(BIOLOGY AND FISHERIES OF
THE NORWEGIAN SPRING SPAWNING HERRING
AND BLUE WHITING IN THE NORTHEAST ATLANTIC)

Proceedings of the fourth Soviet-Norwegian Symposium
Bergen, 12-16 June 1989

Ed. by Terje Monstad

Bergen 1990

Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
Murmansk

Institute of Marine Research
Bergen

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<div style="text-align: center">CONTENTS</div>

Blue whiting:

PREFACE

Many of the fish resources of the Norwegian Sea and adjacent waters
are shared betweewn the Soviet Union and Norway and both countries
accomplish scientific investigations on the fish stocks in this area.
To be able to coordinate this work, the Polar Research Institute of
Marine Fisheries and Oceanography (PINRO) in Murmansk and the
Institute of Marine Research in Bergen are developing a programme of
close cooperation, which is under the aegis of the Mixed Soviet-
Norwegian Fisheries Commision. As a part of this programme a series
of symposia have been planned, dealing with important aspects of the
fish stocks and their enviroment in the Northeast Atlantic.

This volume presents the contributions presented to the fourth of
these symposia, held i Bergen 12-16 June 1989, and delt with the
Norwegian spring spawning herring and the blue whiting stocks. The
three previous symposia focused on (1) the Artic cod, (2) the Barents
Sea capelin and (3) the effect of oceanographic conditions on
commercial fish stocks in the Barents Sea.

In addition to this version in the English language, the contri-
butions will also appear in a version in the Russian language
published by PINRO, Murmansk.

The editor of this version is responsible for some modest editorial
changes in some of the contributions in which it has not been possible
to obtain the authors approval. It is, however, believed that this has
not resulted in any change of meaning or in loss of clarity of the
paper. The final English text of all the Soviet contributions except
one, were in advance also given to the Soviet scientists.

The editor is indebted to Ole J. Gullaksen for review and revision of
the English grammar of the text.

<div align="center">
Bergen, October 1990

The editor
</div>

Section I: Life history.

LIFE HISTORY AND EXPLOITATION OF THE NORWEGIAN
SPRING SPAWNING HERRING

by

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ABSTRACT

This paper is a review of the history and exploitation of the Norwegian spring spawning herring stock. In a virgin state the biomass of this stock may have ranged from 15 to 20 million tonnes and it was the most important fish resource in the Northeast Atlantic. The adult stock utilized the rich plankton production along the Polar Front in the Norwegian Sea but spawned during winter on the Norwegian west coast. These spawners formed the basis for the largest fishery in Europe for centuries. The young and adolescent herring are distributed in Norwegian coastal waters and in the Barents Sea where they constitute the most important prey species for many stocks of predators, both of fish, birds and mammals.

Due to technical advances the exploitation of the herring increased tremendously in the 1960's and the adult stock was fished out completely in 1970. Some small components of juvenile herring did however survive, and spawned on the traditional spawning grounds in 1973. After spawning the herring did not migrate to the traditional feeding area in the Norwegian Sea, but remained in Norwegian coastal waters throughout the year. In later years the stock has recovered slowly, but the old traditional migration pattern of herring between the Polar Front area and the Norwegian coast has not yet been retained. It is concluded that the break down of the life cycles of the herring is the prime reason for the recent crisis which has developed in the Barents Sea stocks and fisheries.

INTRODUCTION

The present paper reviews the history of the fishery and research on
the Norwegian spring spawning herring and the regulation measures
introduced to conserve the stock in recent years. In conclusion
emphasis is laid on the importance of the stock for the balance in the
predation/prey relationship in the ecosystem of the Norwegian Sea and
Barents Sea.

STOCK IDENTITY

The term "Atlanto-Scandian herring" was introduced by Johansen (1919)
and is used as a common name for three stocks: Norwegian spring
spawners, Icelandic spring spawners, and Icelandic summer spawners.
The Norwegian spring spawners are the largest of these stocks, with
spawning grounds situated mainly along the Norwegian coast.

STOCK STRUCTURE

Whether the Norwegian spring-spawning herring constitute a single
homogeneous stock has been the subject of conflicting scientific
views. Broch (1908) found that the vertebral counts of the spawners
were not the same throughout the total distribution range. Lea (1929)
observed that the scales of young herring from northern and southern
Norway differed in the pattern of their winter rings, reflecting
differences in their growth rates during adolescence. In the light of
such differences, Schnackenbeck (1931) concluded that the Norwegian
spawning population was divisible into at least two "races", and
Ottestad (1934) splitted the stock into a northern and a southern
component with spawning grounds to the north and south of Møre
respectively. Runnstrøm (1937,1941), on the other hand, claimed that
such a strict separation was not consistent with the available
evidences.

Østvedt (1958) found that there was an increasing intermixing of the
two types with age, and that the proportions of the two types varied
considerably between year classes. He concluded that herring of the
two growth types could not be members of different "races". The
results of the tagging experiments carried out on the Norwegian
spawning grounds and in the oceanic feeding areas (Dragesund and
Jakobsson, 1963) also show that the spawners change their grounds from
year to year along the Norwegian coast. In light of all the available
evidences it is therefore reasonable to assume that the Norwegian
spring spawners are members of a single stock and that the two
distinctive growth types are herring which originate from different
nursery areas.

DISTRIBUTION AND MIGRATION

1. Adult herring

Knowledge of the distribution and migration of the adult herring is
obtained from several sources, such as racial analysis (Fridriksson,
1963), tagging experiments (Fridriksson and Aasen, 1952; Jakobsson,
1963) and acoustic surveys (Devold, 1963; Anon., 1964; and Jakobsson,
1971). For many years these surveys were carried out jointly by
Denmark, Iceland, Norway and the USSR.

2. Herring periods

For centuries this herring has been the basis for one of the largest fisheries in Norway, and for more than 100 years the subject of scientific investigations. In 1857 the Norwegian Government gave Dr.Axel Boeck (1871) the task of investigating the so-called "spring herring". Boeck brought together many historical facts about the Norwegian spring herring fishery and he found that the fishery had periods of high abundance alternating with periods of extreme scarcity. According to Boeck, the symptoms of a Norwegian herring period approaching its end are that the herring arrive later each year at the Norwegian coast, which had been the situation in the 1870's. Boeck found similar periodicity in the herring fishery of Bohuslän in Sweden and suggested that this fishery could originate from the Norwegian spring spawning herring stock. Boeck's view that the spring herring could leave the usual spawning grounds created great fear among the fishermen, and the Norwegian Government asked G.O. Sars to investigate this problem.

After three years of investigation G.O.Sars succeeded in drawing a fairly correct picture of the life history of the Norwegian herring. He believed that the "spring herring" lived in the surface layers of the open sea between Scotland, Norway and Iceland, feeding on copepods, and attaining maturity when being about 6 years old. The spawning area was located off the Norwegian coast between Stavanger and Kristiansund, from which the larvae were spread northwards by the currents. In the years 1868-1874 great quantities of so-called "large herring" were caught off northern Norway in the autumn. Originally he regarded the "large herring" as a special tribe with unknown spawning grounds but later he found that the connection between the "spring herring" and "large herring" fisheries was closer than he earlier believed. With respect to alternating herring periods, G.O. Sars views were differed from those of Boeck. Sars had found juvenile herring further off the coast than was usual and considered it likely that the herring would soon return to the old spawning grounds. He questioned whether herring periods really did exist in the Norwegian herring fisheries and thought it unlikely that there should be any connection between the "spring herring" and the herring responsible for the great herring fisheries in Bohuslän.

Jensen (1881) and Buck (1888) continued the herring studies in the following years and described the herring on the west coast as "new herring" consisting of a mixture of immature and mature herring which in size became similar to the spring herring. The herring spawned on the usual spawning grounds but was far less abundant as before 1870.

The mature herring found in shallow areas off northern Norway in 1868-1874 were investigated by Boeck and Sars and were described as herring of the same size as the "spring herring", but in much better condition. The ovaries showed that they were not ready to spawn. In December, the "large herring" disappeared from northern Norway but their spawning ground was never observed.

During the winter of 1877, great schools of herring were discovered penetrating the Bohuslän skerries, and for 20 winters in succession, a great herring fishery was carried out there. The herring had been absent since 1808, but similar fishing periods in this area are traced back in history for about 1000 years, and it looks as if the Bohuslän and Norwegian "spring herring" fishing periods occured alternately. At the time of the Bohuslan fishery, herring fisheries also grew up on

the Norwegian side of the border to Sweden (Ljungman, 1882; O. Pettersson, 1922; Devold 1963).

During the winter of 1895-96 Norwegian fishermen caught great quantities of large herring in the Skagerak for the last time. It was also the last winter in which great herring fisheries occurred inside the skerries in Bohuslän. The following winter herring concentrations along the coast of western Norway were of the same magnitude as in the good fishing winters before 1870 (Buvik, 1895-99).

In the autumn of 1896 onwards, great schools of herring were discovered off Møre. They were called "large herring", and an extensive herring fishery began on them. These herring schools disappeared before Christmas, but in January new schools arrived and moved southwards along the coast and were later caught from Haugesund southwards to Lindesnes. These schools were called "spring herring". In the beginning of this century the herring fisheries had two seasons, one based on the "large herring", the other on the "spring herring". The large herring arrived each year later in the coastal waters and after 1921 no herring arrived in the Møre region before the 1st of January. In the 1930's the herring spawned in early February, whereas the spawning in the 1950's took place in early March. Simultaneously the distribution area decreased and the center of spawning moved northwards. The spawning grounds south of Bergen were abandoned in the late 1950's, and in later years the spawning has been concentrated on the coast from Møre to Lofoten (Devold, 1963).

The simultaneous changes in the spawning time and in the displacement of the spawning grounds northwards gave rise to a renewed discussion of alternating herring periods between the rich Bohuslän fishery and the winter herring fishery on the Norwegian west coast. In a series of articles and publications in the 1950's Finn Devold supported the theory of alternating herring periods and predicted that the displacement of the spawning grounds and the delay in the spawning time indicated the end of the herring fishery on the Norwegian west coast (Devold 1950,1955,1959,1960,1963,1964). Devold also developed an hypothesis which explained the processes which governed the relation between the spawning behaviour and the migration. His basic assumption was that it takes a little more than one year between successive spawnings. The herring will then arrive at the Norwegian coast later each year and also leave the coast later. When post spawners are leaving late, they have to pass the area on the Norwegian continental shelf after the copepods have entered surface layers, in April. The herring will therefore start feeding here and will move northwards off the Norwegian coast.

In the autumn, the herring used to migrate to the cold arctic water in the East Icelandic Current for wintering. Being off northern Norway they will be far from the arctic water of the East Icelandic Current. Cold water will, however, be available near the Norwegian coast, where the winter cooling of the coastal waters will have started, and these waters will therefore be invaded for wintering. Since the temperature of the coastal water of northern Norway is higher than that of the East Icelandic Current, the gonads of these herring will develop faster and spawning will take place earlier than in the preceding season. After spawning these herring will leave the Norwegian coast early, and return for feeding along the Polar Front earlier than usual. The next autumn their spawning migration will therefore start early., and the migrating schools will have to pass through water masses of a higher temperature than usual. The Norwegian coastal

waters off Møre, where the herring usually arrive, have a surface
temperature above 10⁰C in the autumn. The herring will avoid this warm
water and move toward the Baltic water of a temperature of six to
seven degrees. The herring may then pass through the Norwegian Channel
into the Skagerak, and spawn off the Norwegian south coast, and off
Bohuslän. After spawning the herring invade the coastal areas of
Bohuslän, and the south-east coast of Norway where they spend the
"resting time" in cold water. The delay in spawning time by years will
however increase the chances that the herring meet cold Baltic water
in the Skagerak on the spawning migration. If the Baltic water is too
cold, the herring will find warmer spawning grounds further west. If
the herring have to leave a spawning ground and find a new one, they
will return to this new ground for the succeeding spawnings. In this
way the herring are driven out of the Skagerak, and later also have to
avoid the southern spawning grounds in western Norway. In this way
rich herring periods of the Bohuslän and of the Norwegian west coast
may alternate and the hypothesis also explaine the intermediate
occurrence of the "large herring" wintering in the north Norwegian
fjords.

Devolds hypothesis was strongly opposed by Swedish scientists
(Andersson 1950, 1956, Høglund 1959,1960,1977). Based on size and age
composition analysis of the Bohuslän herring, they claimed that this
stock had no connections with the Norwegian spring spawning herring,
but was related to tribes which were ususally fished in the North Sea,
Skagerak and Kattegat.

The Norwegian west coast herring fishery collapsed in the 1960's due
to depletion of the stock by the fishery. The feeding migration to the
Polar Front area was interrupted in the early 1970's, and in the
subsequent years the postspawners have been feeding off the Norwegian
coast and have wintered in the Norwegian fjords as presupposed by
Devold's hypothesis. The maturing of the herring has, however, not
developed as predicted. The herring have matured in February-March as
they did in the 1960's and have spawned on the traditional spawning
grounds from Møre to Lofoten. In 1989 a small component also spawned
on the southern grounds for the first time since 1959, and this
spawning took place rather late in the spawning season (first half of
March).

3. Migration pattern

The migration of the adult herring stock is recorded in detail since
the early 1950's. After spawning most of the spent herring moved
northwestwards into the Norwegian Sea where they fed on zooplankton.
The larger fish reached the Polar Front in June and July and some
crossed into the cold water. The limit of the summer feeding migration
extended from the Spitsbergen-Jan Mayen area in the north to the
western borders of the East Icelandic Current in the south. The larger
fish moved further to the northwest than the smaller fish (Marty,
1959; Marty and Wilson, 1960).

During the autumn the herring was found in the southwestern part of
the Norwegian Sea along the borders of the East Icelandic Current. The
ripening herring wintered in an area off East Iceland. In December and
January prespawning concentrations moved towards the Norwegian coast.
Devold (1951,1959,1963) described in detail the spawning migration
towards the coast in the 50's. He found that the herring gather in
cold-water pockets before penetrating the warm Atlantic Current into
the colder Norwegian coastal water. The herring usually arrive at the

Norwegian coast off Møre and spread farther south and north to spawn.

This description of the distribution and migratory pattern of the
adult stock refers to a state when the stock was at a relatively high
level. Between 1950 and 1962 the stock declined. The spawning was
gradually displaced northwards, and after 1959 spawning south of
Bergen was negligible (Devold,1963; Dragesund, 1970). In 1950-1962 the
main summer feeding grounds varied somewhat but remained in the
Iceland-Jan Mayen area, but in 1963-1966 a stock component fed and
wintered in an area south of Bjørnøya (Fig.1). The densest summer
concentrations were usually found near the borders of the East
Icelandic Current. In the autumn the herring assembled on the
wintering grounds situated near the southern and southwestern borders
of the East Icelandic Current.
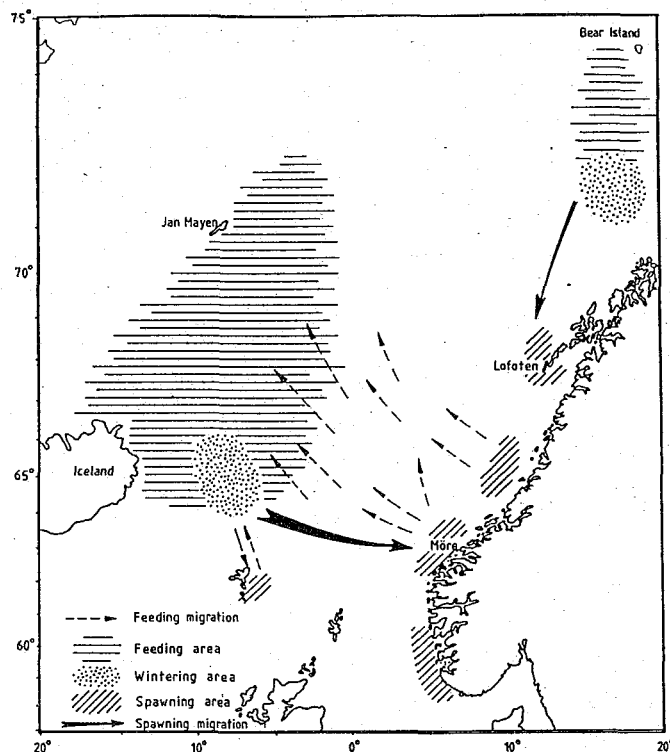
Fig. 1 Migration of Norwegian spring spawning herring prior to 1970.

4. Migration pattern after 1970

The summer and autumn fishery for adult herring terminated in 1969,
and since then no herring have been recorded in the Polar Front area
of the Norwegian Sea. The winter herring fishery on the spawning
grounds decreased sharply after 1967 but continued on the depleted
stock until 1971. The stock of immature herring was almost depleted in
1969, and immature fish recorded in the early 1970's belonged mainly
to the 1969 year class.

The use of herring for reduction purposes was prohibited in Norway
from January 1971. This regulation probably prevented the complete
extinction of the 1969 year class. Purse seiners fishing for capelin
reported concentrations of young herring off the coast of Finnmark
during the winter of 1971, and several catches of fat herring were
released that year because of the ban on the industrial fishery. This

last remnant of the stock probably survived as juveniles somewhere in
the Barents Sea or in the northeastern part of the Norwegian Sea.

In 1972, five purse seiners were chartered to survey the spawning
grounds. Practically no spawning herring were recorded (Dragesund,
Bjerke, and Sangolt, 1972). The absence of spawning herring and
herring larvae in 1972 and the very low abundance of the 1970-1972
year classes in the spawning stock demonstrates that the adult stock
of Norwegian spring-spawning herring collapsed in the early 1970's.

In November 1972 shoals of maturing herring were recorded off western
Finnmark (in the Ingøy Deep), and in January 1973 a Norwegian purse
seiner located herring shoals some 50 nm northwest of Ingøy. Most of
these herring belonged to the 1969 year class, and were obviously on
their way to the coast to spawn. Maturing herring of the 1969 year
class were found, later in 1973, off Vesterålen and Lofoten. These
herring probably spawned in the Lofoten area in March, because herring
larvae were found there in April. The traditional spawning grounds off
Møre and Trøndelag were surveyed throughout the spawning season in
1973. No concentration of spawning herring was found, but gill-net
catches of herring with running gonads indicated that some spawning
took place. This was later confirmed by the larval survey that year.
The spawning stock off Møre was also dominated by the 1969 year class
(Dragesund, Bjerke, and Sangolt, 1973).

Two components of immature herring survived the heavy exploitation in
the 1960's, one in the Barents Sea and the other on the west coast of
Norway. Both components spawned for the first time in 1973, one off
the Møre coast, the other off Lofoten. According to recordings of
maturing herring in 1973, the northern component was by far the
larger. After spawning, the herring did not leave the coast as in
previous years, but migrated into inshore waters to feed during summer
and autumn. No spawning was observed off Lofoten in the winter of
1974. The northern component migrated southward, and since 1974
spawning has taken place on the traditional spawning grounds off Møre
and Trøndelag (Dragesund et.al 1980).

The traditional migration pattern of the herring was thus interrupted
in the early 70's and has not yet been retained. The two stock
components have developed as separate units, with different spawning
grounds, feeding areas and wintering localities (Figure 3).

The southern component has spawned on the southern coast off Møre and
some years also further south. As already mentioned, shoals of
spawning herring were in 1989 recorded on the southern spawning
grounds in the beginning of March. These grounds have been abandoned
by the herring since the late 1950's. The southern component has fed
during summer and autumn off the coast of Møre and Trøndelag, and
wintered in the fjords of northern Møre. The southern component has
usually left the wintering area in late January and arrived at the
spawning ground in the early February. Growth rate, recruitment and
age structure of the herring indicate that this stock component has
developed as a separate unit. This is also supported by the recovery
of tagged herring. The southern component of spring spawners has to
some extent been mixed with autumn spawners and herring from local
stocks which spawn in the fjords.

The northern component has spawned in the area from northern Møre
(Buagrunnen) to Lofoten. This herring has spawned some weeks later
than the herring of the southern component. The northern component has

also fed on the Norwegian shelf during summer and autumn, but more
offshore and farther north. The shoals have moved northwards during
the summer and have usually been found off Lofoten in the early
autumn. In September they have migrated into the Vestfjorden area and
wintered in the fjords of Lofoten and Vesterålen. The herring have
returned to the same fjords every year but when the abundant Barents
Sea component of the 1983 year class migrated to the coastal area for
wintering in the autumn 1986, the wintering area was expanded to
include several new fjords in the same region.

In the years 1988 and 89 most of the 1983 year class wintered in the
inner part of Vestfjorden. When the 1983 year class recruited to the
spawning stock the separation of the herring in two different stock
units disappeared. Tag returns from the winter fishery in 1989 do,
however,indicate that the Barents Sea component of the 1983 year class
has invaded all spawning grounds on Møre, whereas the herring from the
Møre-Trøndelag area are displaced to spawning grounds farther to the
south (Fig. 3B).

5. Distribution of young and adolescent herring

Until the beginning of the 1960's little was known about the
distribution and migration of the early stages of Norwegian spring
spawners. 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 part of the total
0-group population entered the Norwegian fjords. From later
investigations it can be stated that the distribution of the young and
adolescent herring is widespread, ranging from the fjords of northern
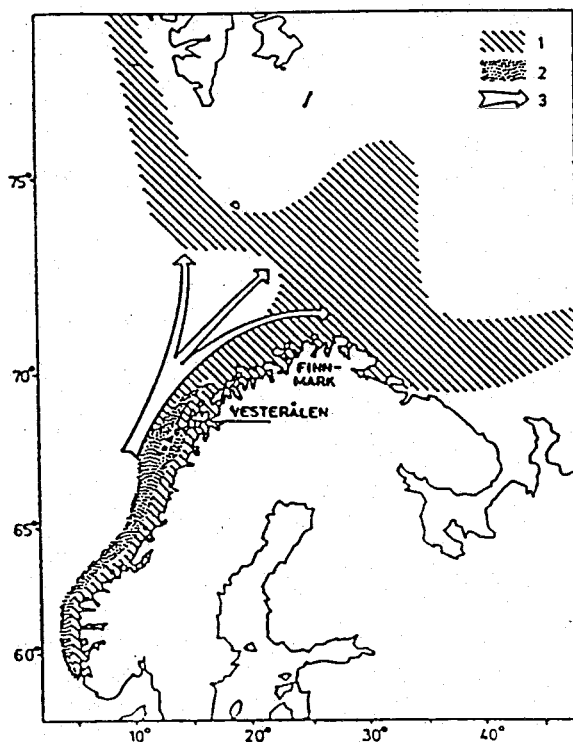
Fig. 2. Distribution of young herring. (1) nursery area, (2) larval
        distribution, (3) direction of post-larval drift to the
        offshore nursery area.
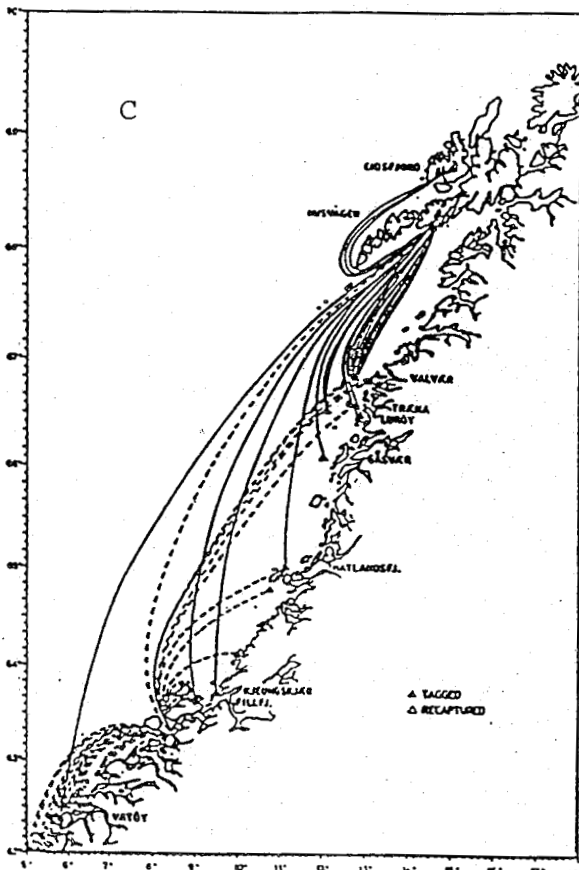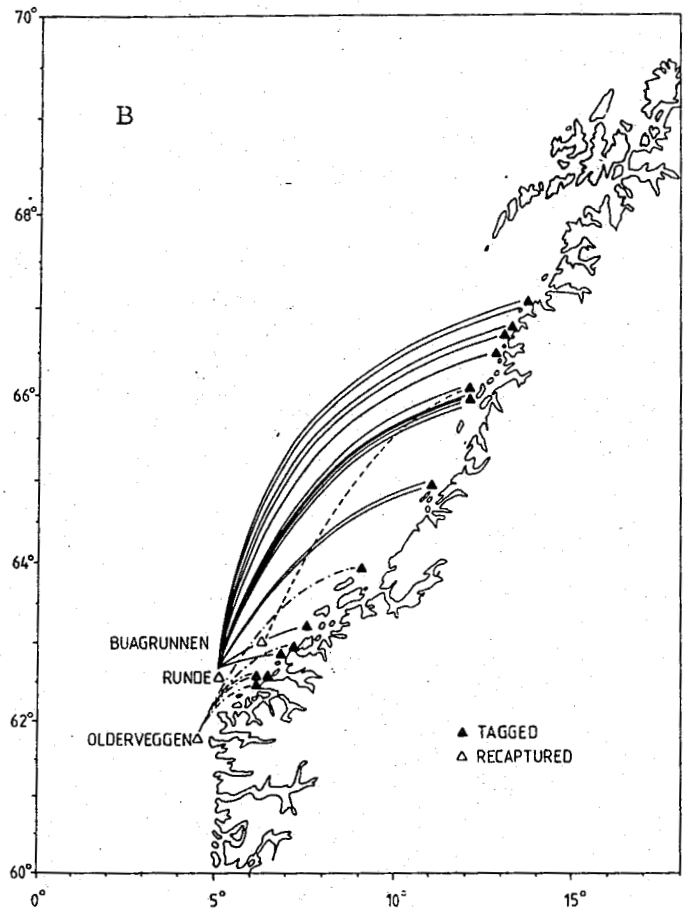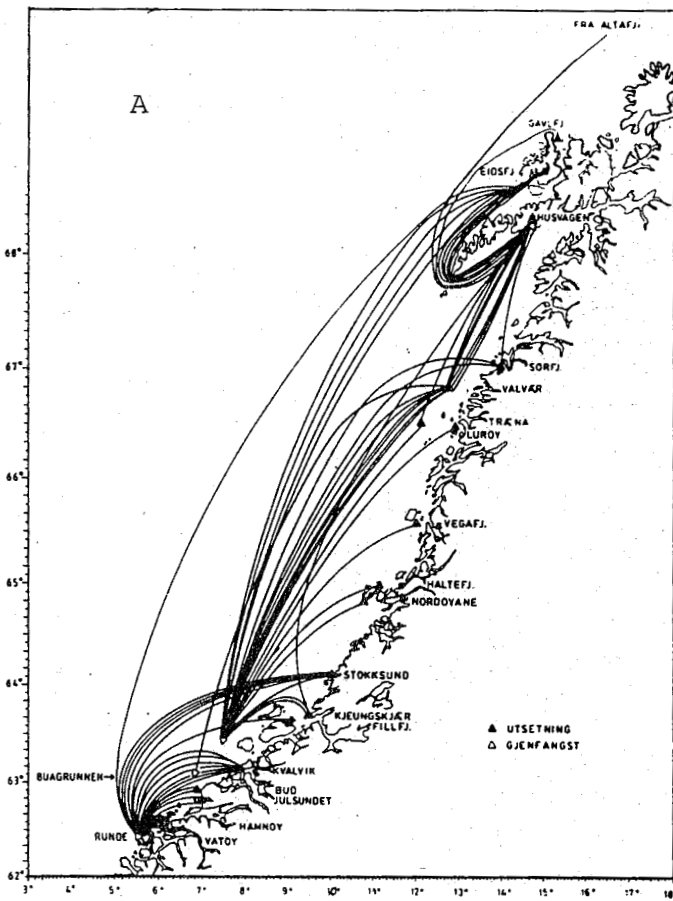
Fig. 3. Distribution of tag returns. A= returns from the winter fishery in 1979, B=returns from the winter fishery in 1989, C= returns from catches taken in the northern and southern wintering areas of the herring during late autumn.

Norway to the open ocean of the Norwegian Sea and the Barents Sea
(Dragesund and Hognestad, 1960; Devold, 1968; Jakobsson, 1968;
Dragesund, 1970). When recruitment conditions are favourable, most of
the juvenile herring are found in the Barents Sea (Røttingen, 1987).

Figure 2 shows a schematic illustration of the general distribution of
the early stages. Soon after hatching, the larvae rise into the upper
water layers and are transported northwards from the spawning grounds.
During the northward drift, part of the larvae accumulates at the
entrance to the fjords along the Norwegian coast. In late summer and
early autumn 0-group herring are generally recorded in the top water
layers along the Norwegian coast and in the Barents Sea (Dragesund,
1970; Anon., 1970). The offshore distribution is, however, more
variable and is closely related to year class strength, and hence the
inflow of Atlantic water to this region (see section 5).

In late autumn a major part of the 0-group in offshore waters is
concentrated along the fronts between the cold arctic water and the
warmer water masses off the Spitsbergen-Bear Island and in the central
and southeastern parts of the Barents Sea. The herring remain in this
area during the following winter and spring. During spring and early
summer, the I-group herring distributed in the northern and
northeastern part of the Barents Sea move southwards. At the same
time, herring of the same age, which have wintered in the fjords of
northern Norway, migrate from the coast and mix with the open-sea
concentrations. During the following winter the 2-group herring are
found in almost the same area, although the distribution is more
restricted to coastal banks and to the central and southern part of
the Barents Sea.

During summer and autumn part of the 2-group herring, the fastest
growing fish, move westward into the Norwegian Sea. However, most of
the fish remain in the Barents Sea and in the area off Finnmark for
another year before they start the westward migration into the
Norwegian Sea to join the adult stock. The slowest growing fish start
their emigration from the Barents Sea during the 4-group stage. The
adolescent herring moving into the Norwegian Sea usually have an
oceanic stage before they mature. Some individuals mature after one
year, others after two or three years (Dragesund et.al 1980).

This distribution and migration pattern of young and adolescent
herring in the Barents Sea is in accordance with the observations of
the movement of the 1983 year class (Røttingen, 1989). The coastal
component of the 1983 year class from the fjords in Finnmark mixed
with the Barents Sea component in 1984 and the mixed stock left the
Barents Sea during the spring and the summer 1986. Most of these
herring had a one year oceanic stage before they matured and spawned
for the first time in 1988. In 1963-66 the 4-years old immature
herring wintered in the Bear Island wintering area, but most of the
1983 year class wintered as immature in Vestfjorden as 4 year olds.

RECRUITMENT AND AGE COMPOSITION

The age structure of the adult herring stock has been known since the
beginning of this century (Hjort, 1926). In a virgin state, the life
span of herring is about 20-25 years. The maturation of a year class
takes place about some five years, which means that the adult stock
may consist of as much as 15-20 year classes. The recruitment is more-
over variable and these factors govern the age structure of the stock

and the stability of stock abundance. The age composition of herring
from 1908 onwards compared with general information on stock abundance
indicate that the stock recovered gradually at the end of the previous
century. An extraordinary strong year class was recruited in 1904
which may have rebuilt the spawning stock to a level of 5 to 10
million tonnes in the second decade of this century (Marty and
Fedorov, 1963). Three rich year classes occured between 1900-1930, the
year classes 1904, 1918 and 1923. The 1930's constituted a period of
good recruitment and only the year classes 1931 and 1936 were poor. In
the 1940's there were three rich year classes, those of 1943, 1944 and
1947 and another very abundant year class occurred in 1950. According
to Marty and Fedorov the periodicity of occurrence of abundant year
classes ranged from one to 14 years, whereas a seven years interval
had been typical from 1923 to 1950. The autors also showed that the
occurrence of abundant year classes coinsided with increasing inflow
of warm water to the Barents Sea, which affects the mean Kola Meridian
temperature. In a recent paper Sætersdal and Loeng (1984) have shown
that a similar correlation does exist between the temperature of the
Kola Meridian and recruitment success for Northeast Arctic cod.

