	293	829	189	55	628	143	42
1972	302	534	122	37	404	92	28
1973	317	344	78	25	260	59	19
1974	321	221	50	16	168	38	12
1975	334	143	32	11	108	25	8
1976	341	92	21	7	70	16	5
1977	364	59	13	5	45	10	4
1978	388	38	9	3	29	7	3
1979	388	25	6	2	19	4	2
1980	388	16	4	1	12	3	1
1981	388	10	2	1	8	2	1
Total		5596	1274	336	4240	966	257