Since 1950 abundant herring year classes have occurred in 1959 and
1960 coinsiding with a warm climate in the Barents Sea. In the early
70's, another warm period occured, but at that time the spawning stock
of herring was depleted. In relation to spawning stock the herring
year class 1973 was known extra-ordinary strong. The late 1970's was a
cold period in the Barents Sea. The climatic conditions improved in
the early 80's and strong year classes were recruited in the years
1983-85. The herring year classes 1984-85 were however depleted by
increased predation from a very strong 1983 year class of cod.
Recruitment after 1985 has been poor.

Plots of VPA-estimates of recruitment versus spawning stock biomass
are shown in Figure 10 for the years 1950 onwards.The VPA figures are
derived from the catch in number by year classes adjusted by a
constant natural mortality by age groups. Variations in the mortality
due to predation or other forms of stock interactions have not been
accounted for. Judging from the stock interrelationship observed in
recent years it is assumed that these recruitment figures are grossly
underestimated, particularly the recruitment in warm periods when the
cod have had favourable recruitment conditions. The stock-recruitment
plot demonstrates a linear releationship between stock biomass and
recruitment when recruitment conditions are favourable. When using
catch-related recruitment figures, this applies to the first year
class which is recruited in a good recruitment period. The year
classes of the subsequent years may however also have been abundant
as 0-group herring, but may have been reduced at a young age by
predation from abundant year classes of cod.

EXPLOITATION

The main fishery on adult herring has been the winter herring fishery
during the spawning season. In the period 1925-1960 the winter herring
catches were shared about equally by purse seiners and drifters.
Earlier in this century the land seine was also extensively used.
Originally the purse-seine fishery was carried out by vessels equipped
with a purse seine operated from two dories. The ring-net technique
with power block replaced the two-dory system in the early 1960's, and
most of the herring has been caught by this technique in later years.
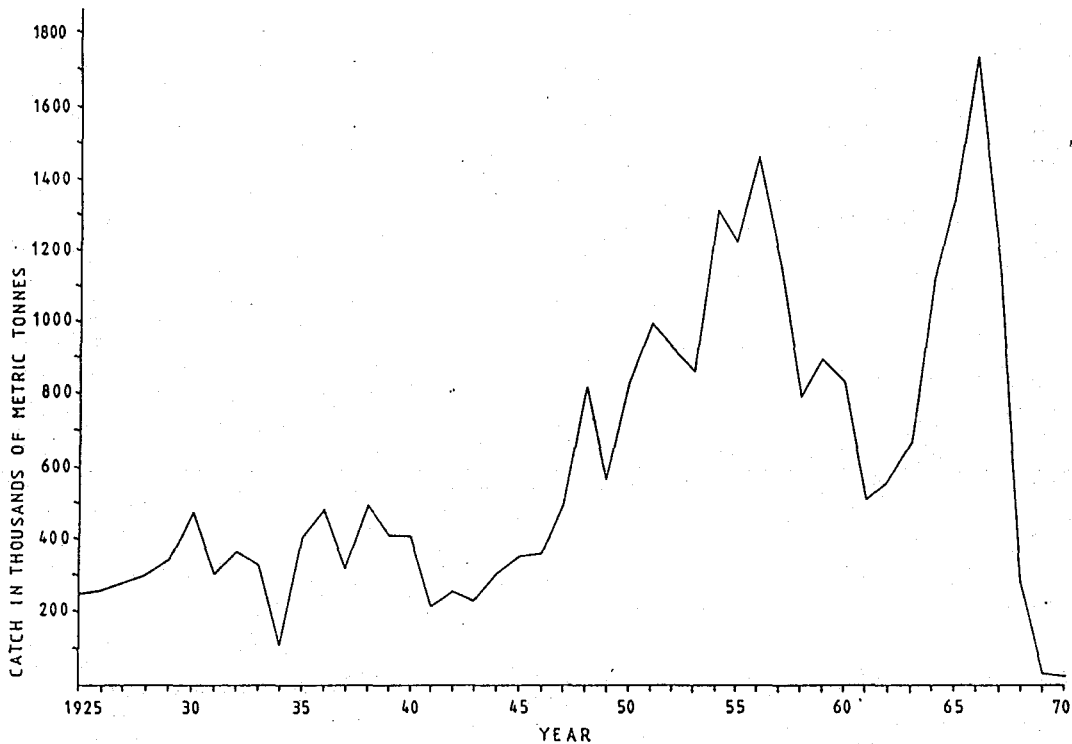
Fig. 4. Total catch of adult herring 1925-1970.

The annual catches from the adult herring fishery over the period
1925-1970 are shown in Figure 4. Details of the herring catches 1950-
1988 are given in Table 1. Although the catches fluctuated
considerably, they did not show any major trend up to 1947. Thereafter
the catches rose steadily to about one million tonnes in 1954-1956,
when the rich 1950 year class started to recruit to the spawning
stock. The catches then fell steadily, up to 1963, to a level near
that of the poorest year of the prewar period. There was a recovery in
1964 when the rich year classes of 1959 and 1960 entered the stock.
From 1965 onwards a rapid decrease in the stock size took place, and
the winter-herring fishery collapsed in 1970.

The summer and autumn fishery on adults, took place on the feeding
grounds along the Polar Front in the Norwegian Sea. This fishery was
located for a long period off northern and northeastern Iceland
(Jakobsson, 1963). The fishing season normally lasted from June to
early September, and up to 1950 the stock was mainly exploited by
Icelandic and Norwegian vessels.

In the early 1960's new technical advances improved the technique in
the Icelandic fishery, as they did in the Norwegian herring fishery,
and the fishery extended seawards. During the 1960's the fishery took
place far offshore in the Norwegian Sea, and the fishing season lasted
until October-November. In 1966 when the record catch of adult herring
was taken, Iceland caught 40% whereas Norway and USSR caught about 30%
of the total catch each (Table 2).

The Soviet driftnet fishery on feeding herring in the Norwegian Sea
started in 1950. Initially, the fishery was purely a summer one,
exploiting the grounds between Spitsbergen, Jan Mayen, and Iceland. In

1952 an autumn and winter fishery started along the migratory routes
of the prespawning concentrations towards the spawning grounds off the
Norwegian coast.

The change in the migratory pattern of the adult stock during the
1960's strongly influenced the location of the summer and autumn
fishery. Off Iceland it became negligible and most of the summer and
autumn fishery in the 1960's took place off the shelf south and, west
of Bear Island-Spitsbergen. From the 1970's onwards most of the
herring has been caught in Norwegian coastal waters within a range of
some 20 n.m. off the coast.
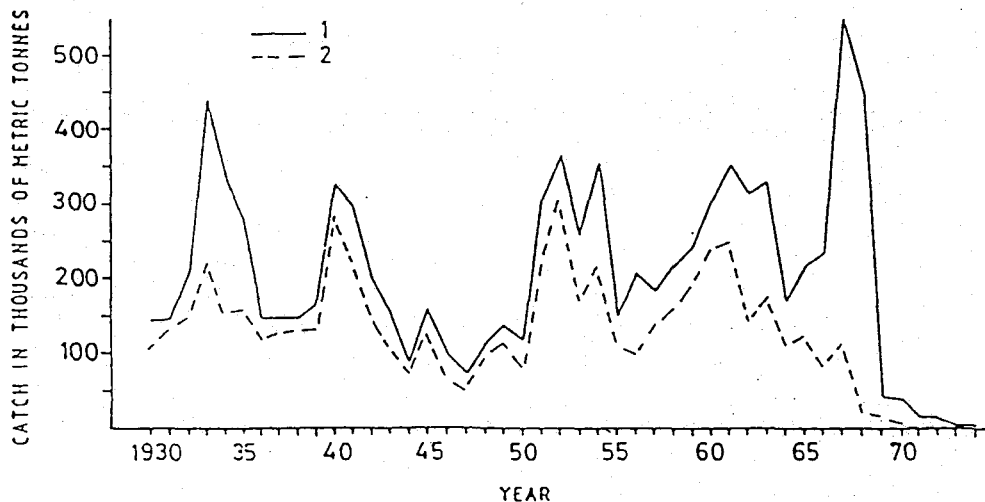
Fig. 5. The catch of young and adolescent herring. (1) the
        total catch, (2) the catch of small herring.

In addition to the fishery on adults, the young and adolescent herring
were fished at the Norwegian coast and in the fjords (Figure 5).
Almost all the catches were taken with purse seine, and from 1964
onwards the ring-net technique was used and the efficiency increased.
The most important small-herring fishery occurred in the fjords from
late autumn to early spring.

STOCK ASSESSMENT

The abundance of the Norwegian spring spawning herring stock has been
assessed by various methods. Marty and Fedorov (1963) assessed the
stock abundance and year class strength for the period 1904-1960 on
the basis of catch by year classes in succesive years after a method
developed by Denzhavin (1922). Dragesund and Jakobsson (1963)
estimated stock size and total mortality rate for the period 1953-1960
on the basis of tag returns from internal tagging experiments and
Østvedt (1963) estimated total mortality from catch and effort data in
the driftnet fishery for the period 1950-1960. The ICES Working Group
on Atlanto-Scandian herring (hereafter termed the Working Group), has
in two reports (Anon. 1970, 1977) assessed the state of the stock for
the period 1953-1959, using data from various sources. A conventional
VPA for the years 1950-1971 is published by Dragesund and Ulltang
(1978) and the results of a somewhat adjusted version of this are
shown in Figure 7 (Dragesund et.al 1980). The ICES Working Group
results are included for comparison. In the period 1975 onwards, the
stock has been assessed by VPA, tagging and acoustic methods.
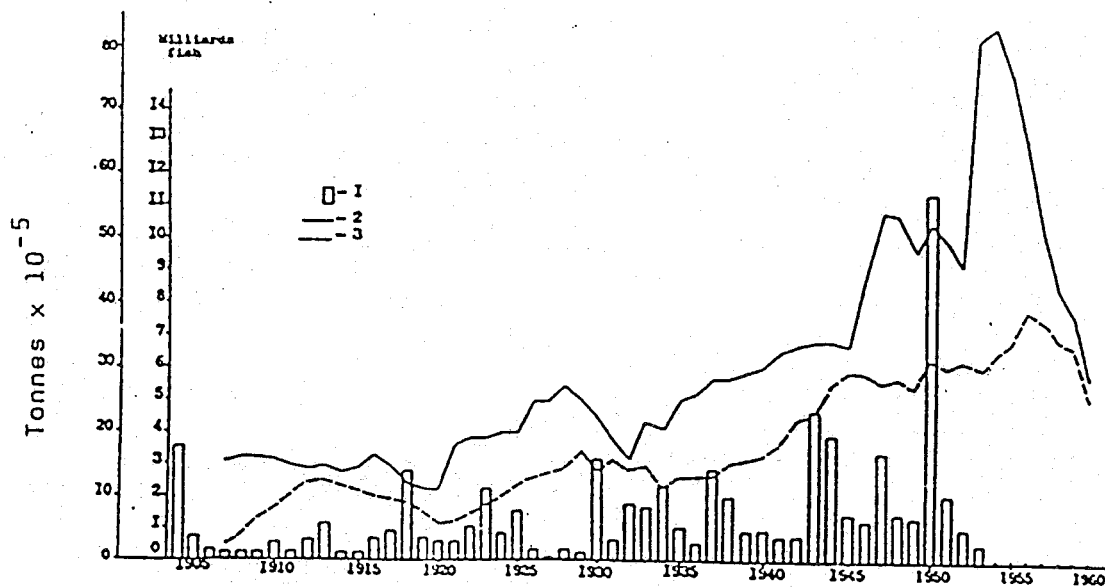
Fig. 6. (I) Abundance indices of some year classes of Norwegian
        spring spawning herring in billions of fish, stock values
        of herring from three year olds and older, (2) mature
        herring, (3) by years in million metric centners (Marty
        and Fedorov 1963).
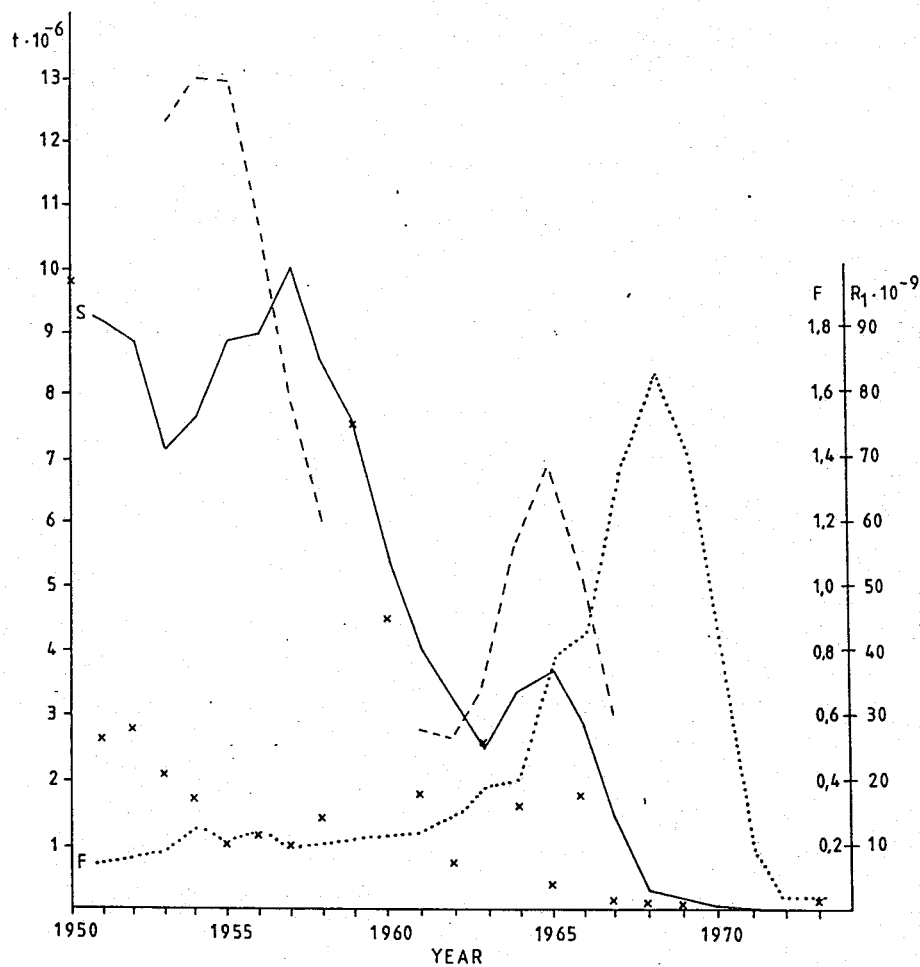
Fig. 7. Estimated spawning stock (S), fishing mortality (F) and
        recruitment (X) of herring 1950-1973 as 1 year old. The
        broken line shows stock estimates given by the Working Group.

The stock abundance estimates of herring older than 3 years for the
period 1904 to 1960 are shown in Figure 6 (Marty and Fedorov, 1963).
The natural mortality has not been accounted for in these estimates.
According to this method, the accumulated catches ranged between 1.5
and 2.0 mill. tonnes prior to 1925. Assuming that the fishing
mortality at that time was lower than the natural mortality, Marty and
Fedorow found that the standing stock biomass must have been five to
six times greater than the accumulated catch figures or in an order of
magnitude of 10 mill. tonnes. For the 1950's the Dezhavin's method
gave a stock estimate of 7 to 8 mill. tonnes. Assuming that the
fishing mortality in the 1950's was 5 times higher than the natural
mortality the author concluded that the stock may have remained on a
steady state level of an order of magnitude of 10 mill. tonnes
throughout the whole period under study.

According to the VPA (Figure 7), the spawning stock size was at a
level of about 9 million tonnes in 1950 and decreased to about 7
million tonnes in 1953. From 1954 to 1957 the strong 1950 year class
gradually recruited to the spawning stock, resulting in an increase in
stock size to about 10 million tonnes in 1957. The stock then
decreased to about 2.5 million tonnes in 1963 mainly as a result of
poor recruitment. From 1963 to 1965 the spawning stock size increased
again, reaching about 3.7 million tonnes in 1965. From 1966 onwards
there was a rapid decrease in spawning stock size owing to an almost
complete lack of recruitment to the adult stock and rapidly increasing
fishing mortalities. The rise in F during the years 1963-1966 was
caused by increasing fishing effort, but the further large increase in
F in 1967 onwards was probably mainly the effect of decreasing stock
size caused by both the increase in fishing mortality in previous
years and the failure in recruitment (Ulltang 1976).
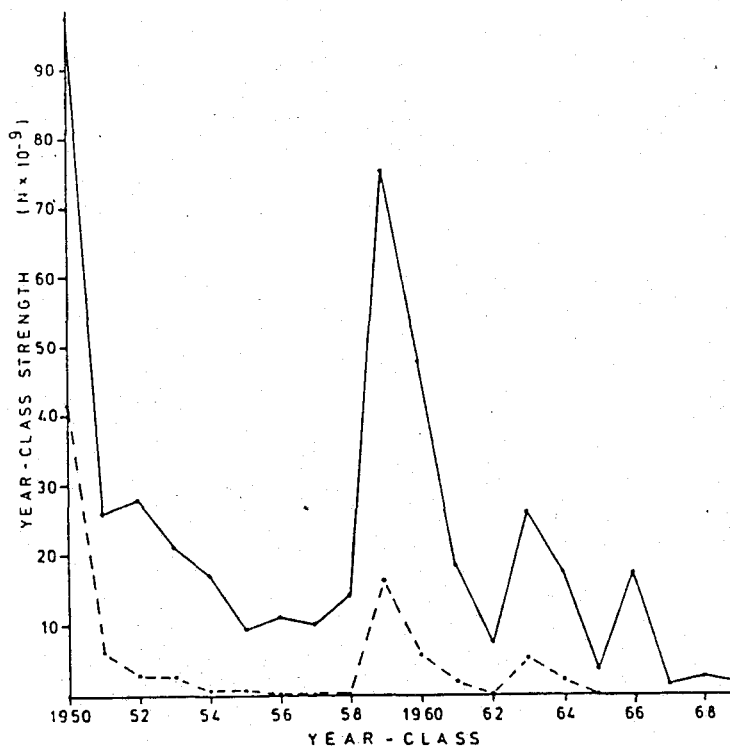
Fig. 8. Year-class strength in number as 0-group and 4 year olds
        (broken line), 1950-1969 (Dragesund et al. 1980).

Comparing the present estimates of stock size and rate of exploitation
of adults from VPA with earlier Working Group estimates, it can be
concluded that the Working Group assessed the situation more or less
correctly until the rapid increase in fishing effort started in the
early 1960's, i.e. before the introduction of the ring-net technique.
Thereafter the Working Group badly overestimated the stock size.

The exploitation rate of young herring was also high during the period
1950-1969. In Figure 8 are given the VPA estimates of year class
strength as 0 and 4 years old in the period. The Figure shows that
year classes in the 1950's which have traditionally been described as
weak, were all of what could be called normal strength $10 \cdot 10^9$ to
$30 \cdot 10^9$ fish at the 0-group stage. However, year class of strengths
less than $20 \cdot 10^9$ as 0-group survived the fishery only in small
quantities to reach the age of 4 years. The 1965 year class was the
first one in the period studied which really should be classified as
weak at the 0-group stage (Dragesund and Ulltang, 1978).

The VPA clearly shows that the fishing pressure, on young and
adolescent herring in general and on adult herring in the years 1965-
1968, was the primary factor in the collapse of this herring stock. As
mentioned previously some few herring of the 1969 year class survived
as juveniles in the early 1970's in the Barents Sea and some very few
survived on the Møre coast. These stock components have in later years
been assessed by an acoustic method and by tagging as adults. An echo
abundance survey of 0-group herring in the Norwegian fjords were
initiated in 1975 and extended to cover the distribution area of
0-group herring in the Barents Sea since 1983. The survey are carried
out in November-December and the technique used is the same as that
applied for capelin (Nakken and Dommasnes 1975). The results appear
from the text table below:

Year	Coastal comp.	Barents Sea
1975	1.0	
1976	3.8	
1977	0.4	
1978	1.2	
1979	3.4	
1980	0.2	
1981	0.2	
1982	2.9	
1983	13.7	35.7
1984	1.4	6.2
1985	1.0	41.5
1986	0.4	0
1987	0.3	0
1988	2.5	9.8

These recruitment figures are not comparable to the back calculated
recruitment number of 1-group herring (R_1) derived from the VPA. In
the stock prognosis the acoustic 0-group estimates have been used as
indices of recruitment at age 3 by scaling the number down by a
calculated conversion factor of 0.51 (Anon. 1986).

Compared to the period before the stock collapse in the late 1960's
the recruitment in later years has been extremely low except for the

years 1983-85. The stock has been grossly recruitment overexploited, but in the years 1975-82 the rate of recruitment has also been low. This was probably due to unfavourable recruitment condition, linked to low water temperatures in the Barents Sea (Marty and Fedorov 1963, Hamre 1988).

Assessment by tagging

In the period 1975-1986 the state of the adult stock has been assessed by tuning the VPA against stock estimates obtained from tagging (Anon. 1980,1986). The tagging project as well as the model used for the processing of the data have been described in working documents and reports of the Working Group (Anon. 1984,1986).

The tagging project using internal steel tags was initiated in 1975 and since then herring have been tagged and released annually on various localities along the west coast in April-May. Prior to 1982 the herring were caught by purse seine, towed to the shore and kept in keepnets before tagging. Since 1982 the herring have been brailed from the seine to the RSV-tanks onboard the seiner and tagged and released from the tanks. The tagged herring are released in batches and under various conditions and the mortality due to the tagging is expected to be variable.

The tagged herring are recovered by screening herring catches using a special constructed internal tag detector. The efficiency of the detector is tested by mixing tagged herring with the catch before screening (Gytre and Jakupsstovu, 1977).

The recoveries used for stock assessment are all obtained from winter catches of spawners and prespawners. The commercial herring winter fishery was prohibited until 1984, but experimental fishing for tag recovery was allowed during the winters 1977-83. The commercial winter fishery was opened in 1984 and in later years both commercial and experimental catches have been screened for tags. The herring stock has developed in two separate units, and the data on releases and corresponding recoveries are prosessed by the two stock components separately. The tagging is done during the feeding season, and in areas where shoals from both components are distributed. It has therefore been difficult to allocate the releases on components when released. The tagged herring are released in batches of 2 000 - 10 000 individuals, and the allocation of the batches on components is made on the basis of the recoveries, i.e., the position and the age-composition of the catches from which the bulk of the recoveries are retained. The boundary between the spawning grounds of the two compo-nents runs at about 63°N.

By this grouping of data the consistency of the abundance estimates by years is improved, but the results indicate that no random mixing of the tagged fish in the two stock units is a major source of error in the estimates. The releases and recoveries by components and years are given in Table 3. At the bottom of the table is given the corresponding number of herring effectively screened for tags.

Mortality estimates

The most simple model for explicit estimates of survival rate from two successive releases is the Ricker's model (Ricker 1975):

$$S_1 = \frac{r_{12} \cdot M_2}{r_{22} \cdot M_1} \tag{1}$$

where S_1 = survival rate during year 1

M_1 = number marked at the start of the first year

M_2 = number marked at the start of the second year

R_{11} = recaptures of first-year marked in the first year

R_{12} = recaptures of first-year marked in the second year

R_{22} = recaptures of second year marked in the second year

If sampling is done over a series of years, the recaptures can be summarized over the whole period. A review of models for explicite maximum-likelihood estimates of animal abundance by tagging is published by Seber (1982). These methods presuppose that the tagging mortality is negligible or at least does not vary with releases. This underlying assumption is not fulfilled in the present experiment, and a regression model has therefore been applied.

The regression model estimates the total instantaneous mortality rate Z for equal time periods when Z is assumed to be constant. Two types of models are available. It can be shown that if the returns from one release over a long time serie are grouped in equal time intervals, the logarithm to the number of returns from each of the time intervals plotted against time, will yield a straight line with slope equal to the instantaneous mortality rate (Gulland 1973). It is noted that the mortality estimate from this model is independent of the number released and consequently also of the mortality due to the tagging.

In an analogous way it can be proved that if Z is constant the logarithm to the fraction number released/number recovered from successive releases in the same catch plotted against time in liberty will yield
a straight line with slope equal to the instantaneous mortality Z. If the survivals of the last release are denoted $s_0 \cdot m_0$ the stock size N_0 according to a Petersen estimate is:

$$N_0 = \frac{s_0 \cdot m_0 \cdot C_0}{r_0} \tag{2}$$

where s_0 is the coefficient of survival after tagging and r_0 is the number of recoveries in the catch C_0.

An estimate of N_0 may also be expressed by the recoveries from the previous years' releases as follows:

$$N_0 = \frac{s_1 \cdot m_1 \cdot e^{-Z} \cdot C_0}{r_1} = \frac{s_2 \cdot m_2 \cdot e^{-2Z} \cdot C_0}{r_2}$$

provided that the mortality Z is constant.

In general terms this can be written:

$$N_0 = \frac{s_t \cdot m_t \cdot e^{-Zt} \cdot C_0}{r_t}$$

where r_t denotes the recoveries from m_t released t years prior to time
when the sample c_0 was drawn. Reorganizing this equation and taking the natural logarithm we have:

$$\ln \left[\frac{s_t \cdot m_t}{r_t} \right] = Z \cdot t + \ln \left[\frac{N_0}{C_0} \right] \qquad (3)$$

Here the plots will fall along a straight line if s is a random variable and thus can be regarded as a part of the co-variance of the regression line. This assumption is reasonable, at least for each of the periods when the tagged fish have been handled in an equal way (1975-1981;1982 onwards). The tagging mortality is assumed to be high and the variance in s is considered to constitute the main part of the co-variance of the regression line. A point located far above the line indicates a low survival rate of that experiment (failure of recoveries), a point below the line a corresponding high value of s. If all other sources of model variance were negligible the model provides a method to estimate the relative tagging survival s_r.

In the text table below the relevant model parameters are calculated for the northern component using the recoveries 1984-87 of the releases 1975-83 (Table 3). According to reports of the Working Group there has been no substantial change in the fishing mortality during this period, whereas the fishing mortality of the older age groups may have increased significantly after 1983 (Anon., 1986, 1988).

Release	m_t	r	lnK	t	f(t)	s_r
1975	20991	25	2.13	8	2.09	0.96
1976	15947	11	2.67	7	1.87	0.45
1977	24989	50	1.61	6	1.65	1.04
1978	19998	56	1.27	5	1.44	1.19
1979	8797	23	1.34	4	1.22	0.89
1980	15988	48	1.20	3	1.01	0.83
1981	9977	52	0.65	2	0.79	1.15
1982	14884	35	1.45	1	0.57	0.42
1983	17925	56	1.16	0	0.36	0.45

m_t is the number released in year t, r is the corresponding number of tags retained from the screened winter catches in 1984 to 1987. f(t) is the function value of lnK calculated from the regression line and s_r is a calculated index of relative tagging survival.

The plots of lnK (where $K = m/r \cdot 10^{-2}$) versus time in liberty t are shown in the Figure below:

lnk

2,5

2,0

1,5

1,0

z = 0, 216
r = 0, 956

1982   1980   1978   1976
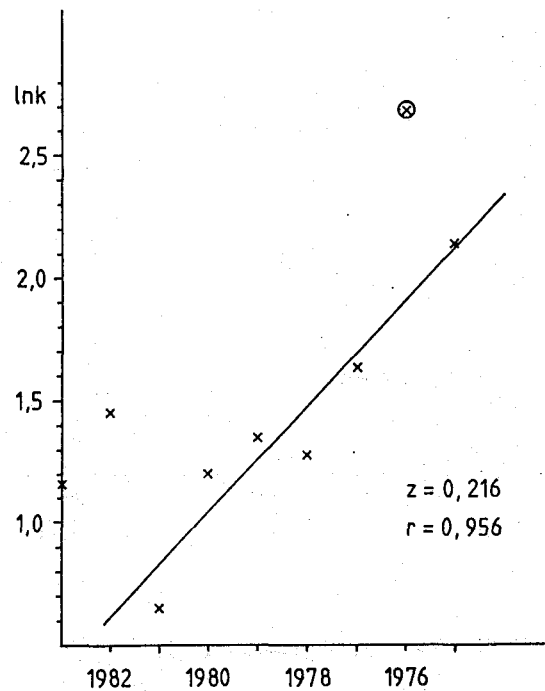
Plot showing lnK versus time in liberty

As pointed out by the Working Group the returns from the 1982 and 1983
releases indicate a substantial increase in the tagging mortality
after 1981 (Anon. 1986). The Working Group has therefore not used tag
returns from releases after 1981 in the assessment of the stock.

The returns from the 1976 releases do also indicate an extraordinary
high tagging mortality although no likely reason for this is known.
The 1976 sample has therefore been considered as an exception from the
assumed random variation in the tagging mortality and has been omitted
in calculation of the regression line. The other points for the period
1975-1981 fit well to a straight line with slope Z= 0.216 and an
intercept of the lnK axis of 0.358. The correlation coefficient of the
points is 0.956.

If we assume no substantial change in Z from 1981 to 1983, the most
simple way to calculate the stock number in 1983 is to use equation
(3):

$$f(0) + \ln 10^2 = \ln \frac{N_0}{C_0}$$

where f(o) is the intercept of the regression line with the lnK-axis
and C_0 is the sum of screened catches 1984-87 (Table 3):

$$0.358 + 4.605 = \ln \frac{N_{83}}{C_{84-87}}$$

$$N_{83} = 1541 \cdot 10^6$$

This stock estimate refers to the year classes 1981 and older and has

not been adjusted for tagging mortality. The estimate is in accordance with the stock estimate given by the Working Group in 1986 (Anon. 1987).

As mentioned previously the model provides a method to estimate a relative tagging survival coefficient (s_r) assuming that the variance in the tagging mortality is the main source of the co-variance of the line. This index is derived from the formula:

$$\ln(s_r)_t = f(t) - \ln K_t \tag{4}$$

where $f(t)$ is the function value of $\ln K_t$ of the releases in year t. The calculated s_r-values by releases are given in the text table above. The 1982 and 1983 releases indicate an increased tagging mortality by the new handling method of the tagged herring in an order of magnitude of 50%.

In the text table below are given the survival estimates s_t by year obtained when the explicit model of Richer (equation 1) is applied to the recoveries in Table 3. s_t' are the corresponding estimates obtained when the releases m_t are adjusted by the corresponding relative survival s_r calculated from equation 4.

Survival	1975	1976	1977	1978	1979	1980	1981
s_t	1.57	0.45	0.68	1.07	0.86	0.54	2.24
s_t'	0.74	1.03	0.78	0.80	0.80	0.75	0.82

The two sets of survival estimates demonstrate the necessity of applying a regression model in processing of tag recovery data when tagging mortality is variable. It should be noted that the 1976-estimate is expected to be biased upwards due to a low number of tags retained.

The releases in 1983 to 1985 provide data to estimate yearly survival rate by the use of equation (1). The model yields survival estimates of 0.93 and 1.11 for the years 1983 and 1984 respectively. It is likely that these estimates reflect trends in the tagging mortality rather than trends in the survival rate of the population. The Working Group has therefore not used these data in recent stock estimates, but tuned the VPA against acoustic estimates of the spawning stock (Anon. 1988).

Similar data for mortality estimates of the southern stock component are given in the text table below. The recoveries refer to the winter catches 1984-87, the details appear from Table 3.

Release	m_t	r	lnK	t
1975	5000	15	1.20	8
1976	7998	11	1.987	7
1977	16044	38	1.44	6
1978	11998	31	1.35	5
1979	5995	35	0.54	4
1980	19994	47	1.45	3
1981	24967	163	0.43	2
1982	12380	31	1.39	1
1983	15891	134	0.17	0

K is set equal to $m/r \cdot 10^{-2}$, and the plot of lnK against time in liberty (t) is shown in the figure below:
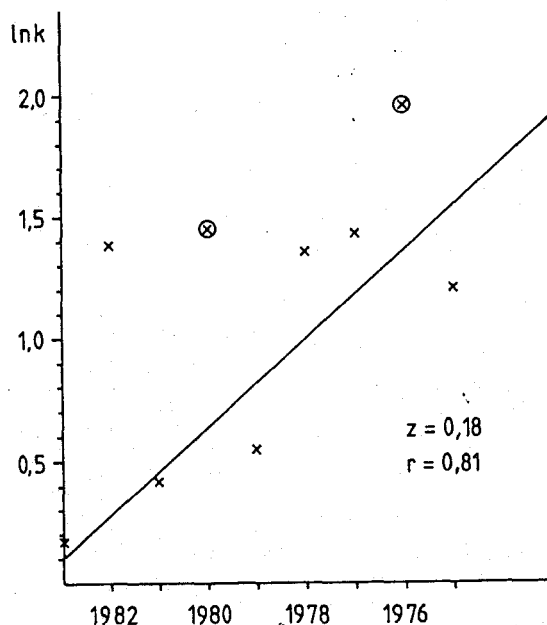
Plot showing lnK against time in liberty

The consistency of this plot is rather poor and is assumed to reflect variable tagging mortality and the occurrence of mixed stocks in the southern area. It is known that autumn spawners probably from the North Sea and herring from local stocks which spawn in the Norwegian fjords are mixed with the herring of the southern component when the fish are tagged. In some cases this has been quantified and adjusted for in the calculation. Based on recoveries from the northern spawning area it has moreover been calculated that some 30% of the releases allocated to the southern stock originated from the northern stock component (Anon. 1987). The basic supposition of random mixing of the tagged fish in the area where the stock is sampled for tags is therefore not fulfilled. This is probably the main reason for the poor symmetry in the variance of the plots. The Working Group has, however, used the recoveries of the releases in 1975-81 for assessment work, omitting the releases in 1976 and 1980 in the calculation of the regression line (Anon.,1986). The remaining plots yield a straight line with slope z= 0.18 and an intercept of the lnK axis of 0.1. Using

equation (3) and a screened catch of 18.680 · 10^6 (Table 3), N_{83} is calculated to some 2000 · 10^6. Herring of the northern stock component account for 30% of this number (Anon.,1987) and the 1983 stock estimate of the southern component is therefore in an order of magnitude of 1400 · 10^6, before the estimate is adjusted for tagging mortality. This is likely to be an overestimate of the Atlanto-Scandian herring because a part of the tagged herring may also originate from autumn spawners and from local stocks, which spawn in other areas.

It may be noted that the plot of the 1983 releases is located close to the intercept of the regression line. This indicates that the tagging mortality in 1983 equals the average tagging mortality of the previously used tagging method. This is in conflict with the previous findings, but the relatively high return rate of the 1983 releases may on the other hand be explained by a low contribution of tagged herring from other stocks in that particular year. The confidence of this observation is therefore considered to be rather poor. The consistency of results obtained by using the releases after 1981 in equation 1 is also poor and these data have not been used for assessment purposes.

The Working Group has adopted an average tagging mortality of 30% (Dragesund and Jacobsen, 1963). Recent tests of tagging mortality carried out in an indoor basin gave results of tagging mortality ranging from about 10% to 25% (Hamre and Toresen, 1989). These estimates are, however, not accounting for the mortality caused by the catching of the tagged fish. The sum of the two stock component estimates in number, adjusted by 30% tagging mortality and converted to weight, yields a spawning stock biomass in 1983 of some 600 000 t. The further development of these year classes in subsequent years is assessed by tuning the VPA against the stock estimates obtained from tagging prior to 1984. For the year classes younger than the 1981 year class the state of stock is measured by the acoustic method. The total stock biomass for the years 1977-1989, and by components for the years 1977 to 1984 are shown in Figure 9. The Figure shows that whereas the northern component has remained in an approximately steady state during this period, the spawning stock of the southern component has increased from below 100 000 tonnes in 1977 to about 250 000 tonnes in 1983. When the strong 1983 year class recruited to the spawning stock the occurrence of the stock in two separate components disappeared.
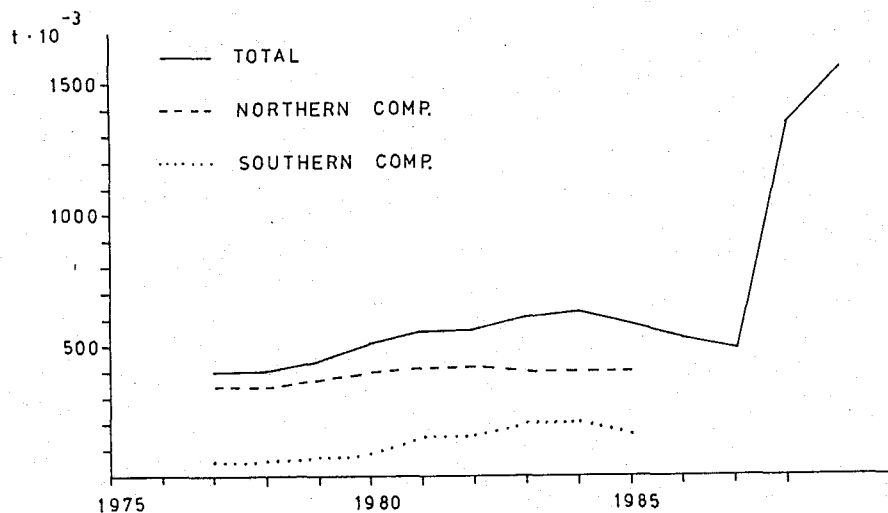
Fig. 9. Estimate of spawning stock by components 1977-1988.

The 1983 year class has increased the spawning stock biomass to about
1.5 mill.tonnes in 1989, but the prospects for further stock
development is not promising. The year classes younger than the 1983
year class are all weak, and the spawning stock is expected to de-
cline in the 1990's.At present about 95% of the spawning stock belongs
to the 1983 year class.

FISHERY MANAGEMENT

After the drastic decline in catches in the late 1960's, the Working
Group considered the state of the stock and found that there had been
almost no recruitment to the adult stock since 1966, owing to the
heavy exploitation of the 1963-1964 year classes in the fishery of
juveniles. The Working Group concluded that in view of the critical
state of the stock it would be advisable to keep the exploitation rate
of small and fat herring at a much lower level than in previous years
(Anon., 1972). A minimum landing size $_0$of 20 cm was set on the
Norwegian herring fishery north of 62^0N in the spring 1970, and the
use of herring for reduction was prohibited from 1 January 1971. A
total ban of the Norwegian winter fishery was introduced in 1972. The
minimum landing size of 20cm was replaced by catch quotas on small and
fat herring in 1973 and 1974, limiting the catches to 6800 t and 6300
tonnes respectively. From 1975 to 1983 the Norwegian herring fishery
has been regulated by catch quotas and by a minimum landing size of 25
cm. The commercial fishery on the spawning grounds was closed in 1972
but was reopened in 1984. The ICES's recommended catches (1000 t) and
the national quotas set for the years 1984-89 are shown in the text
table below. For the years 1975 to 1983 ICES's recommended a total ban
on the fishery.

YEAR	1984	1985	1986	1987	1988	1989
Recom. catch	38	50	150	150	150	100
Agreed catch	38	60	126	115	120	90

ICES considers the Norwegian spring spawning herring as a recruitment
overexploited stock, and the recommended catch should not be regarded
as a catch quota, but as a maximum level the catch should not exceed.
2.5 million tonnes is set as the preferred minimum level of spawning
stock.

STOCK INTERRELATIONSHIP

The Norwegian spring spawning herring is the largest catchable fish
resource in the Northeast Atlantic and constitutes as a plankton
feeder the most important link in the food chain above fish level in
the ecosystem of the Norwegian Sea and the Barents Sea. This stock is
of particular importance for the marine life on the Norwegian shelf
and in the Barents Sea due to the migration pattern of the adults and
to the distribution and migration of the juveniles. Prior to the
1960's the spawning migration of the herring constituted a huge
displacement of biomass from distant areas of the Norwegian Sea to the
Norwegian west coast. This migration was followed by hords of marine
predators which made the Norwegian west coast   one of the most
profitable fishing areas in the world. When the stock collapsed in the
late 1960's this huge input of biomass terminated and the immidiate
effect was a drastic decline in the yield from the Norwegian west

coast fisheries. The lack of income from the coastal fisheries had a
marked impact on the activities and social life of the coastal
communities in the area south of Lofoten.
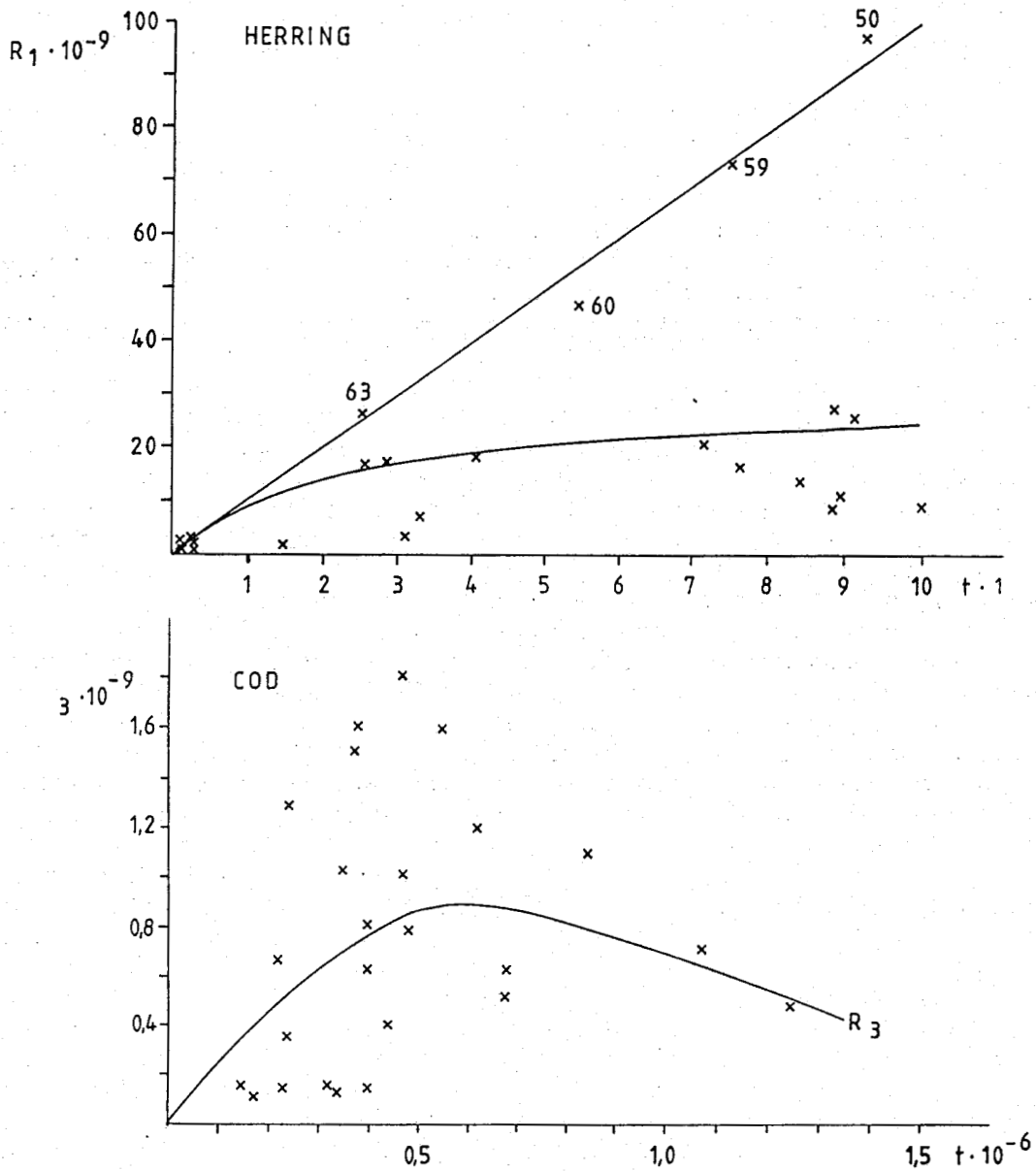
Fig.10. Stock/recruitment relationships for herring and cod.
        spawning stock in million tonnes, recruitment
        billion individuals.

A new crisis has struck the Norwegian coastal fisheries in recent
years and this has developed in the stocks and fisheries of Northern
Norway and in the Barents Sea. The crisis is obviously linked to an
unbalanced state of the predator/prey relationship in the Barents Sea
which became exposed in 1986 onwards when starved cod, sea-birds and
seals appeared in Norwegian coastal waters. The prime reason for the
lack of prey species in the region is most probably related to the
overexploitation of the herring (Hamre 1988). Herring and cod are the
key species in the predator/prey relationships in the Barents Sea.
This because they are the largest stocks in the region and their

success of recruitment is governed by common environmental factors,
i.e. the inflow of warm Atlantic water to the area (Sætersdal and
Loeng, 1984). Both stocks were reduced in the early 1980's, but only
the herring stock was grossly recruitment overexploited. This
constituted a latent unbalanced state of the ecosystem released by a
shift from a cold to a warm climate in the early 1980's. Extraordinary
strong year classes of herring and cod were recruited in 1983 to 1985,
but the spawning stock of herring was not rebuilt to a sufficient
level to take full advantage of the improved climatic condition. The
recruited year classes of herring were not sufficiently large to meet
the food demand of the cod. In the years 1983 to 86 the rapid growing
stock of young cod together with other predators grazed down the
plankton feeders and other available food items in the area (Mehl,
1988). The high predation pressure resulted in a collapse of the
Barents Sea capelin stock in 1986, and due to lack of food the
abundance of cod declined substantially in the subsequent years
(Anon.,1986 b, 1988 b).

The recent development in stocks and fisheries in the Barents Sea
demonstrates the importance of the herring for the ecobalance in the
region. The dynamics behind the development are understood from the
differences in the stock/recruitment functions of the two species
(Figure 10). For herring there seems to be a linear relationship
between spawning stock biomass and recruitment in periods of
favourable recruitment conditions. The food supply for abundant cod
year classes in form of juvenile herring is thus proportional to the
state of the adult herring stock. The stock/recruitment relationship
for cod shows, however, that cod recruits strong year classes on
relative low stock levels. This means that in a state of reduced stock
sizes for both the stocks for instance after a long period of low
temperature in the Barents Sea, as in the 1980's, the balance in the
predator/prey relationship may change dramatically in the shift from a
cold to a warm climate. This recruitment mechanism explains the
paradox that a crisis in stocks and fisheries may develop when
recruitment conditions of the main species are improved.

CONCLUDING REMARKS

The stock structure of the Norwegian spring spawning herring is not
yet properly known. The stock components which have developed as
separate units in recent years, show similar characters of being
members of different races as the stock components described by
Schnackenbeck and Ottestad in the 1930's. These components may,
however, not be selfsustained, but may consist of groups of indi-
viduals which inhabit different areas throughout their life span
according to the location of their nursery area as juveniles. This
form of stock separation is difficult to identify and distinguish from
separation in races. Knowledge of the homogeneity of the stock is
crucial for the interpretation of the stock estimates obtained from
tagging and for a proper management of the stock as well. Studies of
stock structure should therefore be given high priority in future
herring research.

The distribution pattern and migration of the herring changed during
the period when the stock size declined. This resulted in speculations
regarding the prime reason for the disappearance of the herring,
whether the collapse of the stock was caused by overfishing only, or
whether the stock depletion was also due to natural causes. The
collapse seemed to occur as a combined effect of increased effort in

the adult fishery and the continuation of the high exploitation rate
on the immature stock. It has been shown that a regulation in one of
these two fisheries would have had a significant effect on maintaining
a spawning stock size at a reasonable level up to 1970. It is there-
fore concluded that the collapse of the stock in the 1970's was mainly
due to overexploitation.

With respect to Devold's hypothesis of alternating herring periods
which predicted that the Norwegian spring spawning herring was on the
point of leaving the Norwegian west coast in the 1960's, for later to
occur at Bohuslän, the question is whether the herring would have
disappeared from the west coast irrespective of the increased exploi-
tation. The depletion of the stock by the fishery will from this point
of view be a logical explanation to the absence of a subsequent
Bohuslän fishery in the 1970's. The knowledge obtained in recent years
do, however, not support the crucial point in the dynamics of the
migration theory developed by Devold, namely that higher temperature
in the wintering area should accelerate the maturing of the herring
and thus affect the spawning time accordingly. Since 1974 the maturing
herring in northern Norway have wintered in relatively high water
temperatures as presupposed by the migration theory, but the time of
spawning has not been affected as predicted. In general, some simi-
larities in the state of the stock in the 1970's compared to that in
the 1870's are, however, observed. The occurence of the large herring
in northern Norway in the previous century indicates that the
traditional migration pattern was broken as in recent years, but
lasted for only 6 years. The occurence of the mixed herring on Møre
and Trøndelag and the two fishing seasons which developed at the end
of the century, may moreover be taken as evidence for a stock
recovery process of two stock components similar to the recovery of
the stock observed in recent years. At the end of the previous century
the spawning took, however, place in the early winter, and after
spawning the herring obviously left the coast. The prolonged stay of
the herring in the Norwegian coastal waters in recent years may
therefore be related to the late spawning time.

The herring stock was fished out in 1970, and without protection the
immature stock would probably also have been depleted in 1971. This
history shows that the efficiency of the fishing techniques directed
at schooling fish has reached a level at which the survival of stocks
is endangered. It is thus thought provoking to note that the most
important fish resource in the Northeast Atlantic may have survived
exploitation only on account of regulations introduced at the very
last moment. The stock is now increasing, but is still below the
critical level of 2.5 mill. tonnes where recruitment is assumed to be
affected. The stock consists mainly of one year class, the year class
1983. The younger age groups are all poor and the spawning stock is
expected to decline in the 1990's. The future development of the stock
will to a large extent depend on the survival conditions of the
herring fry in coming years, but the recovery of the stock is still
dependent on effective protection.

As the main plankton feeder in this region the herring must have
played a decisive role for all top carnivores . The herring fishery
has not been replaced by any fishery on other plankton-feeding species
which may have utilized the production which previously maintained the
herring stock. The consequence of the collapse of the herring stock is
therefore that the production, in one of the richest areas in the
Northeast Atlantic, became unavailable to top carnivores, including
man. The depletion of the herring may have changed the balanse in the

ecosystem of the region fundamentally and is probably the prime reason
to the severe crisis which has developed in the Barents Sea's stocks
and fisheries in recent years. The depletion of the Norwegian spring
spawning herring resulting in a break down of the life cycle of one of
the largest fish stocks in the world, is likely to be the most
destructive encroachment to a marine ecosystem ever done by a
commercial fishery.

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Table 1.   Catches (in thousand tonnes) of Norwegian spring-spawning herring during the period 1950-1988

Year	Winter herring	Summer and autumn herring	Total adult herring	Small and fat herring	Grand total
1950	771.3	54.8	826.1	106.9	933.0
1951	889.3	104.9	994.2	284.2	1278.4
1952	829.4	89.8	919.2	335.6	1254.8
1953	678.6	171.3	849.9	240.7	1090.6
1954	1119.1	187.3	1306.4	338.1	1644.5
1955	1004.4	213.1	1217.5	142.3	1359.8
1956	1192.8	267.8	1460.6	198.8	1659.4
1957	856.5	291.8	1148.3	171.2	1319.5
1958	429.1	355.9	785.0	201.6	986.6
1959	510.2	372.9	883.1	228.0	1111.1
1960	401.0	420.1	821.1	280.7	1101.8
1961	146.3	351.6	497.9	332.2	830.1
1962	133.5	417.7	551.2	297.4	848.6
1963	132.8	538.0	670.8	313.7	984.5
1964	420.2	697.7	1117.9	163.9	1281.8
1965	391.2	934.6	1325.8	221.9	1547.7
1966	631.8	1091.7	1723.5	231.5	1955.0
1967	458.8	672.7	1131.5	545.7	1677.2
1968	44.8	228.3	273.1	439.1	712.2
1969	20.5	3.6	24.1	43.7	67.8
1970	20.9	-	20.9	41.4	62.3
1971	6.9	-	6.9	14.2	21.1
1972	-	9.9	9.9	13.2	23.1
1973	0.1	6.6	6.7	0.3	7.0
1974	0.9	6.1	7.0	0.6	7.6
1975	0.1	3.4	3.5	0.3	3.8
1976	-	0.2	0.2	0.2	0.4
1977	0.4	11.8	12.2	0.5	12.7
1978	0.5	9.2	9.7	0.2	9.9
1979	0.7	1.9	2.6	0.3	2.9
1980	0.9	7.6	8.5	0.1	8.6
1981	0.8	7.8	8.6	0.1	8.7
1982	1.0	10.4	11.4	0.2	11.6
1983	3.9	13.3	17.2	0.9	18.1
1984	18.7	29.5	48.2	0.3	48.5
1985	29.4	37.2	66.6	4.5	71.1
1986	71.1	55.5	126.6	0.2	126.8
1987	62.9	49.8	112.7	0.2	112.9
1988*	71.0	52.0	103.0		

*   Preliminary

Table 2. Total catch.

Catch (in thousand of tons) of adult and pre-recruit Norwegian spring-spawning herring 1950-1968.

Year	Iceland	Norway	USSR	Faroes	Germany	Total
1950	30.7	781.4	14.0	-	-	826.1
1951	48.9	902.3	43.0	-	-	994.2
1952	9.2	840.1	70.0	-	-	919.3
1953	31.5	692.2	110.0	17.0	-	850.7
1954	15.2	1103.6	160.0	27.6	-	1306.4
1955	18.1	979.3	207.0	13.1	-	1217.5
1956	41.2	1160.7	235.0	23.7	-	1460.6
1957	18.2	813.1	300.0	17.0	-	1148.3
1958	22.6	356.7	388.0	17.7	-	785.0
1959	34.5	426.9	408.0	13.7	-	883.1
1960	26.7	318.4	465.0	11.0	-	821.1
1961	85.0	111.0	285.0	16.9	-	497.9
1962	176.2	156.2	209.0	9.8	-	551.2
1963	177.5	130.4	330.0	12.9	-	650.8
1964	367.4	366.4	365.8	19.3	-	1118.3
1965	540.0	259.5	489.2	31.5	5.6	1325.8
1966	691.4	497.9	447.4	60.2	26.1	1723.0
1967	359.3	423.7	303.3	34.9	9.7	1130.9
1968	75.2	55.7	124.3	-	1.8	257.0

Table 3. Tag releases (m) and recoveries by components 1975-87 including
          yearclasses 1981 and older.
          C= catch (in number) effectively screened

Northern component

Year	Releases m	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	SUM
1975	20991	0	0	7	12	7	8	1	0	0	4	3	18	0	60
1976	15947		0	2	5	2	7	2	0	0	2	4	5	0	29
1977	24989			0	12	10	17	4	0	2	11	5	34	0	95
1978	19998				0	18	15	7	0	2	15	8	27	6	98
1979	8797					0	7	1	0	2	6	5	11	1	33
1980	15988						0	4	0	3	17	4	25	2	55
1981	9977							0	2	5	11	10	29	2	59
1982	14884								0	3	15	3	15	2	38
1983	17925									0	13	8	34	1	56
1984	13957										0	3	30	3	36
1985	18717											0	39	1	40
SUM		0	0	9	29	37	54	19	2	17	94	53	267	18	
C . 10-3				939	705	710	1537	900	103	484	2479	1763	6182	350	

Southern component

Year	Releases m	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	SUM
1975	5000	0	0	4	5	2	1	8	2	3	4	2	7	2	40
1976	7998		0	0	0	3	0	2	2	2	4	7	0	0	20
1977	16044			0	7	15	8	9	12	2	15	10	12	1	91
1978	11998				0	7	8	7	8	2	10	8	13	0	63
1979	5995					0	7	14	9	1	9	10	16	0	66
1980	19994						0	10	23	3	19	10	18	0	83
1981	24967							0	33	13	56	40	66	1	209
1982	12380								0	7	9	8	14	0	38
1983	15891									0	50	36	45	3	134
1984	12221										0	39	70	5	114
1985	12167											0	55	4	59
SUM		0	0	4	12	27	24	50	89	33	176	170	316	16	
C . 10-3					150	241	587	1209	1406	1279	4992	5340	7837	512	
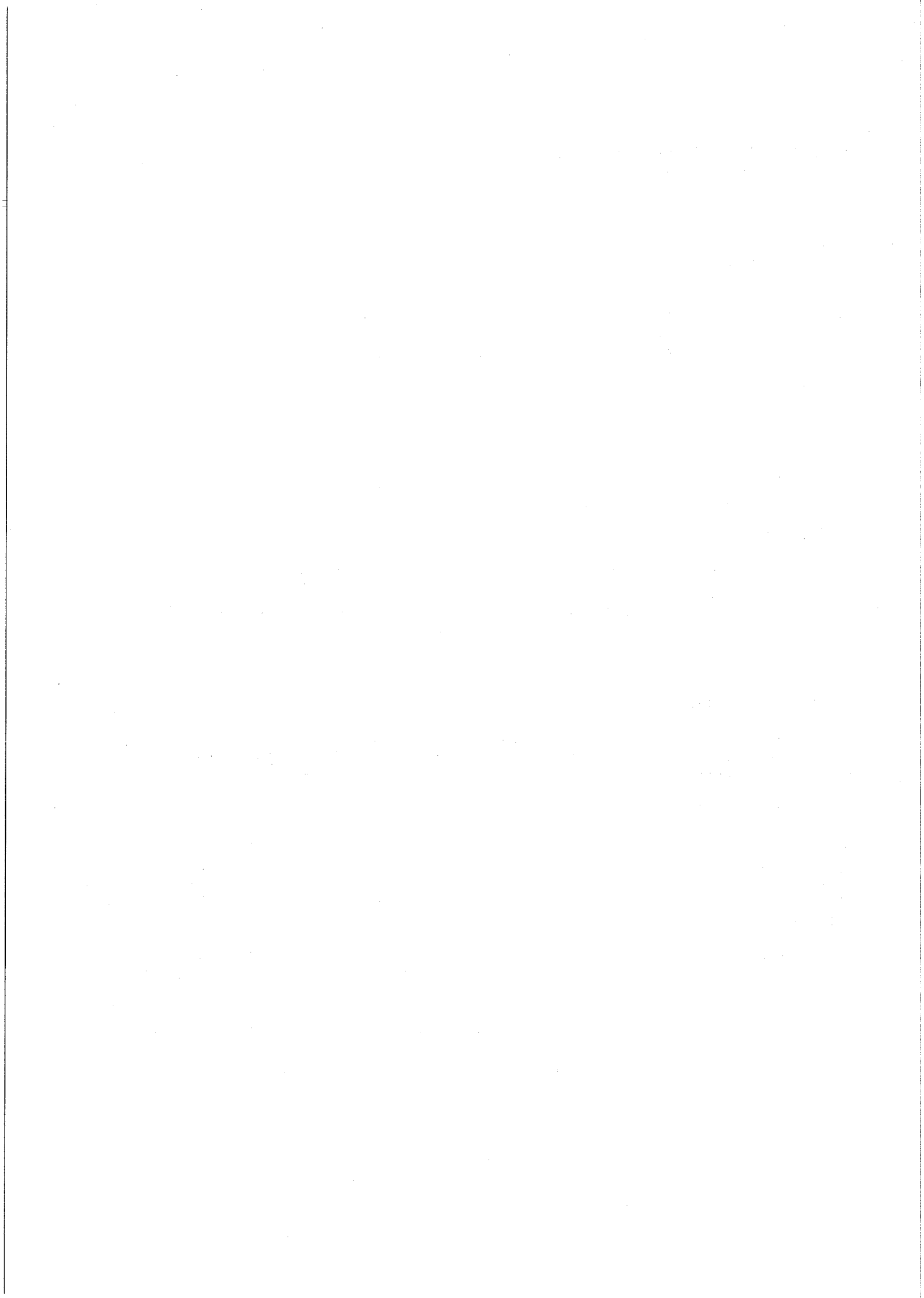
SPAWNING STOCK STRUCTURE AND POPULATION
FECUNDITY OF THE ATLANTO-SCANDIAN HERRING

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ABSTRACT

A great variety of herring habitat from the southwest coast of Norway to Novaya Zemlya results in the appearance of groupings which may be distinguished in a year class by scale structure and growth rate. These groupings occurring in coastal waters of southwest Norway form a southern stock component, in coastal waters of Central and North Norway - a northern stock component, in the Barents Sea - a Barents Sea stock component. The component ratio in year classes with unequal abundance varies. Weak year classes consist mainly of herring of the southern and northern components (herring with a high growth rate and early maturation). Specimens of the northern component predominate in average year classes. The percentage of Barents Sea specimens is about 17. Ratios of specimens of southern, northern and Barents Sea components in abundant year classes are less than 10, about 40 and more than 50% respectively. The Barents Sea component particular to a rich year class, having a low absolute fecundity of individuals as compared to southern and northern components, decreases the population fecundity when recruiting to the spawning stock. The lower number of eggs spawned in the 1960's was one of the factors that caused a sharp decrease in herring stocks.

The level of critical population fecundity of the spawning stock consisting of the southern component is equal to no less than 40×10^{12} eggs, that of the northern component, to 71×10^{12} eggs, and that of the Barents Sea component, to 152×10^{12} eggs, corresponding to biomasses of 0.3, 0.6, and 1.3 mill. tonnes. These data agree with the fact that in 1983 the spawning stock consisted merely of specimens from the southern and northern components of the poor 1969-1980 year classes, and its biomass reached 0.6 mill. tonnes. Favourable conditions for egg and larval development gave rise to the appearance of a rich year class that year. To restore the herring range of the 1950's and 60's, the spawning stock biomass should make up 6.9-7.5 mill tonnes, which complies with a minimum tolerance level of population fecundity of $850-906 \times 10^{12}$ eggs maintaining its natural year class strength variations.

INTRODUCTION

With a sharp decrease in the spawning stock abundance, the Atlanto-Scandian herring ceased to perform migrations of "large" circle described by Soviet and Norwegian authors (Marti, 1956; Marti and Wilson, 1960; Yudanov, 1960; Devold, 1963). From the late 1960's to the present time, their whole life cycle passes in Norwegian territorial waters (Anon. 1970, 1977, 1979). Specimens of year classes originated after 1969 keep all year round to the coastal waters of Norway, within the 12-mile zone from 62^{0} to 70^{0}N where they perform migrations of "small" circle not leaving for the open Norwegian Sea.

The Atlanto-Scandian herring stock is observed to recover in recent years. The 1973, 1976 and 1979 year classes appearing in the 1970's and being exceptional in higher numbers remained, yet, at the level of poor ones. As a result of recruitment of these year classes to the spawning stock, its abundance increased from 99 thousand tonnes in 1973 to 472 thousand tonnes in 1987 (Table 1). In 1983 the year class emerged which at a fingerling stage turned to be comparable with the rich 1960 year class (49×10^{9} specimens). With the 1983 year class recruiting, the spawning stock increased in 1988 to 1.35 mill. tonnes, and the migration cycle of the 1950-1960's was partially renewed. Feeding postspawning herring were found in July-August 1987-88 by Soviet research vessels in open the Norwegian Sea from 64^{0} to 72^{0}N between 5^{0}W and 5^{0}E. Under these conditions rational exploitation of the recovering stock involving provision and implementation of advice on conservation of juveniles over their whole range, introduction of minimum fishing size and regulation of adult herring fishery is extremely important.

An adverse impact of immature herring fishery on adult fish abundance and catch has already been investigated by Soviet and Norwegian scientists (Marti, 1956; Marti and Yudanov, 1962; Benko and Seliverstov, 1969, 1973; Dragesund and Ulltang, 1975).

The intensive fishery for young and adult herring does not only change the age composition of the spawning stock, and its numbers, but also diminishes its reproductive capacity. Fecundity of Atlanto-Scandian herring was exhaustively covered by Lyamin (1966). He revealed the dependence of individual absolute fecundity on the fish length, age and weight, as well as on the year class strength, and he studied it on the spawning population as a whole. The investigations (Seliverstova, 1969, 1973, 1977, 1978; Telkova, 1962, 1966, 1969; Shutova-Korzh, 1960, Lea, 1911, 1929; Ottestad, 1934; Runnstrøm, 1936) showed that the spawning stock consists of groupings with varying growth and maturation rates which may be singled out by scale structure. Analysing the population fecundity of some fish species, Serebryakov (1988) later on developed the method of definition of various reproductive levels for commercial fish populations under varying ecological conditions of year class survival in early ontogeny. The dynamics of population fecundity is analysed in the paper, depending on spawning stock numbers and its structure in 1951-1975. One more reason of possible decrease in herring stock numbers is recognized together with other ones - intensive fishery for immature and adult herring and climatic changes provoking deterioration of stock reproduction conditions.

MATERIAL AND METHODS

PINRO material on age composition of spawning stock for 1950-75, data
on its biomass and abundance used from ICES Working Groups' documents
and a paper by Dragesund and Ulltang (1975) are presented. Samples on
herring fecundity are collected on wintering and spawning grounds.
Ovaries at maturity stages III-IV, IV, V, and V-VI were fixed in 4%
formalin. Eggs were counted in a one-gramme weight and then converted
to the total gonad weight. In all 4325 samples of herring females aged
3-20 were analysed for fecundity in the period from 1954 to 1975.

The population fecundity, survival rates, various levels of population
fecundity were estimated following the method suggested by Serebryakov
(1988).

With regard to age composition and sex ratio (1:1) on spawning grounds
and also to the ratio of southern, northern and Barents Sea components
in year classes of varying abundance (structure), individual absolute
fecundity of herring of various   components,   the   contribution
(population fecundity) of each age group of the above components to
the total amount of yearly spawned eggs in 1951-75, population
fecundity levels and the corresponding spawning stock biomasses
determining its reproductive power under natural conditions are
estimated.

STRUCTURE OF ATLANTO-SCANDIAN HERRING YEAR CLASSES

Drifting juveniles of Atlanto-Scandian herring are spread along the
Norwegian coast and transferred into the Barents Sea (Manteifel and
Marti, 1939; Marti, 1956; Ryzhenko, 1938). The larval transport to
that or another area depends on the intensity of the Norwegian
Current. As the investigations showed (Fedorov, 1962), in years with
a high Norwegian Current water heat content, the   larvae   are
transferred into the northern and northeastern Norwegian and Barents
Seas. In cold years, relevant to hydrology, they do not drift far
north, but settle in coastal waters of Central and south Norway.
Growing older, young herring expand their range into adjacent areas,
though they preserve a primary distribution pattern. Mature specimens
spawn on the spawning grounds very close to their feeding areas
(Marti, 1956).

Year class strength depends on the Norwegian Current heat content as
well. In hydrologically warm years, herring year classes vary much in
high numbers, in cold years poor generations appear (Benko and
Seliverstov,1969; Seliverstov, 1970; Seliverstov and Penin, 1974;
Yudanov, 1964, 1964a, 1968, Anon., 1965-1987).

Hence, depending on the intensity of the warm Norwegian Current and
its separate branches, the herring range is found the coastal zones of
the Norwegian and Barents Seas. A wide variety of herring habitat from
the southwest coast of Norway to Novaya Zemlya leads to the appearance
of groupings which can be singled out in the generation by scale
structure and growth rate.

Studies of year class structure initiated by Norwegian scientists Lea
(1911, 1929), Ottestad (1934), Runnstrøm (1936) were further proceeded
by Østvedt (1958, 1964), Telkova (1962, 1966, 1969) and Seliverstova
(1969, 1973, 1978). Norwegian scientists divided   the   spawning
population into a southern and a northern component (with a southern

and a northern type of scale respectively). Further studies
(Seliverstova, 1969, 1973, 1977, 1978) showed that the northern
component is heterogeneous and consists of one type of herring, grown
up in coastal waters of Central and North Norway (northern component)
and another one, grown up in the Barents Sea and also having the
northern type of scale (Barents Sea component). Type of scale is
determined by the structure of rings being laid in the coastal period
of life. Specimens from the south coast of Norway have vague rings,
those from the north and the Barents Sea have clear ones. The number
of herring with the northern type of scale increases from the
southwest coast towards the north. In accord with ecological
conditions, herring spend 1 to 6 years in the coastal zone. Essential
distinctions of habitat also influence the specimen growth rate. The
highest growth rate is observed in herring grown up in coastal waters
of Southwest Norway, further north it decreases. Environmental
factors, such as temperature conditions, food supply and vegetation
period are responsible for great differences in the growth rate of
young herring. Six types of growth may be discerned by a number of
biological characteristics (Seliverstova, 1969; Shutova-Korzh, 1960;
Ottestad, 1934). Differences in growth type are observed only prior to
maturation. Certain scale formulae - different ratio of coastal,
oceanic and spawning rings (Seliverstova, 1969, 1973, 1978; Lea, 1929;
Runnstrøm, 1936) - correspond to each growth type. Exceptional
distribution of herring in the coastal zone in the 1970-1980's
resulted in an absence of the oceanic period of life and the
corresponding rings on the scale. Thus, groupings AS1+1, AS2+1, AS2+2
(southern component) are formed in coastal waters of Southwest Norway;
AN2+1, AN2+2, BN2+1, BN2+2, B-CN2+2, B-CN3+1 - in coastal waters of
Central Norway, AN3+0, AN3+1, CN3+0, CN3+1, CN3+2 - in coastal waters
of North Norway (northern component). Groupings DN4+0, DN4+1, C-DN4+0,
C-DN4+1, A, C, D, C-DN6+0, A, C, D, C-DN6+1 are typical of the Barents
Sea (the Barents Sea component).

Herring reach maturity at 3-8 years. Yet, specimens of the southern
component mature at 3-5 years, mainly at 3-4 years, those of the
northern component, at the age of 3-6, mainly 4-5, and those of the
Barents Sea component, at 4-8 years, mainly 5-6 years. Average lengths
(Tables 1, 2, 3,) of spawning herring of the southern component are
24.9-28.5 cm, those of the northern component are 25.8-28.9 cm, and
those of the Barents Sea component are 24.8-28.4 cm. Thus, the average
length of spawning herring is 25-29 cm (Seliverstova, 1977, 1978).

Poor year classes appearing in years with a low water heat content
occupy on the whole a smaller area, spreading mainly on the Southern
Norwegian Shoal with more auspicious conditions favouring faster
growth and earlier maturation. As a result, 60% of the specimens
recruit to the spawning population at the age of 3-4, and maturation
is completed by 5 years. Year classes of average abundance and higher
recruit to the spawning population at 4-5 years by 70%. In rich year
classes about 70% of specimens recruit to the spawning stock at age
5-6, and in the richest ones (1950) 30% more may join the spawning
population at age 7-8 years (Seliverstova, 1977, 1978).

Thus, each component (southern, northern and Barents Sea one) consists
of groupings which differ in growth rate and maturation. Component
ratio in year classes with different abundance is heteroge-neous. Poor
year classes consist mainly of herring of the southern and northern
components (groupings with high growth rate and early maturation -
AS1+1*, AS2+1, AS2+2, AN2+1, AN2+2, BN2+1, BN2+2, B-CN2+2).
Specimens of the northern component prevail in average by number year

classes (groupings - AN2+1, AN2+2, BN2+1, BN2+2, CN3+0, CN3+1, CN3+2, B-CN2+2, B-CN3+1), per cent of the Barents Sea specimens (DN4+1) is about 17%. In year classes with high numbers, basic groupings are AN2+1, AN2+2, BN2+1, BN2+2, CN3+0, CN3+1, CN3+2, B-CN2+2, B-CN3+1, DN4+0, DN4+1, C-DN4+0, C-DN4+1, A, C, D, C-DN6+0, A, C, D, C-DN6+1; specimens of the southern component account for no more than 10%, those of the northern component for about 40%, while those of the Barents Sea component count for more than 50% (Table 4).

*) AS1+1-A-type of growth, S-southern type of scale; 1-one coastal ring; 1-one oceanic ring; first spawning at age 3. CN3+0-C-type growth; N-northern type of scale; 3-three coastal rings; 0-no oceanic rings; first spawning at age 4.

Year class structure affects the dynamics of individual absolute fecundity as well. Specimens of the southern component have a higher absolute fecundity in all age groups compared to those of the northern and Barents Sea components. Due to this, poor year classes consisting mainly of herring of the southern component have a higher fecundity than average and rich ones. Knowledge of year class structure makes it easy to follow changes in the stock, allows us to estimate the percentage of separate groupings and, consequently, components in each year class and in the spawning stock.

YEAR CLASS STRUCTURE AND INDIVIDUAL ABSOLUTE FECUNDITY

The decrease in the herring stock abundance from 36.9×10^9 specimens in 1950 to 0.09×10^9 specimens in 1971 (Dragesund and Ulltang, 1975) led to considerable changes in age composition of the spawning population in the years under review (Table 5). 16 to 19 age groups related to year classes of varying abundance spawned in the 1950's. Their number decreased to 8-10 in the 1970's, and they were represented by specimens of poor year classes. With the decrease in the number of spawning age groups, the importance of rich year classes increases, and with low spawning stock numbers, that of the poor year classes too. Considering the many-aged structure of the spawning stock in the 1950's, specimens of the rich 1950 year class at age 4-6 years (predominant age of maturation) constituted 14.8-46.6%. In the 1960's, when the number of spawning age groups decreased, specimens of the abundant 1959 year class at the same age had already made up 61.0-70.5%. In the 1970's, specimens of the poor 1969 year class at the same age dominated (77.7-89.0%) the spawning stock (Table 5). The contribution of one year class affects not only the age composition of the entire spawning population, but also its mean absolute fecundity due to low recruit fecundity. The 1950 year class is characterized by a delayed maturation. 54.1% of the specimens recruited to the spawning population at the age of 6 years (Seliverstova, 1978). Average absolute fecundity was 64.6 thousand eggs in 1955. 70.4% of the specimens of the 1959 year class matured at the same age. As a result, average absolute fecundity was 54.7 thousand eggs in 1964 (Table 6).

Absolute fecundity of year classes with varying abundance is different. If absolute fecundity of herring of poor year classes at the age of 4 was 62.7 thousand eggs, that of abundant ones was 33.1 thousand eggs. The difference does not disappear with age (Table 7). This fact was also acknowledged by Lyamin (1966). Fecundity of above hundred thousands of eggs is registered in specimens of poor year

classes at an earalier age than in specimens of average and rich year
classes. Absolute fecundity of equal by number year classes turns out
to be different too. Fecundity of herring of the rich 1950, 1959, and
1969 year classes at the age of 5 was 50.0, 42.5 and 38.7 thousand
eggs, and at the age of 10, 72.5, 90,1 and 100.8 thousand eggs
respectively. Average absolute fecundity in average year classes of
the 1960's is also higher than that in year classes of the 1950's. So,
fecundity of herring of the 1951 year class at the age of 5 was   42.4
thousand eggs, while that of the 1961 year class at the same age was
57.3 thousand eggs. Fecundity of 9 year olds differs markedly too;
76.9 and 95.2 thousand eggs respectively (Table 6). This difference in
individual absolute fecundity between age groups results   from
different fecundity of separate groupings of herring maturing at one
and the same age and also from their ratio in year classes. Fecundity
of southern groupings is higher than that of northern ones which
confirms the regularity found for many marine fish species (Nikolsky,
1974). Absolute fecundity of herring of southern grouping AS2+1 at the
age of 4 is 49.3 thousand eggs, that of BN2+1 from coastal areas of
Central Norway at the same age is 39.7 thousand eggs, and that of
CN3+0 from North Norway 28.2 thousand eggs (Table 8). The difference
is traced in subsequent years. Absolute fecundity of herring of the
above groupings at the age of 9 was 92.0, 88.7 and 81.4 thousand eggs
respectively. The Barents Sea herring groupings DN4+0, C-DN4+0, DN4+1,
C-DN4+1, A, C, D, C-DN6+0, A, C, D, C-DN6+1 have a low absolute
fecundity. Recruit fecundity of these groupings is 24.5-43.0 thousand
eggs, that of the southern groupings AS1+1, AS2+1 and AS2+2 is   40.9-
58.6 thousand eggs, and that of the northern groupings AN2+1, AN2+2,
BN2+1, BN2+2, CN3+1, CN3+2, B-CN2+2, B-CN3+1, AN3+0,AN3+1 is 37.3-68.7
thousand eggs. Absolute fecundity of the Barents Sea grouping DN4+1 at
the ages of 9 and 10 years was 82.1 and 85.7 thousand eggs, that of
the southern grouping AS2+1 at the same ages was 92.0 and 103.9
thousand eggs respectively (Table 8). The value of individual absolute
fecundity depends as well on the number of spawnings experienced
during their life cycle. If herring of groupings AS2+1 and AN2+1
having matured at the age of 4 spawned 13 times and its absolute
fecundity was 120.9 and 139.9 thousand eggs at the age of 16, the
Barents Sea grouping DN4+1 having matured at the age of 6 spawned only
10 times and its absolute fecundity did not exceed 93.5 thousand eggs.
Thus, the earlier herring mature, the higher their absolute fecundity,
and the larger the number of eggs of their whole life cycle.

Having found that herring groupings have a varying fecundity, it was
quite natural to follow the absolute fecundity dynamics in accord with
the year class numbers. Analysis of Table 9 shows that southern
groupings AS1+1, AS2+1 and the northern one AN2+1 of poor year classes
have higher absolute fecundity than those of rich year classes.
Absolute fecundity of coastal grouping BN2+1 from Central Norway and
of Barents Sea grouping DN4+1 is higher in rich year classes. If
specimens of poor year classes stay in coastal waters of southern
auspicious areas due to lower intensity of the Norwegian Current, the
higher intensity of this Current maintains good conditions for herring
growth in the northern areas, promoting fecundity increase in northern
groupings of rich year classes.

Thus, they year class structure is heterogeneous and depends on the
year class strength. Weak year classes consist mainly of herring of
the southern component. Specimens of the northern component prevail in
average year classes, the percentage of the Barents Sea component is
about 17. Herring of the Barents Sea component dominate in abundant
year classes.

Individual absolute fecundity of herring of weak year classes is by
far higher than that of average and strong ones.

Herring of southern groupings in all age classes have higher
individual absolute fecundity than specimens of northern and Barents
Sea groupings. Thus, individual absolute fecundity of poor year
classes is determined by individual absolute fecundity of groupings
forming the southern component, that of rich year classes - of
groupings constituting the northern and Barents Sea components.

Individual absolute fecundity of herring year classes of the 1960's is
higher than that of the 1950's, which is associated with different
fecundity of separate groupings maturing at the same age and with
their ratio in year classes with varying abundance.

SPAWNING STOCK STRUCTURE AND POPULATION FECUNDITY

Knowledge of individual absolute fecundity dynamics depending on the
year class and spawning stock structure makes it possible to determine
each grouping and each component contribution in the population
reproduction.

Analysis of spawning stock population fecundity in 1951-75 shows that
it decreases with the stock numbers reduction (Tables 10 and 11). But
a more detailed study indicates that the relation between female
numbers and population fecundity value is not always direct.
Investigations included years when female abundance was the same and
the number of eggs spawned in compared years was different. Five pairs
of years having an almost similar female abundance were chosen (Table
12). 1952/1958 and 1953/1959 were studied in the 1950's. In general,
there is a direct relation between female numbers and population
fecundity value. The equal number of females spawns an equal amount of
eggs, and with the decrease or increase in the number of females the
population fecundity decreases or increases respectively. The relation
changes in the 1960's. With the increase in the number of females the
amount of eggs spawned is nearly halved. In 1960 the number of females
was $8.6x10^9$ specimens in the spawning stock, and they laid $718.4x10^{12}$
eggs. In 1965 the female number was somewhat higher, $8.9x10^9$ specimen,
yet, the amount of eggs laid was twice as small. The same pattern is
registered for 1961/1964 and 1962/1966.

The spawning stock consists of specimens grown up prior to maturation
under varying conditions and differing, consequently, in growth and
maturation rates and individual absolute fecundity values. In the
1950's, specimens of the northern and southern components prevailed in
the spawning stock, as did those of the Barents Sea component in the
1960's (Table 13). As it has been shown, the Barents Sea specimens
have lower individual absolute fecundity compared to herring of the
southern and northern components. In the 1950's the lower absolute
fecundity of Barents Sea herring did not affect the spawning
negatively, since the many-aged structure of the spawning stock (16-18
age groups), a large percentage of older age groups in all components
having the highest fecundity delayed recruitment to the spawning
stock, with the rich yearclass smoothing down the influence of the
Barents Sea specimens on the amount of eggs laid in that period (Table
12). In the 1960's when there were only 8-10 age groups in the
spawning stock, the older specimens constituted no more than 2-4%, and
herring of the abundant 1959 year class about 70% (Table 5). The
Barents Sea component prevailing in this year class and, consequently,

in the spawning stock, the importance of the Barents Sea specimens turned out to be decisive those years (Table 12). In 1965 the number of females in the Barents Sea component increased by 1.6 times, while the population fecundity even decreased. In 1964 the number of Barents Sea specimens was 1.3-fold higher than in 1961, though the amount of eggs laid was 1.5 times smaller. The same is observed with specimens of the northern component recruiting to the spawning stock. In 1964 the number of herring of this component was 1.2 times lower and the amount of eggs laid was twice as small. The rich 1950 and 1959 were registered in the 1950's and 1960's respectively. Yet, the rate of maturation and age of recruitment to the spawning stock is different in species of these two year classes. In 1956 the percentage of the southern and Barents Sea components in the 1950 year class was 12.4 and 14.5 respectively, but if specimens of the former component laid 58.6×10^{12} eggs, those of the latter laid only 41×10^{12} eggs. In 1957 the percentage of Barents Sea specimens in the 1950 year class was twice as low compared to that of the northern ones, but the amount of eggs laid by the former specimens turned out to be 3.3 times smaller (Table 14). Specimens of the 1959 year class at the age of 5 accounted for 68.9% of spawning stock. The percentage of Barents Sea specimens in the above year class was 46.0, that of northern ones 43.9, while the amounts of eggs laid were 68.5×10^{12} and 99.1×10^{12} respectively. Specimens of the 1959 year class at the age of 6 accounted for 70.5% of the spawning stock. The number of Barents Sea specimens in the year class was 2.6 times higher than that of northern ones, but the amount of eggs laid was only 1.8 times greater (Table 14).

Combined with the pronounced adverse abiotic conditions in the 1960's, the decrease in the number of eggs laid, together with the simultaneous increase in immature and adult herring catches were factors which entailed sharp reduction of fish stocks. The numerical strength of herring year classes fluctuates very much. A very rich 1959 year class (21175×10^6 specimens of 3 year olds) appeared from 946.6×10^{12} eggs and a poor 1955 year class (494×10^6 specimens of 3 year olds) - from 1421.6×10^{12} eggs (Tables 11 and 15). The 1951-1975 year classes are summarized by their yeara class strength, numbers of 3 year olds and survival rates (Table 16). In the 1950's the highest survival rate was observed in the rich 1959 year class (0.002237). Year classes of above average numbers appeared as well in years with favourable conditions for juvenile survival. The survival rate of these year classes varies from 0.000615 to 0.004089, being on an average 0.001707. The survival rate of the poor 1969, 1973 and 1974 year classes is high. However, favourable conditions for juvenile survival and growth did not lead in these years to the appearance of rich year classes since the number of the spawning stock , and consequently , population fecundity were low. The survival rate of poor year classes vary in ten year periods by an order. It was 0.000030 in the 1950's, 0.000868 in the 1960's and 0.003287 in the 1970's (Tables 16 and 17).

The habitat of the various components of herring is diverse. In years with a considerable heat content increase in the Norwegian Current, conditions are favourable for year classes of high and above average numbers of the northern and Barents Sea components. In hydrologically warm years, the survival rates are high just for these components. In cold years conditions are favourable for the southern component (Table 18).

Knowing the survival rates for a year class on the whole and for its components in particular we may estimate various levels of population

fecundity and spawning stock biomass. There are the following levels
of population fecundity (Serebryakov, 1988): guaranteed population
fecundity (GPF), when a rich year class can appear under average
conditions - the ratio of the number of 3 year olds of a rich year
class to survival rate corresponding to average conditions; minimum
tolerance population fecundity (MTPF) ensures natural fluctuations of
the year class strength when a rich year class appears under
favourable conditions, an average year class under average conditions,
and poor year classes in years with unfavourable conditions (the ratio
of the number of 3 year olds of an average year class to survival rate
corresponding to average conditions); critical population fecundity
(CPF), when a rich year class can only appear under the most
favourable conditions (the ratio of the number of 3 year olds of a
rich year class to survival rate corresponding to herring survival
under the most favourable conditions). Lower than critical. A level
lower than the critical population fecundity stipulates the appearance
of poor year classes and results in a prolonged depression of the
spawning stock (Serebryakov, 1988).

Only one very rich year class, 1959, (21×10^9 specimens of 3 year olds)
and four year classes of above average abundance appeared in the
period from 1951 to 1975. A high occurrence of year classes of above
average abundance gave rise to the estimation of population fecundity
levels including the number of 3 year olds of such year classes

The guaranteed population fecundity level is the highest one. It
corresponds to 15.7 million tonnes of spawning biomass. The minimum
tolerance level is maintained with 6.9 million tonnes. The critical
level shows agreement with 0.6 million tonnes of the spawning biomass
(Table 19).

An analysis of each component contribution (Table 20) into population
fecundity showed that the critical population fecundity value of
specimens of the southern component constituting the spawning stock
should be no less than 40×10^{12} eggs, that of the northern component -
71×10^{12} eggs, corresponding to a spawning stock biomass of 0.3 million
tonnes in the first case and 0.6 million tonnes in the second. These
data comply with the fact that in 1983 the spawning stock consisted of
specimens from nothing but the southern and northern components of the
poor 1969-1980 year classes and its biomass reched 0.6 million tonnes.
Conditions for egg and larval development this year favoured the
appearance of a year class comparable in fingerling numbers with the
rich 1960 year class (49×10^9 specimens of the 1983 year class and
47×10^9 specimens of the 1960 yearclass). The critical population
fecundity of the Barents Sea component is much higher - 152×10^{12} eggs.
Such an amount of eggs can be laid by a stock whose biomass is 1.3
million tonnes (the critical spawning stock consisting of Barents Sea
specimens).

Data from Tables 19 and 20 show that average weight and individual
absolute fecundity increased from the 1950's to the 1970's, due to
variations not only in the structure of the spawning stock, but also
in its abundance during these years.

Depending on the number, age composition of the spawning stock,
component ratio, abiotic conditions in the 1950-1970's, the survival
rates of the most favourable years are different for each ten-year
period. In this connection the critical population fecundity value of
the Barents Sea component varies from 152×10^{12} eggs in the 1950's,
258×10^{12} eggs in the 1960's to 381×10^{12} eggs in the 1970's. A critical

(unexploited) stock consisting of Barents Sea herring in these three ten-year periods must have reached 1.4, 2.3 and 2.9 million tonnes respectively. In 1988 the spawning stock biomass, 80% of which consisted of Barents Sea specimens, reached 1.35 million tonnes (Anon., 1989), half as much as the estimated unexploited spawning stock making a rich year class available under the most favourable conditions of the 1970's (Table 21).

A spawning stock with a biomass of 0.3-1.3 million tonnes guaranteeing the emergence of a rich year class under the most favourable conditions will preserve the present herring range - the narrow coastal zone of Norway - and will only leave for the spawning grounds in the open sea. To restore the range of the 1950's - early 1960's, the spawning stock biomass should make up 6.9-7.5 million tonnes, corresponding to a minimum tolerance level of population fecundity (MTPF) of 850 - 906×10^{12} eggs.

Estimated year class strength (by number of 3 year olds) by the use of 9 different survival rates and various levels of population fecundity (Table 22) showed that 5 rich, 2 average and 2 poor year classes can appear from a spawning stock biomass of 6.9 million tonnes with a population fecundity of 840×10^{12} eggs. The probability of the appearance of poor year classes (Table 23) increases with decreasing population fecundity.

Thus, the Barents Sea component of rich year classes characterized by a low individual absolute fecundity reduces population fecundity when recruiting to the spawning stock. The smaller amount of eggs laid was one of the factors causing a sharp decrease of the herring stock in the 1960's.

The minimum tolerance level of 839.8×10^{12} eggs maintaining natural variations of year class strength is consistent with a spawning stock biomass of 6.9 million tonnes while the critical level (76.5×10^{12} eggs) is consistent with that of 0.6 million tonnes.

The critical population fecundity of a spawning stock consisting of herring of the southern component should be no less than 40×10^{12} eggs, of the northern - 71×10^{12} eggs, of the Barents Sea component 152×10^{12} eggs which corresponds to spawning stock biomasses of 0.3, 0.6 and 1.3 million tonnes respectively.

A spawning stock with a biomass of 0.3-1.3 million tonnes making rich year classes available under the most favourable conditions will keep to the present herring range - Norwegian territorial waters.

To reestablish the range of the 1950-1960's the spawning stock biomass should reach the level of 6.9-7.5 million tonnes, which is consistent with the minimum tolerance level of population fecundity of 850-906×10^{12} eggs.

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        1976/H:43;   1978/H:33;   1979/H:65;   1980/G:53;   1981/G:78;
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Table 1. Length of Atlanto-Scandian herring of the southern
component during first spawning, cm.

Year class	Year class abundance estimate	Age of first spawning					
		3		4		5	
1947	average			25-29	27.2		
1948	average			25-29	27.0		
1949	average			24-29	26.9		
1950	rich	23-26	24.9	24-30	26.9	25-29	27.5
1951	average	24-27	25.2	24-30	26.8	26-30	28.1
1952	average	23-27	25.2	24-30	27.0	26-30	28.5
1953	average	22-27	25.0	25-30	27.0		
1954	poor	22-28	25.3	25-30	27.1		
1955	poor	24-27	25.6	26-30	27.2		
1959	rich	22-28	25.0	23-29	26.5	27-30	28.4
1960	rich	23-26	24.9	23-29	26.3		
1961	average	22-28	25.3	24-29	26.7		
1962	poor	24-29	25.5	26-28	27.1		
1963	average	23-27	25.2	24-27	26.4		
1964	average	24-28	25.8				
1968	poor	24-28	26.8	25-30	27.8	27-30	28.5
1969	poor	25-29	26.9	26-30	27.9		
1972	poor	24-28	26.1				

Note: 23-26 = minimum and maximum fork length of herring;
24.9 = mean length.

Table 2. Length of Atlanto-Scandian herring of the northern
component during first spawning, cm.

Year class	Year class abundance estimate	Age of first spawning					
		4		5		6	
1947	average	24-28	26.6	25-30	28.0		
1948	average	23-29	27.0	24-31	27.9	27-31	28.9
1949	average	24-29	26.8	25-31	27.4		
1950	rich	23-29	26.4	23-30	27.5	26-31	28.5
1951	average	24-28	26.5	25-30	27.1	27-30	28.6
1952	average	24-28	26.4	25-30	27.5	27-29	29.7
1953	average	24-29	26.5	25-31	27.1	27-30	28.7
1954	poor	25-29	26.6	25-30	27.7		
1955	poor	24-29	26.4				
1959	rich	23-29	26.2	23-31	27.0	27-30	28.5
1960	rich	24-28	26.2	23-29	26.2	26-30	27.7
1961	average	23-29	26.4	25-29	26.7	28-29	28.7
1962	poor	26-30	27.3	25-29	26.8		
1963	average	23-29	25.8	25-30	27.5		
1964	average	25-28	26.9	25-30	27.8	26-29	26.7
1968	poor			25-31	27.7		
1969	poor	23-30	27.4	26-30	28.8		

Note: 24-28 = Minimum and maximum fork length of herring;
      26.6 = mean length

Table 3. Length of Atlanto-Scandian herring of Barents Sea
component during first spawning, cm.

Year class	Year class abundance estimate	Age of first spawning					
		5		6		7	
1947	average			26-30	28.1		
1948	average			26-30	28.0		
1949	average			26-31	28.2		
1950	rich			25-30	27.5	25-31	28.2
1951	average			25-29	27.2	27-31	28.4
1952	average			24-29	27.1		
1953	average			26-30	27.8		
1959	rich	22-27	24.8	25-29	27.2		
1960	rich	23-27	25.0	24-29	26.9		
1969	poor	27-30	28.4				

Note: 22-27 = Minimum and maximum fork length of herring;
      24.8 = mean length

Table 4. Ratio of various herring components in year classes, %.

Year class abundance estimate	Year class	Component			No.
		southern	northern	Barents S	
Poor	1954	32.6	62.8	4.6	175
	1955	45.0	54.0	1.0	100
	1956	39.1	58.5	2.4	41
	1957	50.0	50.0	-	34
	1958	34.2	50.0	15.8	38
	1962	29.6	56.8	13.6	88
	1965	25.0	67.9	7.1	28
	1966	47.8	47.7	4.5	44
	1967	52.0	48.0	-	25
	1968	39.0	54.7	6.3	95
	1969	30.1	65.7	4.2	662
	1970	55.0	45.0	-	20
	1954--1970	38.2	56.3	5.5	1350
Average & above average	1947	23.5	62.3	14.2	380
	1948	13.4	67.2	19.4	313
	1949	22.0	64.1	13.9	296
	1951	20.1	62.8	17.1	879
	1952	34.2	55.8	10.0	511
	1953	25.8	66.0	8.2	368
	1961	30.8	41.9	27.3	662
	1963	23.3	59.2	17.5	103
	1964	15.1	39.6	45.3	86
	1947--1964	24.6	58.1	17.3	3598
Rich	1950	7.5	59.0	33.5	2497
	1959	7.8	32.7	59.5	3520
	1960	9.7	15.0	75.3	1390
	1950--1960	8.1	38.2	53.7	7407

Table 5. Age composition of Atlanto-Scandian herring in Norwegian
Sea spawning grounds in 1951-1975, %.

Year	AGE																					No.
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1951	-	-	5.7	7.0	9.5	14.8	10.5	5.4	5.7	6.0	9.7	10.5	7.8	3.6	2.6	0.6	0.6	-	-	-	-	718
1952	-	0.3	2.7	20.4	5.1	6.5	16.7	11.9	6.2	6.2	8.2	7.8	4.4	2.7	0.3	0.6	-	-	-	-	-	294
1953	-	0.6	1.2	9.6	20.3	1.7	5.6	14.7	10.8	4.5	4.0	7.3	9.6	7.3	1.7	-	1.1	-	-	-	-	177
1954	-	0.4	14.8	3.9	11.6	13.2	3.1	14.0	9.3	4.2	3.9	5.0	5.1	5.5	2.8	2.0	0.8	0.4	-	-	-	257
1955	-	-	0.2	14.6	5.3	6.8	9.3	10.4	12.6	10.4	6.0	6.0	6.0	5.8	3.7	1.3	0.7	0.9	-	-	-	452
1956	-	0.6	8.6	13.6	46.6	3.8	5.7	4.4	4.1	2.6	2.4	1.8	1.8	1.0	1.6	0.7	0.6	0.1	-	-	-	886
1957	-	2.2	4.4	6.7	11.8	38.1	4.5	4.9	4.6	4.4	6.2	2.7	2.8	1.7	2.1	1.4	1.0	0.4	0.1	-	-	1139
1958	-	0.1	0.4	3.0	6.8	11.0	50.2	4.7	6.5	5.1	3.5	2.4	1.8	1.9	1.2	0.5	0.6	-	0.1	-	0.2	1087
1959	-	0.1	1.3	1.7	5.6	4.8	15.8	43.5	5.1	5.8	4.4	3.6	2.4	1.2	1.7	1.2	0.8	0.5	0.4	-	0.1	1096
1960	-	0.3	0.6	1.0	1.5	5.3	5.7	20.5	44.1	6.3	5.8	2.5	1.3	2.3	0.9	1.4	0.4	0.1	-	-	-	683
1961	-	-	0.1	0.4	2.7	2.8	8.5	10.4	18.5	42.5	4.5	3.7	2.0	1.9	0.8	0.6	0.3	-	0.3	-	-	642
1962	-	3.9	1.5	1.9	3.3	3.9	2.9	10.2	9.8	20.1	31.2	3.2	5.0	0.6	0.6	1.1	0.4	0.2	0.2	-	-	462
1963	-	1.7	61.0	1.0	0.7	0.1	1.4	4.1	4.9	6.8	8.5	7.9	1.5	0.1	0.3	-	-	-	-	-	-	898
1964	-	1.0	5.2	68.9	0.9	1.4	0.5	1.6	3.2	3.9	4.0	4.0	4.7	0.4	0.1	0.1	-	-	-	0.1	-	930
1965	-	0.1	5.7	14.0	70.5	0.4	0.2	0.7	0.5	1.5	2.1	2.3	1.3	0.7	-	-	-	-	-	-	-	934
1966	-	-	0.4	10.6	28.2	57.3	0.6	0.3	0.2	0.3	0.5	0.5	0.3	0.6	0.2	-	-	-	-	-	-	1090
1967	-	0.9	1.4	0.7	11.1	27.1	53.0	0.6	0.2	0.1	0.3	0.6	0.2	1.1	1.7	0.9	-	-	0.1	-	-	882
1968	-	0.1	-	1.2	0.8	14.3	28.1	50.1	0.8	0.1	0.2	0.9	0.5	0.5	0.6	1.2	0.6	-	-	-	-	809
1969	-	0.1	0.5	5.0	4.0	3.2	16.6	32.6	33.9	1.0	0.3	0.5	0.7	0.1	0.4	0.6	0.2	0.3	-	-	-	929
1970	-	0.2	4.3	3.6	15.9	3.8	4.2	13.9	29.8	21.7	0.2	0.2	0.5	0.8	0.3	0.2	-	0.2	0.2	-	-	560
1971	-	-	0.5	2.4	2.9	4.3	9.0	14.6	26.5	25.6	14.2	-	-	-	-	-	-	-	-	-	-	211
1972	-	19.8	19.8	22.2	11.6	5.8	4.6	2.3	7.0	4.6	2.3	-	-	-	-	-	-	-	-	-	-	86
1973	-	5.3	77.7	10.9	1.5	1.9	0.4	0.4	-	-	0.4	1.1	0.4	-	-	-	-	-	-	-	-	265
1974	-	-	0.5	96.8	1.6	0.8	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	370
1975	0.4	5.0	0.4	0.2	89.0	3.5	1.1	0.2	-	0.2	-	-	-	-	-	-	-	-	-	-	-	457

Table 6. Absolute fecundity variation dependent on
herring age in 1954-1975, thousand eggs.

Age	YEAR SURVEYED				
	1954	1955	1956	1957	1958
3	-	-	-	-	-
4	38.6-52.8 44.9/3	24.8-44.3 34.5/5	14.0-49.9 27.4/4	86.9- 86.9/1	-
5	37.0-42.6 39.8/2	28.1-94.3 50.0/24	27.8-61.2 42.4/4	33.1-80.4 55.1/6	-
6	49.4-98.5 73.9/2	41.9-94.8 68.8/4	19.1-78.7 48.1/17	55.6-66.6 60.0/3	-
7	42.1-85.2 63.5/6	74.1- 74.1/1	41.6-81.6 60.4/3	44.1-88.8 65.3/10	72.4-126.0 98.7/3
8	90.8-91.3 91.0/2	85.0-94.6 89.8/2	61.9-102.2 77.3/3	45.8-116.5 81.2/2	68.6-128.8 92.7/6
9	63.3-102.8 80.7/8	86.2- 86.2/1	65.2- 65.2/1	50.5-105.5 78.0/2	92.7-124.7 108.7/2
10	75.5-85.0 79.5/3	68.6- 68.6/1	40.6-82.2 57.7/3	52.7-92.8 72.7/2	-
11	33.8-11.0 82.2/10	128.0- 128.0/1	101.8- 101.8/1	98.3-107.8 103.0/2	80.8- 80.8/1
12	63.1- 63.1/1	126.3- 126.3/1	-	-	100.4-116.9 106.2/4
13	63.1-86.3 76.3/3	75.9-98.0 87.0/2	84.8- 84.8/1	84.4- 84.4/1	110.2- 110.2/1
14	68.4-89.7 77.5/4	-	-	-	74.6-87.0 80.8/2
15	72.3-97.6 81.4/3	95.7- 95.7/1	74.9- 74.9/1	88.2- 88.2/1	83.0-130.7 108.2/4
16	96.3- 96.3/1	41.3-161.9 97.4/6	67.1-109.3 88.7/4	94.7-131.2 112.3/3	-
17	81.0- 81.0/1	-	-	-	-
18	-	-	-	95.5- 95.5/1	-
19	114.0- 114.0/1	-	-	76.8- 76.8/1	-
20	-	-	-	-	-
Mean/no.	75.4/50	64.6/49	56.3/42	74.3/35	99.1/23

Note: 38.6-52.8 = minimum and maximum fecundity;
      44.9/3 = mean fecundity and number of specimens.

Table 6 continued.

Age	YEAR SURVEYED				
	1959	1960	1961	1962	1963
3	-	-	-	-	-
4	54.5-61.4 57.9/2	35.0-57.4 46.2/2	69.6-84.8 74.8/4	-	14.0-51.8 31.3/22
5	71.3-84.2 77.3/3	55.0-57.2 56.1/2	39.0- 39.0/1	-	50.1- 50.1/1
6	67.0-81.9 76.5/4	53.7-83.9 68.8/2	65.4-108.8 83.2/11	99.8-111.4 105.6/2	62.9- 62.9/1
7	56.3-102.4 84.0/10	53.0-105.1 69.2/3	67.4-119.4 86.5/9	79.1-120.1 103.4/4	72.4-95.8 84.1/2
8	49.3-109.8 72.5/17	62.1-124.6 83.2/21	54.7-120.7 84.6/32	73.3-129.1 103.8/7	81.9-136.0 99.5/5
9	40.6-99.6 73.4/39	51.0-110.2 76.9/41	59.2-132.7 89.6/32	71.3-155.8 96.1/13	53.9-143.9 93.9/9
10	62.9-99.0 78.2/3	41.5-116.7 72.5/80	58.9-130.2 91.0/56	51.1-144.9 96.7/19	56.4-123.7 81.6/18
11	60.9-93.9 79.0/9	55.0-107.7 75.8/10	54.5-152.0 86.3/133	67.5-161.7 98.9/24	55.9-114.9 83.7/19
12	68.0-98.5 82.4/4	56.9-111.0 83.0/7	58.2-119.7 88.6/16	64.7-126.3 95.7/39	53.8-121.0 81.4/23
13	68.7-119.7 87.9/10	63.4-102.5 76.2/5	61.8-161.9 95.0/21	106.6-151.1 129.0/5	58.9-127.6 85.7/28
14	75.6-138.6 100.0/3	62.0-88.1 75.8/5	67.9-113.9 94.6/5	69.7-115.1 96.0/5	63.4-74.3 68.8/2
15	51.1-103.1 85.0/4	72.4-131.8 88.7/6	83.8-125.7 105.9/5	86.5-113.4 97.0/5	101.3- 101.3/1
16	-	68.2-89.8 79.0/2	75.8-112.9 94.6/3	93.3-107.9 99.0/3	-
17	82.7- 82.7/1	87.5-98.5 93.4/3	73.0-110.6 88.3/4	-	-
18	-	77.0-89.0 83.0/2	69.5-91.5 79.5/4	-	-
19	73.9- 73.9/1	-	-	94.2-110.7 102.5/2	-
20	-	-	-	-	-
Mean/no.	77.6/110	75.5/201	88.9/340	98.9/128	75.4/131

Table 6 continued

Age	YEAR SURVEYED				
	1964	1965	1966	1967	1968
3	23.8-32.6 28.2/2	-	-	-	-
4	11.6-49.8 33.2/23	23.1-63.0 41.2/7	-	-	-
5	11.4-97.2 42.5/328	12.2-103.1 38.7/33	24.5-91.2 57.3/17	-	59.7-60.5 60.1/2
6	51.6-74.4 63.0/2	16.9-109.6 53.2/265	22.0-95.6 54.9/57	44.7-98.1 69.6/15	78.0-89.1 83.5/2
7	60.6-88.3 74.5/3	50.4-71.0 59.9/4	32.5-118.5 63.6/190	38.6-96.6 66.6/38	46.8-138.4 83.8/71
8	75.5-98.2 83.7/3	85.0-101.1 93.1/2	-	52.5-119.2 80.7/78	44.3-146.8 81.8/176
9	83.2-104.1 92.3/4	82.2-124.5 97.6/3	66.1-106.6 86.4/2	-	39.6-155.2 87.7/301
10	77.7-108.4 90.1/12	72.8-125.0 98.2/8	-	95.1- 95.1/1	127.3- 127.3/1
11	63.8-137.1 100.8/17	55.4-120.1 89.7/14	92.3-92.4 92.4/2	-	98.3- 98.3/1
12	76.8-144.2 107.5/17	74.4-150.8 109.6/12	93.0-104.2 97.5/3	-	75.7- 75.7/1
13	57.8-115.2 82.9/22	68.3-177.1 105.1/15	79.7- 79.7/1	-	107.8-128.3 122.4/4
14	73.2-151.5 99.3/31	62.4-168.7 97.4/14	68.3-130.0 97.0/7	115.0-129.9 122.5/2	95.3-138.9 118.6/5
15	65.4-181.6 123.5/2	82.7-108.9 92.6/7	84.4-136.8 100.0/7	127.7- 127.7/1	101.3-130.9 113.4/6
16	-	126.1- 126.1/1	-	96.5-116.2 106.4/2	106.2-146.2 130.8/3
17	-	-	-	-	97.0-162.8 132.1/11
18	-	-	-	-	112.0-170.8 144.5/4
19	-	-	-	-	-
20	-	-	-	-	-
Mean/no.	54.7/466	60.9/385	63.0/286	77.0/137	87.6/588

Table 6 continued

Age	YEAR SURVEYED				
	1969	1970	1971	1972	1973
3	-	-	-	38.8-48.1 42.9/3	23.6-63.1 41.4/5
4	44.8- 44.8/1	-	-	33.8-82.8 54.0/5	30.9-101.2 65.0/24
5	33.0-60.5 50.6/9	23.7-72.1 50.0/3	-	64.5- 64.5/1	45.5-112.1 82.5/9
6	41.1-90.7 62.6/21	22.3-39.4 26.8/5	-	61.9-109.9 76.4/4	35.1-69.1 52.1/2
7	54.0-101.6 77.4/16	14.7-75.8 53.1/3	-	-	71.4-111.0 89.1/3
8	41.0-137.3 85.1/108	45.1-120.1 88.0/11	75.1-132.9 104.0/2	-	-
9	38.3-167.8 86.2/210	65.3-146.6 95.2/33	102.6-123.5 114.3/3	75.1-76.6 75.8/2	105.8- 105.8/1
10	50.5-154.9 90.1/263	53.8-168.9 100.8/62	93.7-131.7 111.9/6	79.3-108.6 90.3/3	-
11	80.4-151.3 108.0/5	44.1-173.6 102.9/84	111.5-118.7 115.1/2	71.7- 71.7/1	-
12	128.1-150.7 139.4/2	-	97.2-102.0 99.6/2	-	-
13	-	103.1- 103.1/1	-	-	-
14	96.4-142.4 119.7/6	70.8-172.9 121.8/2	-	-	-
15	92.9-99.3 96.1/2	-	-	-	-
16	109.4-119.5 123.1/3	116.1- 116.1/1	-	-	-
17	45.7-139.9 86.0/5	107.2- 107.2/1	-	-	-
18	90.0-139.8 109.4/4	-	-	-	-
19	109.5-119.7 114.6/2	-	-	-	-
20	-	130.2-157.1 143.6/2	-	-	-
Mean/No.	87.1/657	97.6/208	110.1/15	66.4/19	67.9/44

Table 6 completed.

Age	YEAR SURVEYED		
	1974	1975	1954-1975
3	-	30.8-63.6 45.4/6	23.6-63.6 41.5/16
4	-	-	11.6-101.2 44.9/103
5	27.6-182.0 73.2/236	-	11.4-182.0 54.6/681
6	64.7-115.5 81.2/6	58.0-137.2 94.7/151	16.9-137.2 66.4/576
7	-	62.7-104.4 86.9/7	14.7-138.4 70.7/396
8	-	88.4- 88.4/1	41.0-146.8 83.2/478
9	161.1- 161.1/1	97.2- 97.2/1	39.6-161.1 86.7/713
10	135.3- 135.3/1	-	40.6-168.9 88.9/542
11	-	-	33.8-173.6 92.2/336
12	-	-	53.8-150.8 95.0/132
13	-	-	57.8-177.1 92.1/120
14	-	-	62.0-172.9 98.5/93
15	141.1- 141.1/1	-	51.1-181.6 99.3/57
16	-	-	41.3-161.9 104.0/32
17	-	-	45.7-162.8 107.2/26
18	-	-	69.5-170.8 106.3/15
19	-	-	73.9-119.7 99.8/7
20	-	-	130.2-157.1 143.6/2
Mean/no.	74.3/245	92.6/166	77.8/4325

Table 7. Individual absolute fecundity variation of herring year classes of different strength varying on their age, thou.eggs.

Age years	Year class strength		
	Poor	Average	Rich
3	23.6-63.6 43.4/14	23.8-32.6 28.2/2	-
4	30.9-101.2 62.7/38	14.0-86.9 38.7/17	11.6-52.8 33.1/48
5	23.7-182.0 73.0/256	24.5-91.2 53.2/40	11.4-103.1 42.6/385
6	35.1-137.2 92.0/183	22.3-98.5 63.0/54	16.9-109.6 53.2/339
7	50.4-120.1 82.0/48	14.7-138.4 79.9/110	32.5-118.5 64.2/238
8	45.1-136.0 93.7/29	41.0-137.3 83.8/189	44.3-146.8 81.7/260
9	53.9-161.1 99.2/23	50.5-155.8 87.1/140	38.3-167.8 86.1/550
10	72.8-127.3 94.4/25	40.6-144.9 90.2/109	41.5-168.9 88.2/408
11	55.4-151.3 94.5/22	55.0-161.7 90.6/84	33.8-173.6 92.6/230
12	75.7-150.7 107.8/6	53.8-150.8 93.6/84	64.7-126.3 96.6/42
13	103.1-128.3 118.5/5	57.8-177.1 92.9/85	58.9-127.6 85.6/30
14	70.8-172.9 119.6/13	62.0-168.7 95.0/47	73.2-151.5 98.2/33
15	92.9-99.3 96.1/2	65.4-181.6 100.1/39	51.1-141.1 97.6/16
16	116.1- 116.1/1	41.3-161.9 105.6/28	68.2-96.3 84.8/3
17	-	45.7-162.8 115.1/18	73.0-110.6 89.3/8
18	-	77.0-139.8 99.8/7	69.5-170.8 112.0/8
19	-	73.9-114.0 93.9/2	76.8-119.7 102.2/5
20	-	-	130.2-157.1 143.6/2
No	665	1055	2605

Note: 23.6-63.6=min.& max. fec.,43.4/14=average fec./number of spec.

Table 8. Absolute fecundity of various herring groupings, thousand eggs.

Age Years	GROUPING				
	AS1+1	AS2+1	AN2+1	BN2+1	AS2+2
3	23.6-63.6 40.9/17	-		-	-
4	15.9-101.2 68.5/15	11.6-101.2 49.3/43	14.0-70.5 37.3/26	20.8-73.2 39.7/12	-
5	33.1-91.8 63.9/16	16.5-112.1 59.3/87	11.4-146.2 56.8/80	27.2-94.3 48.7/51	39.0-124.9 58.6/13
6	40.6-109.9 77.4/15	44.8-136.7 76.4/60	26.9-137.2 76.6/65	49.4-109.6 69.2/31	41.9-92.4 66.1/7
7	56.3-126.0 86.5/13	50.2-102.4 78.9/33	41.5-138.4 81.2/57	48.2-126.6 77.1/31	54.0-111.0 77.4/11
8	59.6-137.3 89.8/23	45.1-129.1 87.4/44	65.2-146.8 91.2/57	49.6-122.8 86.6/24	45.8-136.0 89.5/4
9	75.3-96.9 82.6/5	50.5-167.8 92.0/41	62.5-146.6 93.8/63	52.9-137.4 88.7/58	74.1-95.7 85.2/4
10	73.2-124.2 94.4/5	76.8-168.9 103.9/23	56.0-146.6 97.5/31	51.1-123.9 89.5/48	52.7-111.1 82.1/8
11	60.1-121.6 93.5/7	68.6-151.3 98.7/23	63.8-148.2 89.9/22	59.8-173.6 96.7/35	62.3-120.4 92.9/6
12	108.8-150.7 125.6/3	75.7-150.8 104.6/14	53.8-138.8 95.2/10	56.9-147.1 100.1/12	105.6- 105.6/1
13	86.4-123.9 105.1/2	66.6-177.1 108.9/8	77.1-151.1 113.3/9	67.0-108.7 85.1/9	102.5-118.6 110.5/2
14	172.9 172.9/1	71.6-138.6 101.8/3	63.4-138.9 93.3/9	67.9-127.1 108.7/8	101.2-113.9 107.5/2
15	113.6 113.6/1	86.2- 86.2/1	98.2-181.6 130.8/4	92.9-136.8 106.7/4	83.8- 83.8/1
16	-	106.2-146.2 120.9/5	139.9- 139.9/1	96.5- 96.5/1	-
17	-	-	138.9-150.7 144.8/2	107.2-125.7 114.2/3	-
18	-	91.5- 91.5/1	139.8- 139.8/1	-	-
19	-	-	-	-	-
20	-	-	130.2- 130.2/1	-	-
No.	123	386	438	327	59

Table 8 continued

Age	GROUPING				
Years	AN2+2	BN2+2	B-CN2+2	AN3+0	CN3+0
4	-	-	-	30.9-60.1 48.7/4	11.6-62.6 28.2/6
5	22.2-93.4 52.9/31	23.7-75.1 48.2/15	33.3-50.1 41.8/3	24.4-117.0 62.9/47	25.8-130.7 61.4/19
6	36.0-132.0 71.5/29	35.1-88.7 61.8/17	61.2- 61.2/1	51.5-126.2 84.9/28	42.9-128.8 84.2/21
7	57.1-93.5 76.1/11	41.6-118.5 79.8/19	92.0- 92.0/1	73.1- 73.1/1	56.7-92.6 69.9/4
8	73.0-93.2 82.8/10	58.2-103.2 80.9/17	47.1-120.7 83.5/4	66.5-80.2 72.5/4	63.1-121.9 92.7/2
9	75.1-115.8 92.2/11	42.1-143.2 82.6/31	56.5-100.6 84.0/9	83.0-100.7 91.8/2	45.8-121.8 81.4/7
10	67.7-128.7 92.2/20	69.8-144.9 96.6/24	40.6-93.2 78.9/6	65.0-111.5 79.9/5	86.5-123.1 97.5/6
11	41.1-151.7 96.0/15	62.0-160.5 96.0/27	69.8-106.4 93.1/9	116.3- 116.3/1	82.0- 82.0/1
12	68.0-121.0 97.8/8	69.4-108.4 91.8/11	77.5-108.2 88.8/5	-	102.0- 102.0/1
13	93.7-119.6 109.8/3	65.1-127.6 93.3/9	66.7-88.4 75.2/4	-	91.0- 91.0/1
14	62.0-87.7 74.8/2	74.6-122.2 85.3/6	76.2-106.6 87.5/3	-	-
15	-	74.2-127.7 96.3/4	101.3-113.5 107.4/2	-	-
16	94.7-100.9 97.8/2	89.5-116.2 104.2/4	112.9- 112.9/1	-	-
17	71.9-139.9 105.9/2	98.5- 98.5/1	125.2- 125.2/1	-	-
18	-	90.0- 90.0/1	-	-	-
No	144	186	49	92	68

Table 8 continued

Age	GROUPING				
Years	AN3+1	CN3+1	B-CN3+1	DN4+0	C-DN4+0
5	12.8-182.0 68.7/132	12.2-106.4 39.3/156	30.9-73.4 47.9/5	17.6-71.0 33.1/6	21.0-29.6 24.5/3
6	24.2-119.2 85.8/64	21.6-117.9 57.5/129	42.0-75.9 55.8/8	16.9-71.8 46.7/18	41.2-58.6 47.9/6
7	54.9-94.5 69.4/9	36.1-113.3 65.7/117	52.0-105.2 71.9/11	48.6-82.2 61.6/8	38.6-66.9 50.5/3
8	69.9-106.6 84.2/6	41.0-129.4 83.4/168	50.8-116.0 83.9/17	86.4-94.8 90.6/2	45.5-105.3 75.4/2
9	63.7-124.7 87.7/15	38.3-155.8 89.4/222	60.2-124.5 86.5/19	57.8-161.1 91.1/11	67.4-102.1 87.5/5
10	70.4-122.5 98.6/8	50.4-151.4 90.5/145	64.6-150.4 101.4/11	57.7-120.3 86.7/8	73.9-111.1 86.7/6
11	77.3-124.5 97.3/4	55.9-156.6 97.2/56	62.6-150.4 94.8/9	-	-
12	-	58.2-128.3 95.9/16	64.3-106.2 88.0/8	-	-
13	-	57.8-123.3 89.7/19	74.1-126.5 94.8/7	107.8- 107.8/1	-
14	-	70.5-168.7 101.9/12	69.7-87.0 81.0/3	-	-
15	95.7- 95.7/1	72.8-130.7 104.0/7	87.4-99.3 92.1/4	-	-
16	-	41.3-140.4 91.9/4	-	-	-
17	-	73.0-136.0 113.7/3	-	-	-
18	-	149.4- 149.4/1	-	-	-
No:	239	1055	102	54	25

Table 8 completed.

Age	GROUPING				
Years	CN3+2	DN4+1	C-DN4+1	A,C,D,C-DN6+0	A,C,D,C-DN6+1
6	25.7-72.9 47.4/9	18.3-109.0 38.8/50	24.1-63.2 40.6/17		-
7	42.1-91.0 69.9/10	31.9-93.7 53.9/43	32.5-85.2 55.0/15	14.7-71.4 43.0/2	-
8	55.3-116.7 77.9/26	49.3-100.8 74.0/35	51.0-104.1 72.6/28	44.3-66.7 59.6/4	-
9	48.8-116.4 82.0/34	45.7-127.9 82.1/114	50.0-115.6 80.9/43	40.6-105.8 66.4/17	71.7- 71.7/1
10	57.1-111.7 79.1/19	50.5-131.8 85.7/86	60.4-135.7 89.8/37	45.2-107.1 73.0/35	41.5-83.1 64.9/11
11	67.1-125.8 86.9/13	33.8-135.4 88.5/43	66.2-129.4 94.6/11	54.5-112.8 82.0/42	64.2-110.8 81.2/12
12	72.6-116.9 92.9/4	68.7-119.7 91.3/14	91.8-134.5 113.2/2	54.8-135.0 89.7/16	64.7-126.3 89.2/9
13	61.8- 61.8/1	64.6-123.8 92.2/12	89.6-94.7 92.1/2	58.9-99.8 80.5/21	60.0-107.2 84.6/9
14	74.1-125.0 104.9/3	68.4-94.7 81.6/8	62.4-130.0 96.2/2	68.3-151.5 98.0/21	73.2-123.1 91.2/5
15	72.4-113.4 96.6/5	65.4-131.8 97.5/7	72.3-141.1 104.9/3	51.1-125.7 89.0/14	-
16	67.1-161.9 110.0/5	68.2-126.1 93.5/6	-	95.9-109.4 102.6/2	77.4- 77.4/1
17	-	45.7-162.8 102.0/8	-	62.8-130.1 93.8/6	-
18	-	69.5-170.8 99.4/4	112.0- 112.0/1	77.0-145.9 103.9/5	95.5- 95.5/1
19	73.9-76.8 75.4/2	119.7- 119.7/1	114.0- 114.0/1	94.2-110.7 104.8/3	-
20	-	-	-	157.1- 157.1/1	-
No.	131	431	162	189	49

Table 9. Absolute fecundity of some grouped year classes of different strength, thousand eggs.

Age years	Year class strength		
	Poor	Average	Rich
	AS1+1		
3	23.6-63.6 43.4/14	23.8-32.6 29.4/3	-
4	54.5-101.2 79.2/11	15.9-62.7 42.8/3	27.5- 27.5/1
5	54.1-91.8 79.4/5	33.1-71.0 51.2/4	33.1-78.6 60.1/7
6	62.5-109.9 88.1/5	71.4-94.8 80.3/6	40.6-83.5 59.5/4
7	74.6-93.5 84.0/2	56.3-126.0 89.0/10	65.9- 65.9/1
8	85.0- 85.0/1	59.6-137.3 88.9/18	81.7-128.8 95.1/4
9	-	75.3-96.6 83.7/3	80.2-81.7 81.0/2
10	78.4-104.5 91.6/3	-	73.2-124.2 98.7/2
11	83.0-121.6 102.6/3	94.4-96.8 95.5/3	60.1- 60.1/1
12	150.7- 150.7/1	108.8-117.2 113.0/2	-
13	-	86.4-123.9 105.1/2	-
14	172.9- 172.9/1	-	-
15	-	113.6- 113.6/1	-
No:	46	55	22

Table 9 continued.

Age	Year class strength		
years	Poor	Average	Rich
	AS2+1		
4	33.8-101.2 64.7/20	24.8-86.9 43.5/6	11.6-52.8 32.2/17
5	45.5-112.1 76.4/28	37.0-80.4 52.1/6	16.5-103.1 51.2/53
6	51.6-136.7 90.6/27	56.4-98.5 72.7/5	44.8-95.6 63.3/28
7	50.4-96.0 79.8/9	53.0-102.4 80.8/17	50.2-88.8 73.3/7
8	45.1-129.1 92.3/10	57.6-115.5 86.5/32	58.2-94.3 76.2/2
9	83.2-106.6 95.3/5	50.0-129.4 87.9/28	62.3-167.8 104.3/8
10	82.9-125.0 97.7/5	76.8-104.6 87.8/5	77.7-168.9 112.5/13
11	72.3-151.3 99.2/3	78.6-134.8 109.0/10	68.6-128.0 88.3/10
12	75.7-128.1 101.9/2	83.3-150.8 103.1/8	97.2-126.3 108.8/4
13	-	66.6-177.1 112.3/7	85.0- 85.0/1
14	95.3- 95.3/1	71.6-138.6 105.1/2	-
15	-	86.2- 86.2/1	-
16	-	106.2-146.2 120.9/5	-
No:	110	132	144

Table 9 continued.

Age	Year class strength		
years	Poor	Average	Rich
	AN2+1		
4	35.0-70.5 53.7/4	14.0-63.0 35.2/5	14.0-48.7 34.1/17
5	41.1-146.2 74.4/23	48.2-54.1 51.2/2	11.4-97.2 49.7/55
6	69.1-137.2 90.1/22	26.9-98.1 69.1/13	37.6-98.6 70.0/30
7	60.6-120.1 94.9/8	46.8-138.4 82.4/32	41.5-104.2 72.4/17
8	84.6-120.1 108.0/5	51.2-132.9 85.8/37	79.9-146.8 98.8/15
9	66.1-143.9 97.6/4	65.3-146.6 95.3/12	62.5-144.9 93.1/47
10	88.7-127.3 103.7/3	70.9-117.8 93.3/9	56.0-146.6 98.5/19
11	89.6-104.2 95.7/5	63.8-110.1 86.2/11	66.4-148.2 91.7/6
12	93.0-104.2 98.6/2	53.8-138.8 94.4/8	-
13	127.3-128.3 127.8/2	77.1-151.1 113.4/5	84.4-112.7 98.5/2
14	70.8-138.9 108.9/3	63.4-129.9 102.1/6	-
15	-	112.4-181.6 141.6/3	98.2- 98.2/1
16	-	139.9- 139.9/1	-
17	-	138.9-150.7 144.8/2	-
18	-	139.8- 139.8/1	-
19	-	-	-
20	-	-	130.2- 130.2/1
No:	81	147	210

Table 9 continued

Age	Year class strength		
years	Poor	Average	Rich
		BN2+1	
4	73.2- 73.2/1	23.8-36.3 30.0/2	20.8-51.8 38.1/9
5	-	41.0-60.5 50.7/2	27.2-94.3 48.7/49
6	-	49.4-68.2 61.3/5	52.1-109.6 70.7/26
7	95.8- 95.8/1	67.1-126.6 85.2/10	48.2-113.8 72.2/20
8	67.6-101.1 81.4/3	58.9-112.6 84.3/9	49.6-122.8 89.7/12
9	74.1-124.5 100.7/4	59.2-97.2 81.9/14	52.9-137.4 89.9/40
10	72.8-109.3 88.5/5	51.1-121.1 86.3/15	58.7-123.9 91.3/28
11	79.1- 79.1/1	59.8-161.7 94.6/11	61.7-173.6 98.5/23
12	-	56.9-147.1 99.2/10	98.6-111.2 104.9/2
13	103.1- 103.1/1	67.0-98.0 79.2/7	108.7- 108.7/1
14	120.3-121.4 120.9/2	67.9-113.5 90.7/2	94.2-127.1 111.6/4
15	92.9- 92.9/1	108.0-136.8 122.4/2	89.2- 89.2/1
16	-	96.5- 96.5/1	-
17	-	107.2-125.7 114.2/3	-
No:	19	93	215

Table 9 continued

Age	Year class strength		
years	Poor	Average	Rich
		CN3+1	
5	43.8-106.4 67.7/28	-	12.2-97.8 33.1/128
6	78.2-117.9 96.6/19	54.8-95.6 75.2/2	21.6-103.6 50.3/108
7	51.2-84.8 70.4/7	49.1-113.3 75.2/15	36.1-103.9 63.8/95
8	73.3-112.7 93.0/2	41.0-129.4 84.2/43	50.1-123.7 83.0/123
9	82.2-116.7 100.8/3	66.3-155.8 93.9/28	38.3-155.2 88.5/191
10	79.3-108.4 92.1/6	50.4-131.7 88.3/26	53.8-154.9 91.0/113
11	100.1-104.2 102.2/2	55.9-140.7 91.6/15	62.7-156.6 99.1/39
12	95.3-128.3 116.9/3	58.2-121.3 90.5/10	84.8-104.7 92.9/3
13	-	57.8-123.3 92.4/17	59.0-73.8 66.4/2
14	121.6- 121.6/1	70.5-168.7 102.1/6	82.5-116.5 97.7/5
15	-	72.8-121.2 79.0/5	87.0-130.7 111.0/3
16	-	41.3-140.4 91.9/4	-
17	-	132.1-136.0 134.0/2	73.0- 73.0/1
18	-	-	149.4- 149.4/1
No:	71	173	812

Table 9 continued

Age	Year class strength			
years	Average	Rich	Average	Rich
	DN4+1		C-DN4+1	
6	22.3-49.4 31.8/5	18.3-62.3 37.2/43	-	24.1-63.2 40.6/17
7	52.0- 52.0/1	31.9-93.7 54.0/42	58.2-85.2 73.4/3	32.5-68.0 50.4/12
8	49.3-75.1 65.9/4	52.5-100.8 75.1/31	71.5-104.1 87.8/2	51.0-101.5 71.4/26
9	70.1-99.4 80.2/6	47.5-127.9 82.1/107	71.3-109.1 90.2/2	50.0-115.6 80.0/40
10	62.9-100.0 84.1/7	50.5-131.8 85.5/78	84.2-122.4 103.3/2	60.4-135.7 89.0/35
11	55.0-106.9 72.3/11	33.8-135.4 95.8/30	57.3-108.5 81.7/3	66.2-129.4 100.3/7
12	68.7-119.7 90.1/11	93.6-97.2 95.7/3	91.8-134.5 113.1/2	-
13	64.6-123.8 92.8/11	84.8- 84.8/1	89.6- 89.6/1	94.7-6 94.7/1
14	68.4-94.7 82.1/7	77.5- 77.5/1	62.4-130.0 96.2/2	-
15	65.4-131.8 94.3/4	93.6-108.9 101.9/3	72.3-101.3 86.8/2	141.1- 141.1/1
16	75.8-126.1 100.8/4	68.2-89.8 79.0/2	-	-
17	45.7-162.8 113.6/4	78.7-110.6 90.3/4	-	-
18	-	69.5-170.8 99.3/4	-	112.0- 112.0/1
19	-	119.7- 119.7/1	114.0- 114.0/1	-
No:	75	350	20	140

Table 9 completed

Age years	Year class strength		
	Average	Rich	Rich
	A,C,D,C,-DN6+0		A,C,D,C-DN6+1
7	14.7- 14.7/1	-	-
8	60.7- 60.7/1	44.3-66.7 59.2/3	-
9	51.0-105.8 71.1/9	40.6-77.0 61.1/8	71.1- 71.7/1
10	65.2-107.1 88.7/9	45.2-100.8 67.5/26	41.5-83.1 64.9/11
11	65.2-112.8 83.2/7	54.5-109.6 81.7/35	64.2-110.8 81.2/12
12	54.8-100.7 83.5/7	76.8-135.0 94.5/9	64.7-126.3 89.2/9
13	68.3-99.8 83.0/11	58.9-98.1 77.8/10	60.0-107.2 84.6/9
14	68.3-114.5 91.5/7	80.6-151.5 101.3/14	73.2-95.5 83.2/4
15	74.9-125.7 93.6/9	51.1-96.7 80.7/5	-
16	95.9-109.4 102.6/2	-	-
17	62.8-130.1 95.3/4	87.5-94.4 90.9/2	-
18	77.0-104.0 93.4/4	145.9- 145.9/1	-
19	-	94.2-110.7 104.8/3	-
20	-	157.1- 157.1/1	-
No:	71	117	46

Table 10. Spawning stock and yield of Atlanto-Scandian herring
          in the Norwegian Sea, 1950-1988.

YEAR	Spawning stock		Herring yield, thousand tonnes		
	thou. t.	spec.x10^9	Adult & maturing	Small & fat	Total
1950	9400	36.9	826.1	106.9	933.0
1951	9100	30.3	994.2	284.2	1278.4
1952	8800	28.8	919.2	335.6	1254.8
1953	7100	23.5	849.9	240.7	1090.6
1954	7600	27.0	1306.4	338.1	1644.5
1955	8800	34.1	1217.5	142.3	1359.8
1956	8900	32.3	1460.6	198.8	1659.4
1957	10000	35.8	1148.3	171.2	1319.5
1958	8500	28.7	784.0	201.6	985.6
1959	7500	23.3	883.1	228.0	1111.1
1960	5600	17.3	821.1	280.7	1101.8
1961	4200	13.1	497.9	332.2	830.1
1962	3300	9.9	551.2	297.4	848.6
1963	1600	7.5	670.8	313.7	984.5
1964	3700	13.6	1117.9	163.9	1281.8
1965	4500	17.8	1325.8	221.9	1547.7
1966	2700	11.2	1723.5	231.5	1955.0
1967	1300	4.8	1131.5	545.7	1677.2
1968	240	1.0	273.1	439.1	712.2
1969	80	0.29	24.1	43.7	67.8
1970	60	0.17	20.9	41.4	62.3
1971	30	0.09	6.9	14.2	21.1
1972	-	-	-	13.2	13.2
1973	99	0.38	0.1	6.9	7.0
1974	119	0.37	0.9	6.7	7.6
1975	118	0.39	0.1	3.6	13.7+
1976	180	0.74	-	0.4	10.4
1977	330	1.28	0.4	12.3	22.7
1978	410	1.24	0.5	9.3	19.8
1979	440	1.19	0.7	2.2	12.9
1980	518	1.38	0.9	7.7	18.6
1981	547	1.56	0.8	7.9	13.7
1982	552	1.57	1.0	10.7	16.7
1983	616	1.64	3.9	14.2	23.1
1984	638	1.75	18.7	29.8	53.5
1985	564	1.53	29.4	41.7	81.1
1986	477	1.41	71.1	55.7	136.8
1987	472	2.94	62.9	50.0	122.9
1988	1353		71.0		

Note: Spawning stock and yield in 1950-1971 (Dragesund and Ulltang,
      1975); in 1972-1988 (Anon.,1989); in 1987 and 1988: prelimi-
      nary data; +- unreported 5-10 thousand tonnes are included in
      yield since 1975.

Table 11. Population fecundity (PF), yearclass strength (nos of
          3 year olds) and survival rate in early ontogeny of
          Atlanto-Scandian herring , 1951-1975.

Year surveyed	PF eggs x 10^{12}	Nos of 3-year-olds spec. x 10^6	Year class strength	Survival rate to age of full 3 years, %
1951	1200.3	7380	Above average	0.000615
1952	1046.3	3448	Average	0.000330
1953	931.1	3220	Average	0.000346
1954	1007.3	600	Poor	0.000060
1955	1421.6	494	Poor	0.000035
1956	995.1	169	Poor	0.000017
1957	1292.3	252	Poor	0.000019
1958	1141.2	241	Poor	0.000021
1959	946.6	21175	Very poor	0.002237
1960	718.4	7337	Above average	0.001021
1961	578.6	2175	Average	0.000376
1962	437.3	203	Poor	0.000046
1963	202.5	8281	Above average	0.004089
1964	347.5	3832	Above average	0.001102
1965	471.3	107	Poor	0.000023
1966	334.6	230	Poor	0.000069
1967	179.7	21	Poor	0.000012
1968	36.4	10	Poor	0.000027
1969	10.2	513	Poor	0.000029
1970	7.0	7	Poor	0.000104
1971	4.0	1	Poor	0.000025
1973	10.1	886	Poor	0.008772
1974	9.0	575	Poor	0.006389
1975	11.1	127	Poor	0.001144

Note: numbers of 3 year olds of the 1951-1968 year classes (Dragesund
      and Ulltang, 1975), of the 1969-1975 year classes (Anon.,1987).

Table 12. Abundance and population fecundity of spawning stock and separate components of Atlanto-Scandian herring in some years.

Characteristic	Parameter	Year surveyed				
		1952 / 1958	1953 / 1959	1960 / 1965	1961 / 1964	1962 / 1966
Spawning stock	Abundance, spec. x 10^9.	14.4 14.4	11.8 11.6	8.6 8.9	6.5 6.8	5.0 5.6
	Population fecundity eggs x 10^{12}.	1046.3 1141.2	931.1 946.6	718.4 471.3	578.6 347.5	437.3 334.6
Northern component	Abundance, spec. x 10^9.	7.2 7.9	5.7 6.5	4.6 2.4	3.3 2.8	2.5 1.4
	Population fecundity eggs x 10^{12}.	514.4 668.3	467.2 554.7	408.1 156.5	303.6 157.2	226.4 96.3
Barents Sea component	Abundance, spec. x 10^9.	4.1 4.9	4.8 4.1	3.4 5.4	2.3 3.0	1.6 3.7
	Population fecundity eggs x 10^{12}.	295.7 346.5	350.1 312.3	258.9 249.6	199.6 133.1	143.2 206.3

Table 13. Component ratio in spawning stock of Atlanto-Scandian
          herring and population fecundity, 1951-1975.

Year surveyed	Component ratio in spawning stock, %			Population fecundity of herring of various components, eggs x 10^{12}.		
	Southern	Northern	Barents sea	Southern	Northern	Barents Sea
1951	28.6	45.1	26.3	312.3	552.2	335.8
1952	21.1	50.7	28.2	236.2	514.4	295.7
1953	11.3	48.0	40.7	113.8	467.2	350.1
1954	19.5	51.1	29.4	172.2	526.8	308.3
1955	27.3	48.2	24.5	376.0	677.1	368.5
1956	26.1	58.5	15.4	257.0	577.2	160.9
1957	19.1	57.8	23.1	226.6	794.8	270.9
1958	10.9	55.2	33.9	126.4	668.3	346.5
1959	8.3	55.9	35.8	79.6	554.7	312.3
1960	6.6	53.4	40.0	51.4	408.1	258.9
1961	13.0	54.0	36.0	75.4	303.6	199.6
1962	17.5	50.3	32.2	67.7	226.4	143.2
1963	11.5	74.1	14.4	22.2	135.4	44.9
1964	14.1	41.7	44.2	57.2	157.2	133.1
1965	12.2	27.5	60.3	65.2	156.5	249.6
1966	8.7	25.7	65.6	32.0	96.3	206.3
1967	10.9	30.2	58.9	18.1	59.0	102.6
1968	11.1	28.9	60.0	4.8	12.4	19.2
1969	12.2	29.2	58.6	1.6	3.4	5.2
1970	10.7	29.7	59.6	0.7	2.1	4.2
1971	5.3	24.6	70.1	0.2	1.0	2.8
1973	50.9	44.5	4.6	5.4	4.1	0.6
1974	5.2	85.9	8.9	0.5	8.4	0.1
1975	14.0	79.9	6.1	1.1	9.4	0.6

Table 14. Component ratio and population fecundity of the 1950- and 1959 year classes of Atlanto-Scandian herring.

Year surveyed	Population fecundity of spawning stock eggs x 10^{12}	Year class		Component ratio in a year class, %			Popul. fec. of components in a year class, eggs x 10^{12}		
		per cent of spawn. stock	Popul. fecund. eggs x 10^{12}	Southern	Northern	Barents Sea	Southern	Northern	Barents Sea
1950 year class									
1954	1007.3	14.8	67.6	42.1	57.9	-	27.3	40.3	-
1955	1421.6	14.6	122.2	36.4	62.1	1.5	47.0	74.1	1.1
1956	995.1	46.6	386.8	12.4	73.1	14.5	58.6	287.2	41.0
1957	1292.3	38.1	427.5	9.2	60.4	30.4	45.9	292.3	89.3
1958	1141.2	50.2	547.1	3.7	52.4	43.9	20.4	327.4	199.3
1959 year class									
1963	202.5	61.0	77.4	10.7	89.3	-	8.1	69.3	-
1964	347.5	68.9	192.4	10.1	43.9	46.0	24.8	99.1	68.5
1965	471.3	70.5	320.5	8.0	25.8	66.2	31.7	104.1	184.7
1966	334.6	57.3	202.6	3.7	22.2	74.1	8.6	52.5	141.5

Table 15. Numbers of 3 year olds and survival rates of
          herring from various components.

Year	Number of 3 year old herring from various components, spec. x 10^6			Survival of herring from various components to age of full 3 years, %		
	Southern	Northern	Barents S	Southern	Northern	Barents S
1951	1815.5	4287.8	1276.7	0.000151	0.000357	0.000106
1952	848.2	2003.3	596.5	0.000081	0.000191	0.000057
1953	792.1	1870.8	557.1	0.000085	0.000201	0.000060
1954	229.2	337.8	33.0	0.000023	0.000034	0.000003
1955	188.7	278.1	27.2	0.000013	0.000020	0.000002
1956	64.6	95.2	9.2	0.000006	0.000010	0.000001
1957	96.3	141.9	13.8	0.000007	0.000011	0.000001
1958	92.1	135.7	13.2	0.000008	0.000012	0.000001
1959	1715.2	8088.8	11371.0	0.000181	0.000854	0.001201
1960	594.3	2802.7	3940.0	0.000083	0.000390	0.000548
1961	535.0	1263.7	376.3	0.000093	0.000218	0.000065
1962	77.6	114.3	11.1	0.000018	0.000026	0.000002
1963	2037.1	4811.3	1432.6	0.001006	0.002376	0.000708
1964	942.7	2226.4	662.9	0.000271	0.000641	0.000191
1965	40.9	60.2	5.9	0.000009	0.000013	0.000001
1966	87.9	129.5	12.6	0.000026	0.000039	0.000004
1967	8.0	11.8	1.2	0.000004	0.000007	0.000001
1968	3.8	5.6	0.6	0.000010	0.000015	0.000002
1969	196.0	288.8	28.2	0.001921	0.002831	0.000276
1970	2.7	3.9	0.4	0.000039	0.000056	0.000006
1971	0.38	0.56	0.06	0.000010	0.000014	0.000015
1973	338.5	498.8	48.7	0.003352	0.004939	0.000482
1974	219.6	323.7	31.6	0.002440	0.003597	0.000351
1975	48.5	71.5	7.0	0.000437	0.000644	0.000063

Table 16. Numbers of 3 year olds and survival rates of Atlanto-Scandian herring year classes of various strength to age of full 3 years.

Rich			Above average			Average			Poor		
Year class	Number of 3 year olds spec. x 10^6	Survival to age of full 3 years, %	Year class	Number of 3 year olds spec. x 10^6	Survival to age of full 3 years, %	Year class	Number of 3 year olds spec. x 10^6	Survival to age of full 3 years, %	Year class	Number of 3 year olds spec. x 10^6	Survival age of fu 3 years,
1959	21175	0.002237	1951	7380	0.000615	1952	3448	0.000330	1954	600	0.000060
			1960	7337	0.001021	1953	3220	0.000346	1955	494	0.000035
			1963	8281	0.004089	1961	2175	0.000376	1956	169	0.000017
			1964	3832	0.001102				1957	252	0.000019
									1958	241	0.000021
			Mean	6707.5	0.001707	Mean	2947.7	0.000351			
									Mean		0.000030
									1962	203	0.000046
									1965	107	0.000023
									1966	230	0.000069
									1967	21	0.000012
									1968	10	0.000027
									1969	513	0.00502
									Mean		0.000868
									1970	7	0.000104
									1971	1	0.000025
									1973	886	0.008772
									1974	575	0.006389
									1975	127	0.001144
									Mean		0.003287
									Mean 1954-1975		0.001362

Table 17. Survival conditions and year class strength
of Atlanto-Scandian herring.

Survival conditions	Survival to age of 3 yrs, %	Number of 3 yr olds spec x10^6	Popul. fecund. eggs x 10^{12}	Year class	Year class strength
Favourable 0.001021-0.008772 [*]	0.002237	21175	946.6	1959	Very rich
	0.001021	7337	718.4	1960	Above average
	0.004089	8281	202.5	1963	Above average
	0.001102	3832	347.5	1964	Average
	0.005029	513	10.2	1969	Poor
	0.008772	886	10.1	1973	Poor
	0.006389	575	9.0	1974	Poor
	0.001144	127	11.1	1975	Poor
Average 0.000104-0.000615	0.000615	7380	1200.3	1951	Above average
	0.000330	3448	1046.3	1952	Average
	0.000346	3220	931.1	1953	Average
	0.000376	2175	578.6	1961	Average
	0.000104	7	7.0	1970	Poor
Unfavourable 0.000012-0.000069	0.000060	600	1007.3	1954	Poor
	0.000035	494	1421.6	1955	Poor
	0.000017	169	995.1	1956	Poor
	0.000019	252	1292.3	1957	Poor
	0.000021	241	1141.2	1958	Poor
	0.000046	203	437.3	1962	Poor
	0.000023	107	471.3	1965	Poor
	0.000069	230	334.6	1966	Poor
	0.000012	21	179.7	1967	Poor
	0.000027	10	36.4	1968	Poor
	0.000025	1	4.0	1971	Poor

Note: [*] = per cent of survival to age 3 years.

Table 18. Survival rates of separate herring components in
the 1951-1975 year classes of various strength.

Year class	Year class strength	Component		
		Southern	Northern	Barents S
1959	Very rich	0.000181	0.000854	0.001201
1951,1960, 1963,1964	Above average	0.000377	0.000941	0.000388
1952,1953, 1961	Average	0.000086	0.000203	0.000061
1954-1958	Poor	0.000011	0.000017	0.000002
1962, 1965-1969	Poor	0.000331	0.000494	0.000048
1970,1971, 1973-1975	Poor	0.001256	0.001850	0.000183

Table 19. Population fecundity levels and spawning stock biomasses of Atlanto-Scandian herring.

Population fecundity levels	Population fecundity, eggs x 10^{12}	Mean individual absolute fecundity, spec x 10^3	Mean weight g	Spawning stock abundance spec. x 10^9 (females)	Total spawning stock biomass mill. tns
F_{gar} (GPF)	1911.0	77.8	321	24.5	15.7
F_{min} (MTPF)	839.8	77.8	321	10.8	6.9
F_{cri} (CPF) 1951-1975(1973)	76.5	77.8	321	0.98	0.63
F_{cri} (CPF) 1951-1959(1959)	299.4	73.5	326	4.1	2.7
F_{cri} (CPF) 1960-1969(1969)	133.4	76.7	318	1.7	1.1
F_{cri} (CPF) 1970-1975(1973)	76.5	85.6	335	0.9	0.6

Note: The year with most favourable conditions for herring development in early ontogeny is given in brackets.

Table 20. Population fecundity levels and spawning stock biomasses of separate components of Atlanto-Scandian herring.

Population fecundity levels	Component population fecundity eggs $\times 10^{12}$	Mean individual absolute fecundity eggs $\times 10^3$	Mean weight g	Component numbers (females) spec.$\times 10^9$	Component biomass (total) mill. t.
Southern component					
F_{gar}	1684.2	77.4	320	21.9	14.0
F_{min}	906.4	77.4	320	11.8	7.6
F_{cri} 1951-1975 (1973)	40.2	77.4	320	0.5	0.32
F_{cri} 1951-1959 (1959)	748.6	73.5	300	10.1	6.1
F_{cri} 1960-1969 (1969)	70.2	77.0	321	0.9	0.58
F_{cri} 1970-1975 (1973)	40.2	82.2	327	0.5	0.33
Northern component					
F_{gar}	1766.1	80.6	331	21.8	14.4
F_{min}	856.3	80.6	331	10.5	7.0
F_{cri} 1951-1975 (1973)	71.5	80.6	331	0.9	0.6
F_{cri} 1951-1959 (1959)	415.5	78.7	334	5.3	3.5
F_{cri} 1960-1969 (1969)	124.8	80.0	332	1.6	1.1
F_{cri} 1970-1975 (1973)	71.5	83.1	327	0.9	0.59
Barents Sea component					
F_{gar}	3046.8	70.5	311	42.9	28.4
F_{min}	850.0	70.5	311	12.0	7.5
F_{cri} 1951-1975 (1959)	152.3	70.5	311	2.1	1.3
F_{cri} 1951-1959 (1959)	152.3	68.6	326	2.2	1.4
F_{cri} 1960-1969 (1963)	257.5	68.3	306	3.8	2.3
F_{cri} 1970-1975 (1973)	380.8	97.7	367	3.9	2.9

Note: The year with most favourable conditions for herring survival in early ontogeny is given in brackets.

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Table 21. Population fecundity levels and spawning stock biomasses of separate components of Atlanto-Scandian herring.

Population fecundity levels	Spawning stock		Component					
			Southern		Northern		Barents Sea	
	PF, eggs $\times 10^{12}$	biomass mill. t.	PF, eggs $\times 10^{12}$	biomass mill. t.	PF, eggs $\times 10^{12}$	biomass mill. t.	PF, eggs $\times 10^{12}$	biomass mill. t.
F_{gar} (GPF)	1911.0	15.7	1684.2	14.0	1766.1	14.4	3046.8	28.4
F_{min} (MTPF)	839.8	6.9	906.4	7.6	856.3	7.0	850.0	7.5
F_{cri} (CPF)	76.5	0.6	40.2	0.3	71.5	0.6	152.3	1.3
F_{cri} 1951-1959	299.4	2.7	748.6	6.1	415.5	3.5	153.3	1.4
F_{cri} 1960-1969	133.5	1.1	70.2	0.6	124.8	1.1	257.5	2.3
F_{cri} 1970-1975	76.5	0.6	40.2	0.3	71.5	0.6	380.8	2.9

Table 22. Forecasting of 3 year old herring abundance dependent on survival conditions, spec. x 10^6.

Spawning stock biomass, mill. t.	Population fecundity eggs x10^{12}	Survival rate of various year classes								
		0.002237 1959	0.001707 1951 1960 1963 1964	0.000351 1952 1953 1961	0.000030 1954--1958	0.000868 1962 1965--1969	0.003287 1970--1975	0.000012 1967	0.008772 1973	0.001329 mean for 1951--1975
6.9	840.0	18791r	14339r	2948a	252p	7291aa	27611r	101p	73685r	11164r
2.7	299.4	6698aa	5111	1051p	90p	2599a	9841aa	36p	26263r	3979a
1.1	133.5	2986a	2279a	469p	41p	1159p	4388a	16p	11711r	1774p
0.6	76.5	1711p	1506p	268p	23p	664p	2515	9p	6711aa	1017p

Note: r = rich year class, aa = above average, a = average, p = poor.

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Table 23. Probability of appearance of year classes of varying
strength at various levels of spawning stock biomass
and population fecundity.

Spawning stock biomass, mill. t.	Population fecundity eggs $\times 10^{12}$	Numbers of 3 year olds, spec $\times 10^6$			
		>10000 rich	6000-10000 above average	2000-6000 average	<2000 poor
6.9	840.0	5	1	1	2
2.7	299.4	1	2	3	3
1.1	133.5	1	-	3	5
0.6	76.5	-	1	1	7

LONG TERM CHANGES OF GROWTH AND MATURATION IN THE NORWEGIAN SPRING SPAWNING HERRING

by

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ABSTRACT

Two periods with great differences in year class abundance and recruitment where chosen for growth and maturation studies, 1950 - 1960 and 1973 - 1983. In the first period, the mean year class strength at 3 years was 6.8×10^9 individuals while in the second period it was 0.4×10^9 ind.. The growth in each period as observed by the length at age, is compared to the year class strength and the abundance of the stock at the time. Variations in growth are observed and before maturation strong year classes has remarkably less growth than weak year classes. The latter period is therefore characterized by far better growth, especially in the early years of life, than the former. According to growth rates of the various year classes, the age at maturity is substantially higher in the first period than in the latter. However, the length at maturity is found to be fairly constant showing the maturation to be size dependent rather than dependent on the age.

INTRODUCTION

After the great reduction in the abundance of the Norwegian spring
spawning herring in the late sixties, the growth as observed by the
length at age and weight at age increased significantly, (Jørgensen
1979). At the same time, the adult stock totally changed its migration
pattern as it ceased migrating into the Norwegian Sea after spawning,
(Dragesund et al. 1980). Since 1970 the distribution has been limited
to the fjords of the western and northern Norway (except for the 1983
year-class). The observed change in growth and maturation is explained
by the severe reduction of the abundance of the stock as observed in
other herring stocks, (Jakobsson and Halldorsson 1984). However, this
change in growth is not necessarily density dependent.
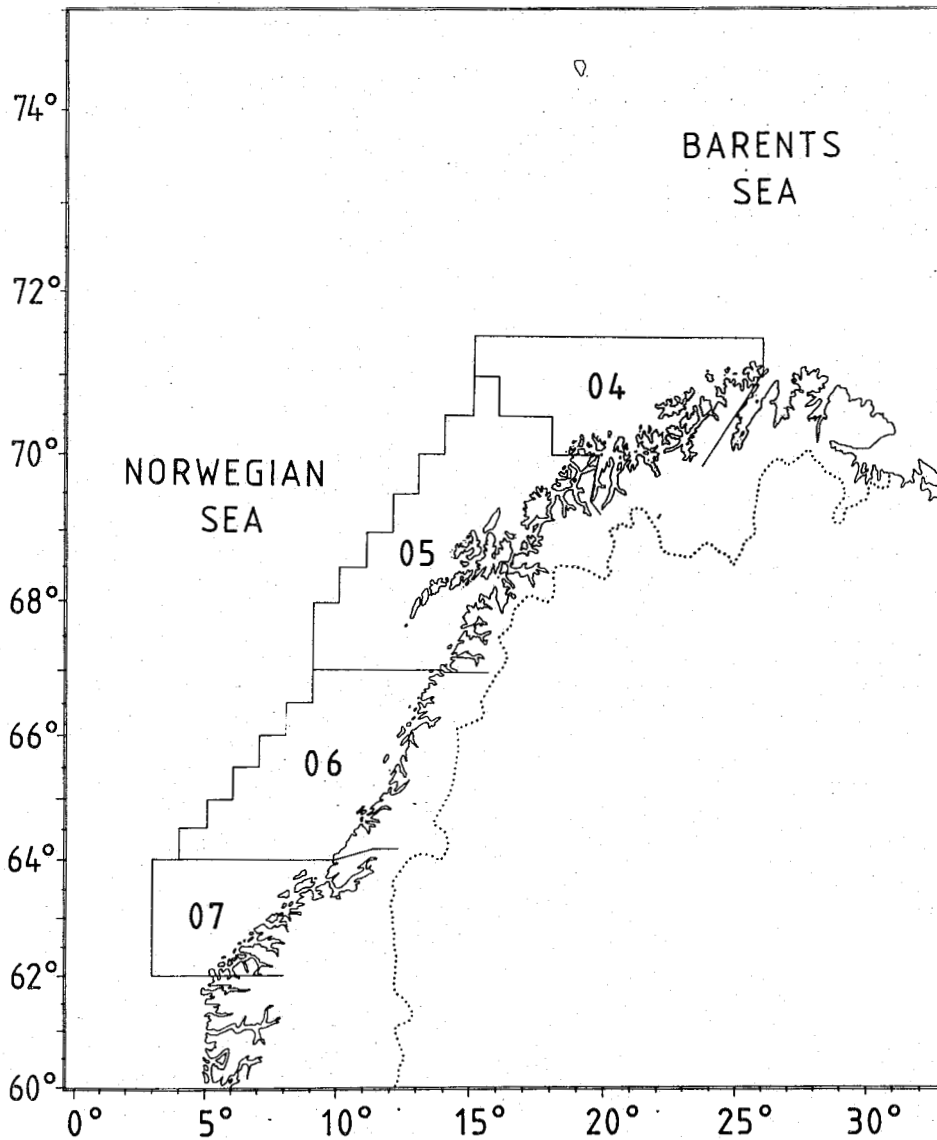
Fig. 1. The areas in which growth is studied.

It should be noted that growth in the Norwegian spring spawners is
extremely variable, depending strongly on the area in which they spend
their adolescent phase. Herring located off Finnmark and in the
Barents Sea during the adolescent phase have a markedly slower growth

than those found off the coast between Møre and Lofoten. As the
maturing process is dependent on the length rather than the age in the
herring (Toresen 1986), the parts of the stock spending their first
years of life south of Lofoten mature earlier than those found further
to the north or in the Barents Sea. Accordingly, immature herring
older than three years are scarce south of Lofoten, whereas off
Finnmark herring in the adolescent stage are common up to four years
of age. This pattern is probably independent of the size of the year-
classes. What is most certainly dependent on the year class strength
is the relative abundance of the stock in the various areas and the
growth within these areas.

Since the recruitment to this stock is so variable, it is of great
importance in the assessment that the prediction of growth is correct,
and it is therefore valuable to know the mechanisms that govern the
growth.

In this paper various aspects of growth in the Norwegian spring
spawners are enlightened especially with respect to the question of
growth and year class abundance. Two periods with quite significant
differences in abundance, recruitment and growth are chosen for this
purpose.

MATERIAL AND METHODS

The immature part of the stock is treated separately from the adults
because the biological samples from the two parts of the stock are not
taken in the same period of the year. The samples from the spawning
stock are taken during the spawning in spring while the samples from
the immatures are taken during autumn.

The immatures

Growth, as expressed by the mean length at age in the autumn (Sept-
Nov) is studied within 4 regions along the Norwegian coast (Fig. 1).
Average values of length at age for the full periods are compared
between the regions. The 1983 year class is treated separately because
it is a very strong one showing a tendency to a level of growth which
is similar to that of the fifties.

The material from the fifties is very poor, as no systematic sampling
of the juvenile part of the stock was carried out at that time. No
weight at age data are available.

The adults

The geographical regions are here cut down to one, the main spawning
grounds in area 07 (Fig 1). Sampling is done during spawning in spring
(Feb-Apr). Mean values of length at age each year in the two periods
are held up against spawning stock abundance. In addition, the mean
length at age for each year class is compared to the year class
strength at three years. Further on, growth as expressed by length
increments in the age intervall from 5-10 years is compared between
the periods and the mean length at age for all year classes in each
period are compared in a plot.

At last, the growth as expressed by the weight at age relationship is
discussed briefly.

Maturation

Age at maturity. The herring stock in the seventies is divided in two
components, one northern type and one southern type. These components
were caracterized by differences in the growth pattern, as the
southern one was more fast growing. Maturity ogives are calculated for
both components separately.

When a year class is fully recruited to the spawning stock the ratio
between the number of individuals in this year class and the number in
the older year classes is constant if total mortality (Z) by age group
is constant.

In the spawning stock, the year classes mix very well and in the
samples taken from the spawning stock the ratio between the various
year classes is quite constant although it may vary somewhat from one
year to another. However, no trend in this variance was detected and
the proportions of each year class in the spawning stock was
calculated as follows:

$$p_i = \frac{N_i}{\sum_{i=1}^{k} N_i}$$

where p_i is the proportion of year-class i in the spawning stock, N_i
is the number of fish in the samples from this year-class and k is the
number of year-classes in the spawning stock that is fully recruited.
The relative abundance of the fully recruited year-classes were then
calculated as the mean of the age groups 6, 7 and 8 years (p_i).
The maturity ogive by year-class is then calculated as the proportions
of the number of fish in the younger age groups to p_i in the samples
of the spawning stock.

RESULTS AND DISCUSSIONS

The immatures

The observed data of length at age for the two periods in four areas
along the Norwegian coast are shown in Table 1 a-d. The data given are
mean values of all samples of young herring from September till
November each year. The mean values of length at age might have been
affected by the time the samples are taken in the autumn. However, the
growth during these months is marginal and it is assumed that the
growth for the season is finished. As can be seen from the tables, the
data from the fifties and early sixties is very poor. However, treated
together, the few samples present give an idea of the growth level in
the full period.

Comparing the length at age within the two periods but between the
different regions show a clear trend of increasing growth when moving
from north to south along the coast (Table 1 a-d). This phenomenon is
earlier described by Dragesund (1970), and is probably related to
environmental conditions. The length distribution of the 0-group
herring may be similar all along the coast, but a difference in length
at age is initiated very soon and this difference increases through
the years. This feature results in earlier maturation of the
components of the stock spending the adolescence further to the south

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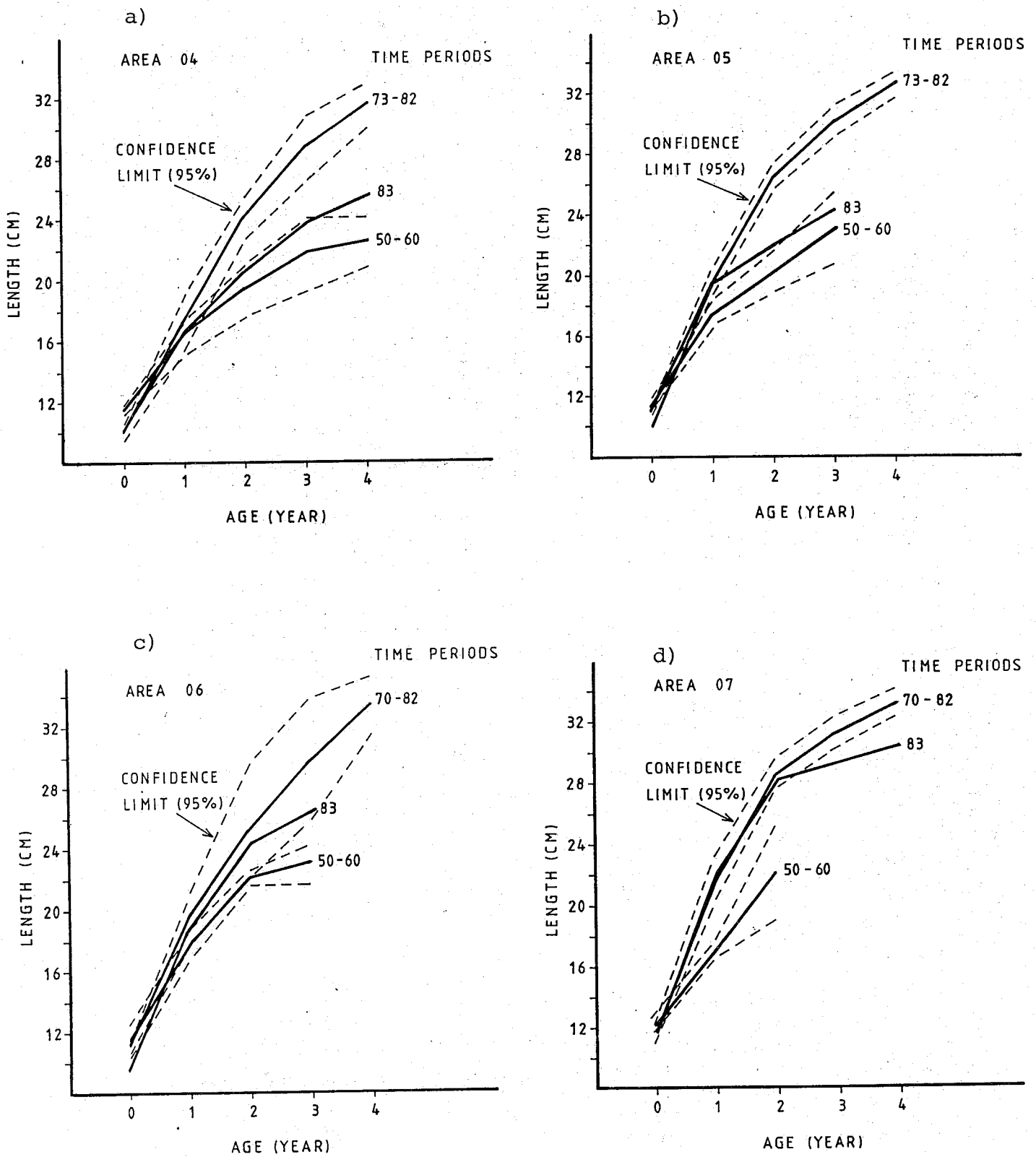
Fig. 2a-d. Plots of length at age in the four regions
in the two periods.

than those found in the north or in the Barents Sea, as the maturation process is related to growth rather than to age. The recruitment to the spawning stock is therefore largely dependent on the geographical distribution of the year classes in the early stages of life.

The difference in growth between the two periods are studied by comparing the average length at age values for each period and region. Figure 2. a-d shows the plots of length at age in the four regions in each period. The 1983 year-class is plotted separately. In all the regions, growth is far better in the seventies than in the fifties. As the plots clearly show, the growth rate is also higher in this latter period leading to greater differences in length at age through the years. This higher growth also leads to maturation at a much younger age for the year classes in the seventies, which was observed down to 3 years.

Is this large difference in growth between these two periods density dependent? The annual recruitment was at a much higher level in the fifties than in the seventies. The mean year class strength at 3 years was $6\ 790 \times 10^6$ individuals in the fifties, while in the seventies this number was reduced to 436×10^6. However, it is a fact that big year classes of Norwegian spring-spawning herring have quite another geographical distribution than small ones. Weak year classes spend more or less entirely the adolescence in the fjords and along the coast. The relative distribution of each year class in the different regions is determined at the 0-group stage. Abundant year classes also distribute in the fjords, but at a certain level of abundance, the 0-group herring also get distributed in the open watermasses of the Barents Sea. The mechanism governing this distribution pattern is not yet known. However, the conditions for high growth rates are less favourable in the open watermasses of the oceans than in the fjords and along the coast, where the temperature is higher and the density of zooplankton is greater. The density of herring in the fjords for these big year classes is still much higher than for small year classes, probably leading to reduced growth due to higher density. In this way, we have two main reasons for reduced growth in big year classes of Norwegian spring-spawners; density dependent growth in the fjords and reduced growth due to distribution in the open watermasses of the Barents Sea. The latter factor is a secondary effect of high density but the reduced growth is not density dependent itself.

Maturation

The results are shown in Table 2. It is quite clear that the recruitment to the spawning stock set in earlier in the seventies than in the fifties and sixties. Especially the year classes, 1973 and 1974 mature to spawn at a very early age and they are almost fully recruited at four. For the year classes 1959-61, they partly mature at three, but only to a very small extent. Full recruitment doesn't occur until they are six or seven.

These maturity ogives are strongly related to the growth. Fast growing herring mature to spawn early, but more or less at the same length as the slow growing ones.

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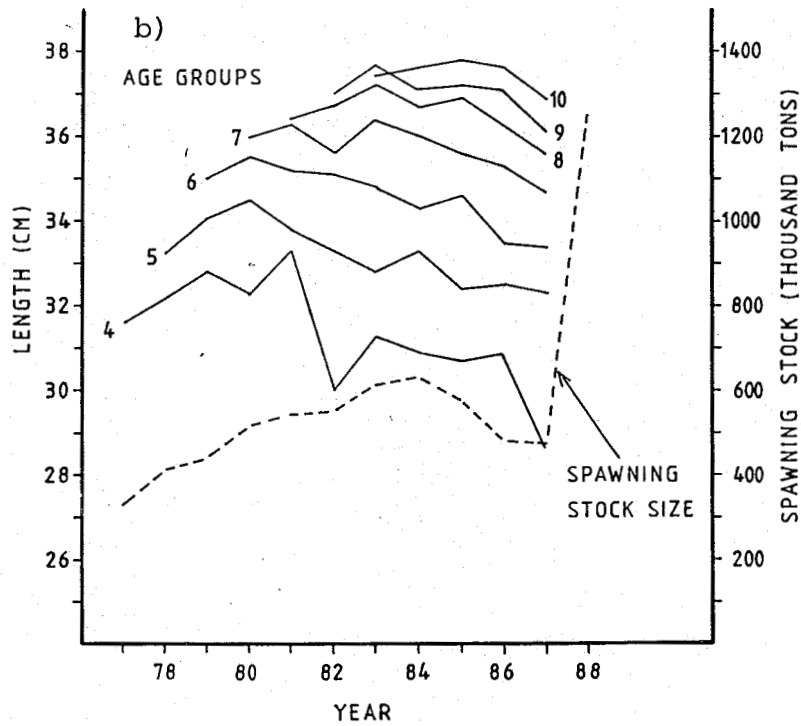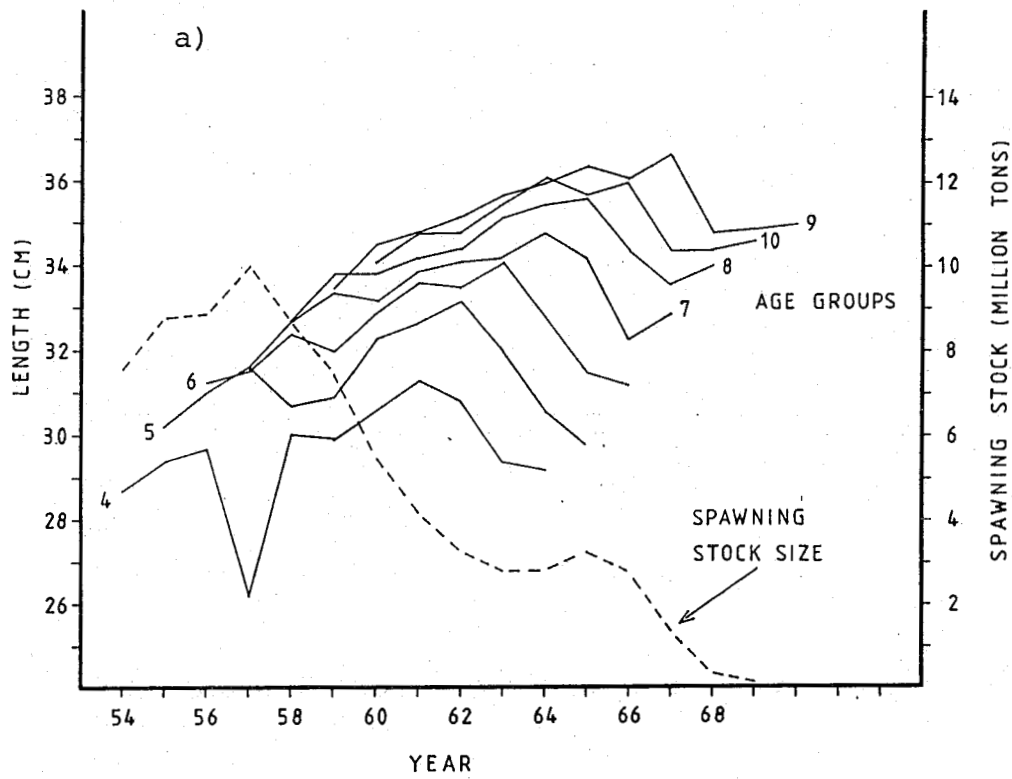
Fig. 3a & b. Mean length at age per year and spawning
stock abundance.

The adults

Length at age. The observed data of mean length at age for the two
periods at the spawning grounds in Area 07 is shown in Table 3.   All
samples taken in the actual time, February - April, are present in the
material.

Mean length at age per year in the two periods and spawning stock
abundance is shown in Fig. 3, a and b. The spawning stock decreases
from a level of about 10 mill tonnes in 1957 till about 3 mill tonnes
in 1965 and further to nearly zero in 1969. Through these years, the
growth, as expressed by the mean length at age per year, show an
increasing trend throughout the fifties. In the beginning of the
sixties however, the growth suddenly start to fall shown by the low
values of mean length at age for the year classes 1958-59 and -60. The
correlation between this pattern of growth and the stock abundance is
not very clear because the change of growth pattern differs from one
age group to another. In fact, it is obvious that the growth pattern
changes in correspondance with the year class strength rather than the
stock abundance.
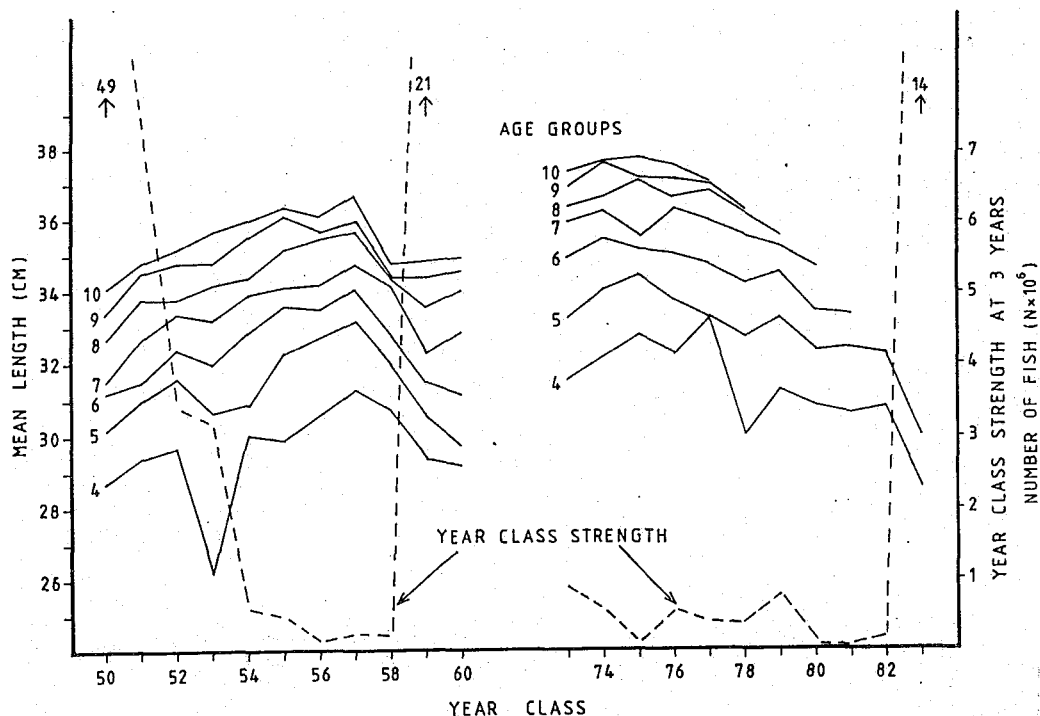
Fig. 4. Mean length at age per year class strength at three years in
        the two periods.

Figure 4 shows the mean length at age per year class and the
corresponding year class strength in the two periods. It is clear,
from the plot that there is a positive correlation between the length
at age for the different year classes and the year class abundance.
The overall growth pattern shows an increasing trend until 1957. The
1958 year class has far less growth than the two or three older year
classes and this decreasing tendency to growth continues for the 1959
year class flattening out for the 1960 year class. This pattern is set
before the herring mature. As shown in Fig. 4, the pattern is clear at

4 years, smoothening a little until the age of ten. The observed drop
in growth for the weak 1958 year class is most certainly caused by
interactions between this year class and the very strong 1959 year
class.

In the second period, only weak year classes occur, except for the
1983 year class which is comparable to strong year classes in the
fifties. It is difficult to draw any conclusions from the appearing
growth pattern. However there is a tendency to decreasing values of
length at age throughout the years (Fig. 3 b). This decrease might
have been affected by the increase in the abundance of the total
stock. However, a clear drop in growth is observed for the strong 1983
year class.

Comparing the curves of mean length at age by year class between the
two periods in Figure 4 gives an impression of better growth in the
seventies than in the fifties. However, the better growth is
restricted to the immature part of the stock only, as the mean length
increments for the age intervall 5-10 years is higher in the former
period than in the latter, 5.87 and 5.08 cm respectively. The length
increment in the age intervall 5-10 years for the year classes with
lowest values of length at 4 years is much higher than for year-
classes with high values of mean length at 4. This phenomenon is
earlier described by Watkin (1927), and Østvedt (1958) and Jakobsson &
Halldorsson (1984) has described this for Atlanto-scandian herring. It
leads to less variation in length within the same year class as the
fish grow older.

Figure 5 shows the plots of mean length at age for all year year
classes in the two periods. The plot illustrates the higher values of
mean length at age in the seventies than in the fifties and the
difference is constant in the whole age interval 5-10 years. The
Figures 2 and 5 compared show very well that the differences in
growth in length is initiated early in life, before maturation.
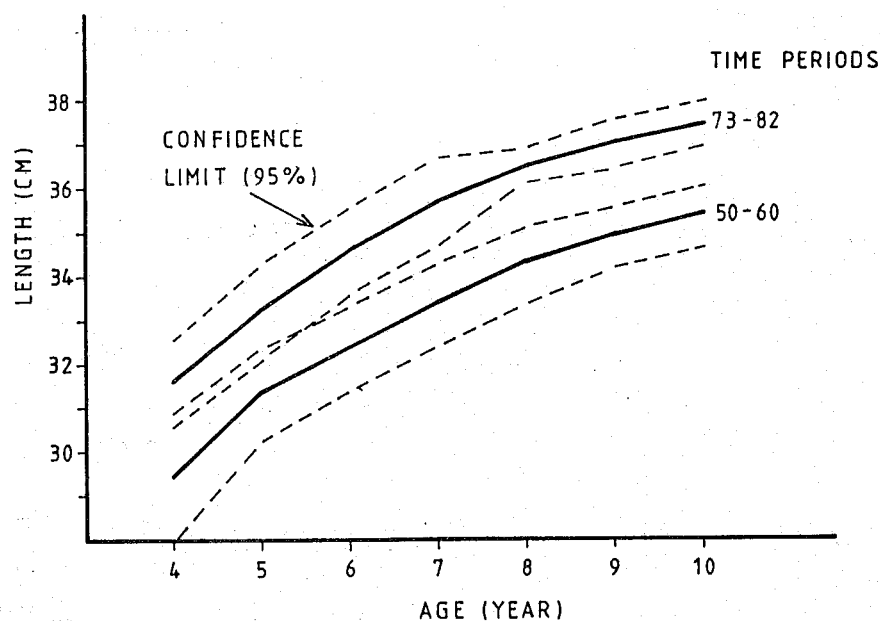
Fig. 5. Mean length at age for all year classes in the two periods.

Weight at age. Table 2 shows the mean weight at age each year for the two periods. These data show exactly the same pattern of growth as the growth of length data did (Fig. 4 and 5). There is a more or less constant difference of 35-60 g between the mean weight at age values for the age groups in the two periods. These differences follows the length at age differences and varies randomly during the age intervall 5-10 years.

MANAGEMENT CONSIDERATIONS

Without any doubt, there is a relationship between year class abundance and growth. The reduced growth due to high abundance might be density dependent in certain areas, but in most cases, it is most certainly due to dispersion of young herring in areas with lower concentrations of food particles and lower temperatures.

The reduced growth leads to later maturation because the maturation is size dependent rather than age dependent. The recruitment of large year classes to the spawning stock therefore tend to be delayed compared to the recruitment of small year classes. This delay may be 2-3 years or even more. The recruitment to the fishery will also be later for larger year classes than for less abundant year classes since the fishery is regulated by a minimum landing size regulation. If the prediction of growth is not thoroughly evaluated in the assessment work, the delay in recruitment may lead to an over-exploitation of the older year classes in the stock. Since the TAC is given in weight rather than number of individuals, a reduced growth also may lead to a general over-exploitation of the stock.

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Table 1 a. Mean length at age.

AREA 04

Year	Age 0	1	2	3	4
1950				19.4	21.1
51				20.8	
52			19.8	23.3	
53			17.6		24.0
54				23.4	
55			22.3		
56			20.7		
57		16.5	16.8		
58	10.8	15.6			
59	12.1				
60					
Mean	11.45	16.40	19.44	21.73	22.55
1973		17.1	23.5	28.7	31.5
74	9.9			29.8	
75			26.8		
76	9.9				
77					
78			23.3		
79		16.9			
80	10.9	17.4	22.8	27.5	32.2
81				29.0	
82	9.0	18.0	24.2	28.4	30.8
83	9.6	16.6	20.5	23.6	
Mean	9.93	17.35	24.12	28.68	31.50

Table 1 b. Mean length at age.

AREA 05

			Age		
Year	0	1	2	3	4
1950			22.2		
51			19.0		
52		17.4		21.7	
53			19.3	24.4	
54		18.2	21.6		
55		18.8			
56			19.6	23.5	
57		14.5			
58	10.9	18.4			
59					
60					
Mean	10.9	17.55	20.34	23.20	
1973		19.2	25.2	29.7	33.2
74	13.5	22.6	29.2	32.4	34.1
75		21.2	29.0		
76	12.6	16.8	28.2		
77		20.2			
78	9.8	19.4	23.3		30.4
79	10.3	18.2		28.5	32.4
80	12.2		24.7	29.5	34.2
81			28.2	31.3	32.7
82	9.7	18.5	24.4	29.3	31.5
83	9.6	19.4	21.9	24.3	29.3
Mean	11.35	19.51	26.53	30.12	32.64

Table 1 c. Mean length at age.

AREA 06

Year	Age				
	0	1	2	3	4
1950			22.3		
51		17.2			
52					
53				23.0	
54			21.7		
55		19.2			
56					
57		17.1			
58	12.1				
59	12.7	17.6			
60	9.7				
Mean	11.50	17.78	22.00	23.00	
1973		21.1	28.5	31.0	33.2
74	13.6	25.4	28.9	31.7	
75		22.7	27.5		32.0
76	11.2	19.4	26.4	31.0	33.5
77	10.8	21.3	27.0	31.5	33.2
78	10.4	18.9	25.7	28.2	31.6
79	10.7	14.1	22.2	28.7	33.1
80	9.5	15.3	21.4	28.2	31.8
81		14.4	27.0		
82	11.4	22.8	23.9	28.7	
83	9.3	18.8	24.3	26.3	
Mean	11.09	19.54	25.85	29.88	32.63

Table 1 d. Mean length at age.

AREA 07

	Age				
Year	0	1	2	3	4
1950					
51		15.8			
52			20.3		
53			20.4		
54		17.7	25.6		
55		19.7			
56					
57		15.2			
58	11.9				
59					
60	11.6				
Mean	11.75	17.10	22.10		
1973		23.6	29.6	32.0	33.3
74		24.9	30.2	32.3	33.9
75	13.1	18.1	28.9	32.0	34.0
76	12.3	20.9	29.2	32.7	33.9
77	10.8	19.8	29.3	31.5	33.2
78	11.3	24.1	27.1	29.6	32.2
79	9.2	20.3	26.9	30.6	32.7
80	15.6	21.2	27.0	28.5	32.8
81	12.6		27.8	31.8	32.3
82		22.3	28.0	30.7	32.3
83		22.0	28.1	27.8	30.3
Mean	12.13	21.69	28.40	31.17	33.06

Table 4. Weight at age in the spawning stock.

| | | | Age | | | |
Year	4	5	6	7	8	9	10
1950	181	213	249	262	293	303	314
51	195	245	272	295	308	321	322
52	208	268	292	307	306	323	334
53	136	242	260	288	304	326	334
54	234	252	284	302	320	327	350
55	221	265	291	313	328	354	370
56		251	300	301	359		369
57	229	294	293	317		354	
58	219	253	264		306	323	383
59	187	211	235	249	294	288	319
60	192	197	222	270	277	309	325
Mean	200.2	244.6	269.3	290.4	309.5	322.8	342.0
1973	231	298	369	385	391	385	430
74	267	338	366	379	361	418	380
75	282	340	347	322	438	366	390
76	262	299	321	386	371	398	384
77	278	262	338	347	382	375	330
78	181	274	307	347	350	321	
79	235	278	313	327	286		
80	234	238	275	275			
81	212	260	250				
82	213	224					
83	151						
Mean;	239.5	281.1	320.6	346.0	368.4	377.2	382.8
Diff;	39.3	36.5	51.3	55.6	58.9	54.4	40.8

Section II: Methodology and models

SURVIVAL TESTS OF INTERNALLY TAGGED HERRING

by

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ABSTRACT

Two separate survival tests were run in an indoor basin. Herring was tagged applying internal metal tags as used in the annual tagging experiments on the Norwegian spring-spawners. The mortality caused by tagging was severe in the first few weeks after release, declining to a normal level in about 8 weeks. The survival of tagged herring in the two tests varied substantially, and the coefficient was calculated to be 0.74 and 0.91 respectively. The difference is explained by the difficulties in handling herring in captivity.

INTRODUCTION

Tagging of fish is a frequently applied method for studying migrations, and to assess the mortality and the abundance of fish stocks. Practical difficulties have been encountered because herring is very sensitive to handling. Dahlgren (1933) tested the performance of different types of tags by comparative experiments, and found that the most successful method proved to be an internal belly tag. This method was introduced in the Norwegian-Icelandic tagging scheme (1947-1952), with the aim to verify the theory that the herring caught during summer off the northern coast of Iceland were identical to the Norwegian winter herring (Fridriksson 1944, Fridriksson and Aasen 1950). The data from this experiment were later used to assess the abundance of the stock (Dragesund and Jakobsson 1963).

In 1975, a new tagging programme for herring was started and since then a total of 30-40 000 tagged herring have been released every spring at different localities on the Norwegian west coast.

The basic assumptions underlying the use of tagging data in stock abundance studies are discussed by Aasen (1958). The survival of tagged herring is a crucial factor in this respect, and mortality experiments were carried out in 1948, 49 and 50 (Fridriksson and Aasen 1950). The conclusions drawn from these experiments were that the tagging did not affect the herring seriously when properly executed on fish in good condition, but no estimate of survival was made. Dragesund and Jakobsson (1963) concluded however, that when the total returns from each experiment where examined, there was a significant variation in returns from the various releases even within the same experiment. The same has been experienced in the recent years. This variation may be due to varying tagging mortality and shedding, but may also be due to non random mixing of the tagged herring in more than one stock unit.

MATERIAL AND METHODS

Two separate survival tests were accomplished, one in 1987, the other in 1988. The fish was caught by purse seine on the coast of western Norway and brought to Bergen in tanks on a commercial purse seiner. Arriving in Bergen, the herring was transfered to an outdoor basin at the Institute of Marine Research.

Test no. 1.
Before tagging, the herring was adapted to life in captivity for 11 weeks to be sure that only healthy fish were used in the test. After 5 weeks of the accomodation period, the fish was moved to an indoor, 185 m^3, basin as shown schematically in Figure 1. Here they dwelled for 6 weeks before the test started. During the accomodation period and in the test period, the fish was fed krill (Euphausiacea), copepods (Calanus sp.) and pellets of dry food. The fish was treated with Flumequine on two occations, to prevent the outburst of vibriosis.

A total of 962 fish were used in the test. About half of them (498) were tagged while the rest (464) remained untagged as a control group. A small seine net was used to catch the fish in the basin and the tagging was done applying the same method as used in the annual tagging programme. A metal tag was shot into the belly of the fish using a tagging pistol as described by Fridriksson and Aasen 1950.
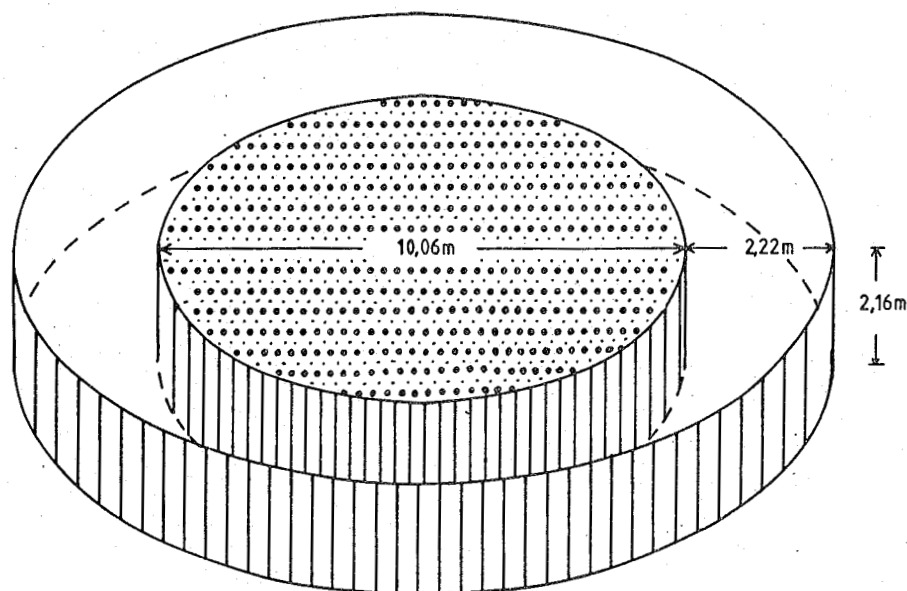
Figure 1. Shape and dimensions of the experimental tank

The number of dead herring was recorded currently and those fishes were examined for tags using a tag detector. Other characteristics such as length, weight, sex, maturation and stomach content were also recorded in 3 samples of approx. 100 fish each, after 9, 14 and 24 weeks respectively. The test was ended after 30 weeks. When ended, 3 tagged herring were found in the gutter and 45 tags were found on the floor of the basin. Of the total of 962 fish used in the test, 922 were recovered. 40 herring were missing, which were probably lost through the gutter.

Test no. 2.
The fish was kept for accomodation in the outdoor basin for 4 weeks and moved to the indoor basin where they were kept for another 4 weeks before the test started. During the accomodation period, and in the test period as well, the fish was fed copepods only. No treatment with Flumequine was necessary because there was no sign of vibriosis in the stock.

400 fish were tagged applying the same method as previously used and no control group of untagged herring was applied.

Records of dead herring were collected currently as in the previous experiment and 1 sample of 100 fish was taken after 8 weeks. The experiment was ended after 17 weeks. When ended, 6 fish were missing and probably lost through the gutter.

RESULTS

Length distributions of the herring used in the tests are shown in Table 1. There is no significant difference in length between the

tagged and untagged fish.

The data of the first test grouped by week are given in the text table below:

Week	Survivals			Deaths			Samples	
	S_1	S_2	S	m_1	m_2	m_3	M_1	M_2
1	498	464	962	1	1			
2				35	3			
3				10	4			
4				3	0			
5				5	0			
6				1	1			
7				0	0	31		
8	366	501	867	2	2			
9				1	1			
10-14				4	1		48	65
15-19				3	3		50	74
20-24				2	2			
25-29				1	2		57	59
30	192	286	478	0	0	12	192	286
Σ 8-30				13	11	43	347	484
Σ 1-7				55	9	31		

S_1 and S_2 denote numbers of tagged and untagged herring at the beginning of the week, and m_1 and m_2 the corresponding numbers of dead herring recorded during the week. m_3 is a calculated figure refering to the herring lost through the gutter. M_1 and M_2 are number of fish sampled during the experiment.

In calculating the survival, one has assumed that the lost herring belongs to the group which for some reason has died during the experiment. Judging from the trend in the death rate, the table shows that the mortality due to tagging is ended, after 6 weeks. The 43 unrecorded dead herring have been allocated to the periods before and after the 7. week in the same proportion as the recorded ones (64 to 24). This gives 31 dead herring allocated to the first period and 12 herring to the last one. Assuming that the latter group is equally distributed on tagged and untagged herring, the number of surviving tagged herring at the beginning of the 7. week is found by summation of the samples and those which have died, i.e. 347 + 13 + 6 = 366 individuals. This gives a total instantaneous mortality coefficient (Z) of:

$$Z = - \ln \frac{366}{498} = 0.308$$

During the next 7 weeks 11 dead individuals were recorded. If we assume that 1/3 of the 12 lost herring died during this period, the total mortality amounts to 15 individuals. This gives a Z value of 0.017.

Considering this as the natural mortality in the stock, the mortality due to tagging is estimated to; Z = 0.291, which corresponds to a

coefficient of survival S = 0.74. This coefficient includes the shedding which is estimated to 46 individuals (498 - (366 + 55 + 31)), pluss some 5-6 of the specimens recorded as dead unmarked herring which have lost their tags during the three first weeks. This means that some 10 - 11 % of the tagged herring have lost their tags.

The data from the second test are summarized in the text table below:

Week	Survivals S_1	Deaths m_1	m_2	m_3	Samples M_1	M_2
1	400	6	1			
2		3	0			
3		4	1			
4		3	0			
5		0	1			
6		1	0			
7		2	0	6		
8	372	0	0		98	2
9		0	0			
10-16		2	0			
17	270	0	0		262	8
Σ 1-17		21	3	6	360	10

Also in this experiment the increased mortality due to tagging is over after 7 weeks. 6 specimens were lost in this test, and it is assumed that these died during the first 7 weeks. Two specimens died from the 8 to the 16 week, which shows that the natural mortality in the test period can be regarded as insignificant (less than 1 %). Altogether, 13 specimens had lost their tags and assuming that all shedding of tags had taken place during the first 7 weeks, the coefficient of survival can be taken as the total survival after the first 7 weeks minus the 10 untagged specimens in the samples.

$$s = \frac{372 - 10}{400} = 0.91$$

Only 3 % of the tagged herring in this test had lost their tags.

DISCUSSION

The result of the tests is only representative for that part of the tagging mortality which is caused by the handling of the fish during the tagging operation and the injuries caused by the insertion of the tag. The mortality caused by the catching operation and the brailing of the fish on board the ship will add to the total tagging mortality in practice, and the survival coefficients derived from these experiments are therefore to be considered as maximum values. Injuries caused by the purse seine operation and brailing of the fish to the tanks may vary with weather conditions and are difficult to measure by experimental techniques. It is, however, experienced that damage of the skin and loss of scales reduce the survival of herring and

the skin and loss of scales reduce the survival of herring and although no herring with apparent damage of the skin is accepted for tagging, it is reasonable to assume that such injuries contribute significantly the total tagging mortality. Another factor which obviously bias the survival estimate in these tests is the absence of predators. The tagged herring are no doubt more vulnerable to predation during the period of recovery than the untagged population.

The significant difference between the survival estimates of the two tests is assumed to be a consequence of the different condition of the tagged fish. In the first case, the herring was more densely stocked, and the fish was suffering from an outburst of vibriosis some 3 weeks before the tagging took place. Although the sample which was tagged appeared to have recovered, the natural mortality in the untagged population was relatively high when the tagging was executed. These circumstances constituted an additional strain on the tagged fish, which is not present in nature. Only the results of the second test are therefore regarded as representative for the tagging mortality of internal tagging by the present method. The test confirms the conclusion drawn by Fridriksson and Aasen (1950) that the tagging do not affect the herring seriously when the fish is in good condition. The mortality caused by the tagging operation under favourable conditions is estimated to be about 10%, but may increase considerably if the condition of the fish is poor. It may be noted that even the shedding of tags may increase when tagging herring in poor condition.

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Tab. 1. Length frequency distribution of tagged (T) and untagged (UT) herring in the 1987 experiment.

EXPERIMENT NO. 1

LENGTH	18/8-87		23/9-87		3/12-87		8/1-88		SUM	
	T	UT	T	UT	T	UT	T	UT	T	UT
23.5								2		2
24.0						2				2
24.5	1	1		1			2	1	3	3
25.0	1	2	1			1	9	4	11	7
25.5	2	5	1	3		3	10	19	13	30
26.0	6	11	6	15	3	6	22	39	37	71
26.5	3	11	8	9	9	9	23	49	43	78
27.0	12	14	10	12	8	7	31	57	61	90
27.5	9	5	9	14	17	14	33	43	68	76
28.0	4	7	3	6	9	6	19	35	35	54
28.5	3	3	6	4	8	1	18	15	35	23
29.0	2	2	2	4	1	3	8	7	13	16
29.5	3	2	1	2	1	3	6	3	11	10
30.0	1	1	1	1		1	2	3	4	6
30.5		1	1	1	1	2	3	3	5	7
31.0	1		1			1	2	2	4	3
31.5							1	2	1	2
32.0							2	1	2	1
32.5							1		1	
33.0										
33.5				1						1
34.0										
34.5								1		1
35.0										
35.5				1						1
SUM	48	65	50	74	57	59	192	286	347	484
MEAN LENGTH	27.3	27.0	27.4	27.3	27.5	26.9	27.4	26.9	27.4	27.0

Tab. 2. Length frequency distribution of tagged herring in the 1988 experiment.

EXPERIMENT NO. 2

LENGTH	30/8-88	2/11-88	5/1-89	SUM
24.5			1	1
25.0	1	2	1	4
25.5	1	3		4
26.0		3		3
26.5	1	10	2	13
27.0	2	13	2	17
27.5	5	31	4	40
28.0	16	26	3	45
28.5	16	36	3	55
29.0	15	38	4	57
29.5	10	39	1	50
30.0	13	33		46
30.5	10	13		23
31.0	3	13		16
31.5	3	5	1	9
32.0	1		1	2
32.5		2		2
33.0	2	1		3
33.5	1	2		3
34.0				
34.5				
35.0				
35.5				
36.0		1		1
SUM	100	271	23	394
MEAN LENGTH	28.6	28.9	28.2	28.6

HM2 (HERRING MODEL 2).
A SINGLE SPECIES COMPUTER MODEL OF THE NORWEGIAN SPRING SPAWNING HERRING STOCK

by

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ABSTRACT

HM2 represents an intermediate, experimental stage of a model that is being developed with the double purpose of being used as an independent single species model for the Norwegian Spring Spawning Herring and of being integrated into the Multispecies Model for the Barents sea (MULTSPEC). The paper describes its development history, and the presently used algorithms for maturation, recruitment, and growth are described and discussed, as well as its input and output options. A brief outline is given of the plans for further development of the model.

INTRODUCTION

The herring model HM2 has part of its origin in a FORTRAN programme
written in 1972 by Carl Christian Hauge of the Christian Michelsens
Institute, Bergen, under guidance from Johannes Hamre of the
Institute of Marine Research, Bergen, in order to simulate
population dynamics in an exploited stock (Hauge, 1972). The programme
was later modified by Knut Hestenes of the Institute of Marine
Research and Johannes Hamre , in order to simulate the Norwegian
Spring Spawning Herring Stock. That programme was called PN157H, and
introduced algorithms for density dependent growth and recruitment
that are also included in HM2.

The concept in the two programmes has also been used as the biological
part of of a bioeconomical analysis of the Norwegian Spring Spawning
Herring, carried out by Sigfus Kristmannsson of the Institute of
Fishery Technology Research in Tromsø , Norway, with assistance from
Johannes Hamre.

HM2 is written in Pascal and does basically the same job as PN157H,
although the user interface is more flexible. Given the same start-
parameters, the two programmes will give the same results.

The purpose of writing HM2 was to get a well documented basis for
the further development of a single species herring model that both
could function well on its own and could be easily integrated into
the Multispecies Model for the Barents Sea (Tjelmeland and Bogstad,
1989). The first step in this process was a model named HM1, which
is documented in a Work Note (Dommasnes, 1986). HM2 represents a
further development of HM1.

At its present stage of development, HM2 will be useful for
simulating the reactions of the Norwegian Spring Spawning Herring
stock to different fishing patterns. It will also be used to try out
various algorithms for growth, maturation, and recruitment.

The programme HM2 and its documentation (Dommasnes, A. 1988) has been
made available to scientists at the Institute of Marine Research, in
order to allow them to test it out and influence its further
development.

Because one of the aims in writing HM2 is to develop a programme that
can be integrated in MULTSPEC, it has an internal structure which is
similar to that used by the capelin part of MULTSPEC. This makes HM2
considerably larger and more elaborate - and slower - than is really
necessary to produce the output given by this version.

ALGORITHMS

HM2 is, basically, a Beverton and Holt model (Beverton and Holt,
1957) which starts in January with numbers for each yearclass
supplied by the user, and updates the numbers one month at a time,
using information about mortality which is also supplied by the
user.

Growth

Growth in length is determined by density alone. This is done by
referring to two stock situations - Stock situation 1 and Stock

situation 2, each characterized by mean length in each age group and total stock biomass. When the programme starts, Stock situation 1 is represented by the year 1950 when the total stock was 15 million tonnes, and Stock situation 2 by the year 1970 when the total stock was 1 million tonnes. The programme will, however, replace one of these years with the year the program starts. Which year is replaced, depends on whether the stock biomass in the start year is closest to 1950 or 1970. Using an iteration procedure, a set of mean lengths on 1 January for the current year is calculated that depends on the size of the stock at that time. Growth in the current year for each age is the difference between the mean length for that age and the mean length for the next age. The growth period is July - October for 0-group herring and June - October for older herring.

Maturation and spawning stock

Maturation is dependent on length alone, and is determined in January. A sigmoid function determines the proportion of each length group that matures. The function presently used is:

MATNUM = NUM / (1 + exp((LM50-ML) * LN(BASE)))

MATNUM	is the number of maturing herring in the length group.
NUM	is the total number of herring in the length group.
ML	is the mean length in the length group.
BASE	is the base in the logarithmic expression.
LM50	is the length where 50% of the herring is maturing.

In the present model BASE=9.0 and LM50=31.2. This gives a maturation curve as shown in Fig. 1.
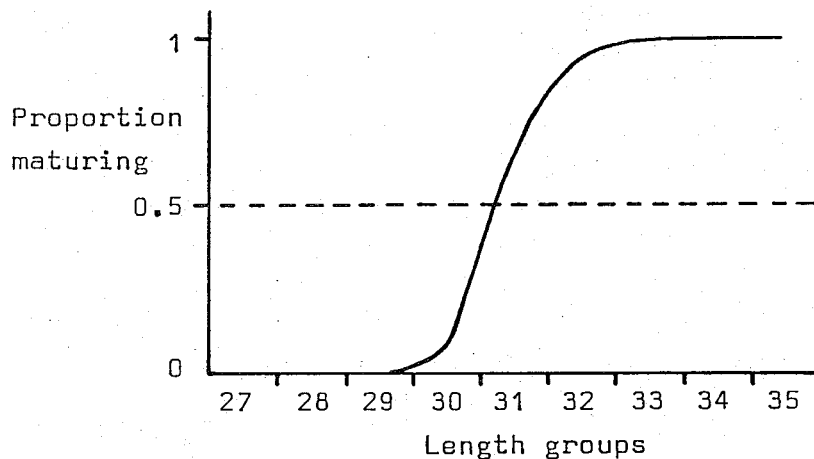
Figure 1. Maturation according to the algorithms used in model HM2 (Base=9.0, LM50=31.2).

Recruitment

Spawning takes place in March. The resulting number of larvae is calculated from the biomass of the spawning stock in January.

The larvae are assumed to join the main stock in June. Between March and June no mortality is applied to the larvae, meaning that earlier mortality is taken care of by the recruitment function.

Two   basic   recruitment functions are available to calculate the
number of larvae that results from a given parent stock. They can be
described in the following way:

Function 1:
RECRUITS = 31.0 * (1 - exp(exp(-1.75) - exp(0.5*(PARSTOCK-3.5))))

PARSTOCK is the spawning stock biomass in million tonnes, and
RECRUITS is the number of recruits, with the dimension 10E9.

Function 2 is more complicated, and internally in the programme it
consists of two functions:

Function 2A:
RECRUITS = PARSTOCK / (0.05*PARSTOCK+0.09)

Function 2B:
RECRUITS = 10*PARSTOCK

The curves for the different recruitment functions are shown in
Fig. 2.
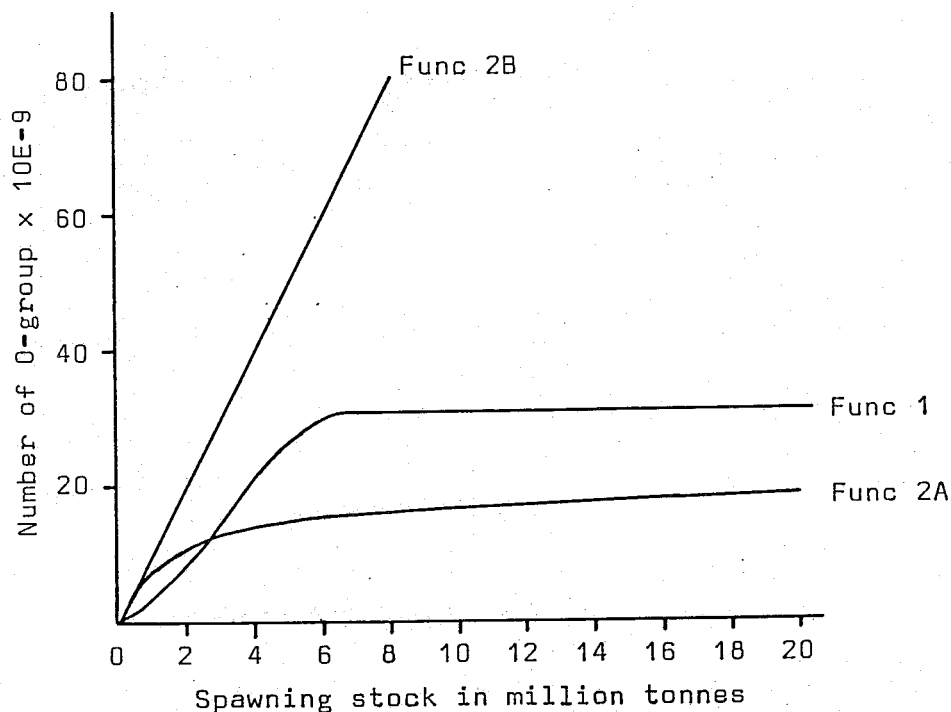
Figure 2. Recruitment according to the algotithms used in model HM2
          without "stochastic recruitment".

Function 1 represents a curve that increases asymptotically towards
31.0*10E9 recruits.

Function 2A represents a curve that increases more slowly than
Function 1, asymptotically, towards a value of 20*10E9 recruits.

Function 2B represents a direct linear relationship between parent
stock biomass and number of recruits.

If "Function 2" has been selected, then Function 2A and Function 2B
are used in the following way:

    If the recruitment is not stochastic
    and the year=1991 or 1999 or ....(period of 8 years)
    then use function 2B else use function 2A

The   years 1991, 1999,..... represent "boon years" with very good
recruitment as described by Function 2B. In between, there   are
periods of rather poor recruitment, as described by Function 2A.

In   addition to the choice of recruitment functions, the user   can
select "stochastic recruitment", which means that the   number   of
larvae calculated is multiplied by a "success-factor" in order   to
simulate the highly variable relationship that is observed in   nature
between parent stocks and number of recruits. The success-factor is
randomly selected from a table of 28 possible numbers as given   in
Table   1, and represents the ratio between the   observed and the
predicted number of larvae in the periods 1950 - 69 and 1973   -   80.
The   data are partly based on Dragesund, Hamre and Ulltang (1980),
but also unpublished information has been used.

Function   2A is never used if stochastic recruitment has been
selected.

INPUT

The   user can select a set of parameters through a system of menus.
The parameters can be stored for later use. When the   programme is
started   the user must either give a file name from which to read
start data, or let the programme generate a fixed set of start data.
When the user has finished entering data, the programme writes a
report of the start data to a file.

The following parameters can be changed by the user:

    condition factors (length dependent)

    natural mortality
    fishing mortality/catch per year
    distribution of catch on months through the year
    recruitment to fishery (length dependent)

    numbers and mean lengths in each age group
        (at the start of the program)

    recruitment function (choice of two)
    stochastic recruitment (yes or no)

    choice of two output reports (comprehensive or condensed)
    number of years to run the model
    number of times to run the model
        (if stochastic recruitment has been selected)

    file names
        (for startdata, report on startparameters, and results)

OUTPUT

Two types of output reports are possible: one rather comprehensive
report and one condensed version.

The comprehensive report gives the following information:

      mean lengths and numbers for each age group for each month
      biomass for the total stock and the spawning stock for each month

      catch in numbers of each age group for each month .
      weight of total catch in each month
      mean weight of the herring caught each month
      fishing mortality each month for the herring that is fully
      recruited

The   condensed   report   is intended for use   when   the   programme is
repeated   many   times   to   see the   possible   effect   of   stochastic
recruitment, and gives the following information:

      success-factor, spawning stock, and catch for each run
      mean and standard deviation of the same parameters
      for all the runs

An example of the kind of tables given in the comprehensive report
and the condensed report is given in Tables 2 and 3, respectively.

DISCUSSION

The algorithm used for density-dependent growth is rather primitive,
and it only takes into account the biomass of the stock in the total
area   of distribution.   Factors   like   geographical   distribution,
temperature, and availability of food in the present year   and
previous   years are not taken into account. These factors may be as
important as the total stock biomass, or even more important.   In
particular,   local variations in density, temperature, and availa-
bility of food may lead to quite different growth patterns   for
different components of the stock. In order to make the model more
realistic, a new growth algorithm must be developed that   takes into
account   the effects of temperature and food availability as well as
density - or allows the user to compensate for these effects in   the
input menus.   New versions of the program, which allow for the divi-
sion of the stock into different areas, can make the simulation more
realistic.

In the present version of the model maturation, weight, and recruit-
ment to the fishery are all length dependent. Thus, too high mean
lengths will give too early maturation, too high spawning stock and
too high total biomass, and the yearclasses will enter the   fishery
at   a too early age. Too low mean lengths will have   the   opposite
effect. A good algorithm for growth is therefore essential for good
simulation.   In addition, a number of other weaknesses in the model
may be masked by a poor growth algorithm.

The algorithm for maturation is of the same kind as the one used by
MULTSPEC for capelin (Tjelmeland and Bogstad, 1989).   The constants
in the algorithm may need adjustment, but this can best be done when a
better growth algorithm has been worked out.

The   algorithms used for recruitment are not well documented at
present. In addition, the optional "stochastic" recruitment   is
highly   speculative. It is necessary to go carefully through the
historical material that is available in order to substantiate   the
relationships   that are expressed in the model - or adjust the
recruitment algorithms.

Experience   with the model shows that it is necessary to be able to
adjust the model to known start situations, and it may be necessary
to add menus that allow the user to control growth, maturation, and
recruitment.

A new version of this model is under development. It will run under
the UNIX operating system, and will include the division of   the
stock   into a number of areas, and migration between the areas.
Natural mortality will be made length dependent, and it will   be
possible   to use a different fishing mortality for each year. An
effort will be made to improve algorithms for growth, maturity, and
recruitment - possibly by using more traditional and straightforward
solutions than those in the present model.

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         14 pp. + 27 pp. program listings etc.

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Table 1. Spawning stock, observed number of recruits, predicted
number of recruits, and ratio between observed and predicted number
of recruits, using recruitment functions 1 and 2 (Predicted 1 and
Success 1, Predicted 2 and Success 2, respectively) for 28 years in
the period 1950-1980. Note that the program has been in mode
STOCHASTIC during the calculation, so that for recruitment function
2 only FUNC2A has been used.

Recruitment function 1: R = 31.0 * (1 - exp(exp(-1.75) - exp(0.5 * ((P/1000) -3.5))

Recruitment function 2: R = P / (0.05*P + 90)

R = number of 0-group * 10E-9 in June
P = spawning stock in thousand tonnes

Spawning stock in thousand tonnes
Number of larvae actually observed * 10E-9
Number of larvae predicted by recruitment function * 10E-9
Success of spawning (observed number/predicted number)

Year:	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
S.stock:	9400	9100	8800	7100	7600	8800	8900	10000	8500	7500	5500	4100	3300	2500
Observed:	97.4	26.1	27.9	21.0	16.9	9.2	11.1	9.7	13.7	75.0	47.5	18.3	7.2	26.3
Predicted 1:	31.0	31.0	31.0	30.9	31.0	31.0	31.0	31.0	31.0	31.0	28.6	21.4	16.1	10.9
Predicted 2:	16.8	16.7	16.6	16.0	16.2	16.6	16.6	16.9	16.5	16.1	15.1	13.9	12.9	11.6
Success 1:	3.1	0.8	0.9	0.7	0.5	0.3	0.4	0.3	0.4	2.4	1.7	0.9	0.4	2.4
Success 2:	5.8	1.6	1.7	1.3	1.0	0.6	0.7	0.6	0.8	4.6	3.2	1.3	0.6	2.3

Year:	1964	1965	1966	1967	1968	1969	1973	1974	1975	1976	1977	1978	1979	1980
S.stock:	3400	3700	2800	1400	280	90	110	90	80	120	240	290	330	380
Observed:	17.3	3.6	17.3	1.2	2.6	2.0	1.2	0.7	0.2	0.7	0.5	0.5	0.7	0.2
Predicted 1:	16.8	18.8	12.8	5.0	0.8	0.2	0.3	0.2	0.2	0.3	0.7	0.8	1.0	1.1
Predicted 2:	13.1	13.5	12.2	8.7	2.7	1.0	1.2	1.0	0.9	1.2	2.4	2.8	3.1	3.5
Success 1:	1.0	0.2	1.4	0.3	3.3	8.1	4.0	2.8	0.9	2.1	0.7	0.6	0.7	0.2
Success 2:	1.3	0.3	1.4	0.1	1.0	2.1	1.0	0.7	0.2	0.6	0.2	0.2	0.2	0.1

Table 2. Example of a comprehensive report from HM2.

RESULTS
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Year 1988

Mean lengths for age groups

Age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	-	-	-	-	-	5.0	6.8	8.5	10.3	12.0	12.0	12.0
1	12.0	12.0	12.0	12.0	12.0	14.1	16.2	18.4	20.5	22.6	22.6	22.6
2	22.6	22.6	22.5	22.5	22.5	23.7	24.9	26.2	27.4	28.6	28.5	28.5
3	28.7	28.7	28.6	28.5	28.5	29.0	29.6	30.1	30.6	31.1	31.0	31.0
4	31.3	31.3	31.2	31.2	31.2	31.5	31.8	32.2	32.5	32.8	32.8	32.8
5	33.0	33.0	32.9	32.9	32.9	33.2	33.4	33.7	33.9	34.2	34.1	34.1
6	34.2	34.2	34.2	34.2	34.2	34.4	34.6	34.8	35.0	35.2	35.2	35.2
7	35.2	35.2	35.2	35.2	35.2	35.4	35.5	35.7	35.8	36.0	36.0	36.0
8	36.0	36.0	36.0	36.0	36.0	36.1	36.3	36.5	36.6	36.8	36.8	36.8
9	36.8	36.8	36.8	36.8	36.8	36.9	37.0	37.2	37.3	37.4	37.4	37.4
10	37.4	37.4	37.4	37.4	37.4	37.5	37.6	37.7	37.8	37.9	37.9	37.9
11	37.9	37.9	37.9	37.9	37.9	38.0	38.0	38.1	38.2	38.2	38.2	38.2
12	38.2	38.2	38.2	38.2	38.2	38.3	38.3	38.3	38.4	38.4	38.4	38.4
13	38.4	38.4	38.4	38.4	38.4	38.5	38.5	38.5	38.5	38.6	38.6	38.6
14	38.6	38.6	38.6	38.6	38.6	38.6	38.6	38.6	38.7	38.7	38.7	38.7
15	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7

Stock
Numbers in millions of individuals
Weight and spawning stock in thousand tonnes

Age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	262	259	256	254	251	248	246
1	262	259	256	254	251	248	246	243	240	237	232	229
2	143	141	137	132	131	130	128	127	125	120	114	113
3	267	264	242	222	219	217	214	212	210	198	186	184
4	150	148	133	118	117	116	115	113	112	105	98	97
5	6997	6922	6128	5426	5368	5310	5253	5196	5140	4798	4477	4429
6	18	18	16	14	14	14	13	13	13	12	11	11
7	10	10	9	8	8	8	7	7	7	7	6	6
8	15	15	13	12	11	11	11	11	11	10	9	9
9	28	28	24	22	21	21	21	21	20	19	18	18
10	23	23	20	18	17	17	17	17	17	16	15	14
11	44	44	38	34	33	33	33	33	32	30	28	28
12	41	41	36	32	31	31	31	30	30	28	26	26
13	1	1	1	1	1	1	1	1	1	1	1	1
14	21	21	18	16	16	16	16	16	15	14	13	13
15	31	31	27	24	24	23	23	23	23	21	20	19
Sum:	8051	7964	7098	6331	6262	6457	6387	6318	6250	5865	5502	5443
Weight:	2931.5	2930.4	2394.0	1932.3	1925.1	2247.9	2396.5	2530.8	2617.8	2457.8	2233.7	2130.8
Spawn:	2875.7	2875.7	2875.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Catch
Numbers in millions of individuals
Weight in thousand tonnes
Mean weight in grammes
Instantaneous fishing mortality per month for the fully recruited yearclasses

Age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	1	2	0	0
2	0	3	3	0	0	0	0	0	4	5	0	0
3	0	20	18	0	0	0	0	0	10	10	0	0
4	0	14	13	0	0	0	0	0	6	6	0	0
5	0	723	639	0	0	0	0	0	289	270	0	0
6	0	2	2	0	0	0	0	0	1	1	0	0
7	0	1	1	0	0	0	0	0	0	0	0	0
8	0	2	1	0	0	0	0	0	1	1	0	0
9	0	3	3	0	0	0	0	0	1	1	0	0
10	0	2	2	0	0	0	0	0	2	2	0	0
11	0	5	4	0	0	0	0	0	2	2	0	0
12	0	4	4	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	1	1	0	0
14	0	2	2	0	0	0	0	0	1	1	0	0
15	0	3	3	0	0	0	0	0	0	0	0	0
Sum:	0	785	695	0	0	0	0	0	319	302	0	0
Weight:	0.0	308.3	250.8	0.0	0.0	0.0	0.0	0.0	146.1	137.4	0.0	0.0
M.wght:	-	392.7	361.1	-	-	-	-	-	457.6	455.8	-	-
F.mort:	0.00	0.12	0.12	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.00	0.00

Table 3. Example of a condensed report from HM2.

RESULTS
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Success = observed/predicted number of larvae
Catch   = catch during the year in thousand tonnes
Sstock = spawning stock in March in thousand tonnes
Tstock = total stock in December in thousand tonnes
SumCT   = catch during the year + total stock in December

Run no.	1988 Success	1988 Catch	1988 Sstock	1989 Success	1989 Catch	1989 Sstock	1990 Success	1990 Catch	1990 Sstock	Catch 1988-90	Tstock 1990	SumCT 1990
1	1.6	843	2876	0.2	605	2041	0.2	436	1448	1884	1260	1696
2	0.2	843	2876	1.0	605	2041	0.6	450	1448	1898	2130	2580
3	0.2	843	2876	1.6	605	2041	0.1	459	1448	1907	2555	3014
4	0.6	843	2876	0.7	605	2041	3.2	445	1448	1893	2159	2604
5	0.6	843	2876	4.6	605	2041	1.3	507	1448	1955	5578	6085
6	1.7	843	2876	3.2	605	2041	0.7	484	1448	1932	4117	4601
7	0.2	843	2876	0.7	605	2041	0.1	444	1448	1892	1708	2153
8	1.0	843	2876	0.6	605	2041	2.3	443	1448	1891	1895	2337
9	1.0	843	2876	0.3	605	2041	1.7	437	1448	1885	1529	1966
10	5.8	843	2876	1.3	605	2041	1.3	455	1448	1903	2487	2942
11	1.3	843	2876	0.2	605	2041	0.2	436	1448	1884	1264	1700
12	0.7	843	2876	1.4	605	2041	0.2	457	1448	1905	2440	2897
13	2.3	843	2876	5.8	605	2041	2.1	523	1448	1971	6724	7247
14	0.7	843	2876	0.3	605	2041	5.8	437	1448	1885	2045	2482
15	0.2	843	2876	1.7	605	2041	0.2	461	1448	1909	2682	3143
16	0.6	843	2876	0.6	605	2041	5.8	443	1448	1891	2338	2780
17	0.7	843	2876	0.7	605	2041	0.2	444	1448	1892	1730	2174
18	0.1	843	2876	0.1	605	2041	0.3	434	1448	1882	1154	1587
19	2.1	843	2876	1.7	605	2041	0.2	461	1448	1909	2682	3143
20	4.6	843	2876	0.2	605	2041	0.3	436	1448	1884	1302	1738
Mean:	1.3	843	2876	1.3	605	2041	1.3	455	1448			
St.dev.:	1.5	0	0	1.5	0	0	1.8	24	0			

Run no.	1991 Success	1991 Catch	1991 Sstock	1992 Success	1992 Catch	1992 Sstock	1993 Success	1993 Catch	1993 Sstock	Catch 1991-93	Tstock 1993	SumCT 1993
1	1.7	340	1024	0.3	334	904	2.3	487	892	1161	2955	3442
2	0.7	498	1021	1.4	730	1629	1.3	843	2266	2071	4181	5024
3	1.3	577	1019	1.0	865	1919	1.3	933	2677	2375	4502	5435
4	0.6	477	1022	0.8	923	1348	4.6	1452	2491	2852	6425	7877
5	1.3	999	1007	2.3	1916	1788	5.8	2204	6293	5119	10186	12390
6	1.4	814	1013	0.6	1462	2084	1.0	1633	4740	3909	6394	8027
7	1.7	427	1022	0.7	519	1369	0.6	636	1462	1582	3511	4147
8	0.3	439	1022	1.3	762	1245	1.7	1141	2344	2342	4962	6103
9	1.3	377	1023	1.4	580	977	2.1	966	1921	1923	5072	6038
10	1.4	553	1019	0.1	932	1756	0.2	1217	2799	2701	4807	6024
11	1.3	340	1024	0.1	335	904	1.0	454	922	1130	2419	2874
12	0.6	556	1019	0.6	822	1853	0.6	838	2557	2216	3247	4085
13	1.4	1123	1003	0.2	2218	1519	3.2	2621	7062	5962	10174	12796
14	2.3	430	1023	1.7	1033	937	0.6	2022	1822	3485	9911	11932
15	0.3	597	1018	1.4	915	1958	1.6	914	2891	2426	4127	5041
16	0.6	482	1022	0.2	1124	1177	1.3	2003	2091	3609	8112	10115
17	1.7	429	1022	1.0	543	1365	0.6	693	1583	1666	3918	4612
18	0.2	318	1024	1.0	277	769	3.2	298	810	893	1793	2090
19	0.2	597	1018	3.2	914	1958	0.2	932	2892	2443	5380	6312
20	0.6	347	1024	0.6	348	938	0.8	401	1017	1096	1944	2345
Mean:	1.0	536	1019	1.0	878	1420	1.7	1134	2577			
St.dev.:	0.6	216	6	0.8	508	428	1.5	655	1680			

Concentrate of data, for all years and all runs
Success = observed/predicted number of larvae
Catch   = catch during the year in thousand tonnes
Sstock = spawning stock in March in thousand tonnes
Tstock = total stock in December in thousand tonnes
SumCT   = catch during the year + total stock in December
Means   = means over years and runs
St.dev. = standard deviations over years and runs

	Success	Catch	Sstock	Tstock	SumCT
Mean:	1.3	742	1897	3362	4104
St.dev.:	1.3	415	961	2352	2681

NORTHERN HEMISPHERE CLIMATE CHANGES AND THEIR EFFECTS ON THE ENVIRONMENT OF ATLANTO-SCANDIAN HERRING

by

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ABSTRACT

Teleconnections for the Northeast Atlantic region are discussed with special reference to the NAO properties. Some speculations about climatic changes in the near future are also discussed, with suggestions how they could affect the environment of herring. The kind of factors being either favorable or unfavorable are considered.

INTRODUCTION

While bringing to light the mechanism of the influence of abiotic factors on fish at various stages of their life cycle is a very complicated task, there is no doubt that climatic changes play an important role in producing fluctuations in fisheries. The climatic indicator most commonly used in studies of recent climatic change is the average surface air temperature of the Northern Hemisphere. Changes in the regional and hemispheric climate, however, may differ greatly from one another, and may even be characterized by different signs. At the same time, in order to interprete regional climatic changes in a right way, they should be considered in the context of global climatic processes. For this purpose it is necessary to have at least a qualitative knowledge of regularities of the climatic system functioning in the time scale in question.

One of the indications of the world-wide interaction of hydrometeoro- logical processes is the coherence in fluctuations occurring in areas situated far from each other. The problem of teleconnections has attracted much attention nowadays. Properties of the earlier discovered North Atlantic Oscillation (NAO), North Pacific Oscillation (NPO), Southern Oscillation (SO) have been studied in greater detail, and also new regions with coherent fluctuations have been found (Wallace, Gutzler, 1981). From a practical point of view, the knowledge of teleconnections can enable us to apply current and predicted hydrometeorological characteristics available for remote areas of the world to develop a more reliable forecast in the region investigated.

In the present study, teleconnections for the Northeast Atlantic region will be discussed with special reference to the NAO properties. Some speculations about climatic changes in the near future and how they could affect the environment of herring will be suggested. But first of all, let's consider what kind of environmental factors are favourable or unfavourable for herring.

RESULTS

It is known (Benco, Seliverstov, 1969) that there is a positive relationship between the recruitment to the herring stock and thermal condition in the spawning grounds: the higher the mean water temperature in spring, the larger is the magnitude of year class strength. Furthermore, water temperature is an important factor not only in the spawning season, but also in the prespawning (because it may induce a shift in the dates of spawning, and also in the first winter of the life of the fish (Fishery Oceanography, 1986).

Reviewing the relationship between the relative abundance of herring and ice conditions, Yudanov (1964), and Beverton and Lee (1965) pointed out that rich year classes of herring occur less frequently in cold periods than in warm. Bogdanov et al. (1969) noted that recruitment to the herring stock fluctuates substantially from year to year in cold periods, whereas in the warm ones the fluctuations are smoother.

To study the relationship between the atmospheric circulation and abundance of herring we constructed composite charts of mean winter and spring sea level pressure (SLP) for years when rich and pure year classes occurred (Figs. 1 and 2). In the case of rich year classes

I904, I9I8,
I923, I930,
I934, I937,
I938, I943,
I944, I947,
I950, I959,
I960, I96I.

I949, I954,
I955, I956,
I957, I958,
I962, I964,
I965.
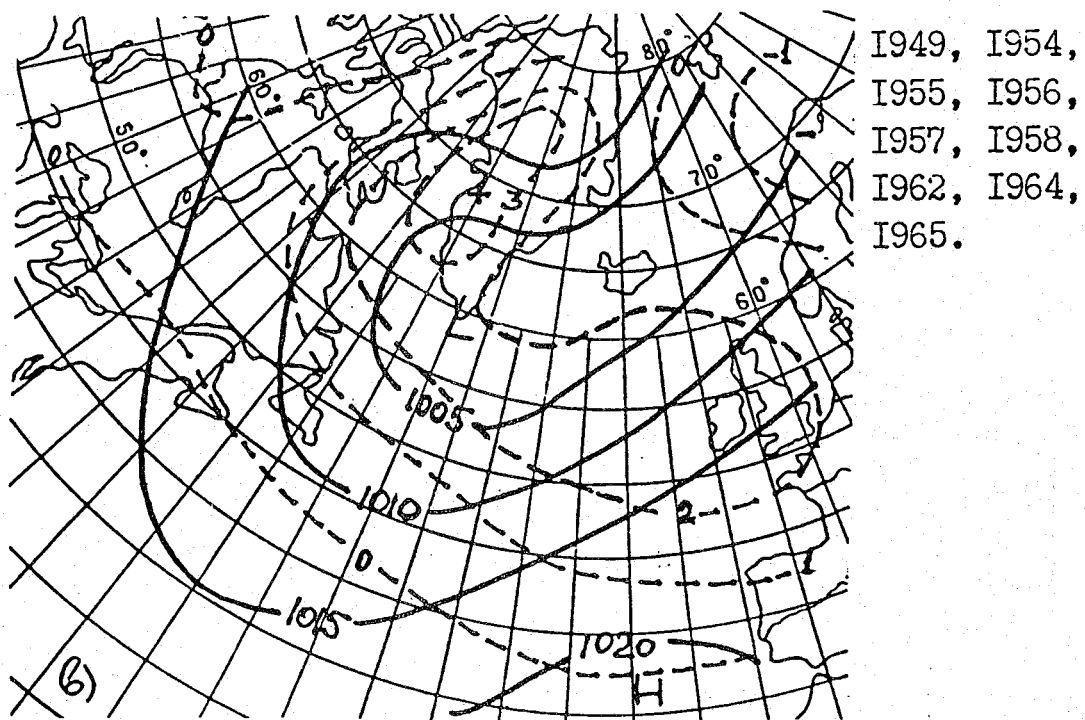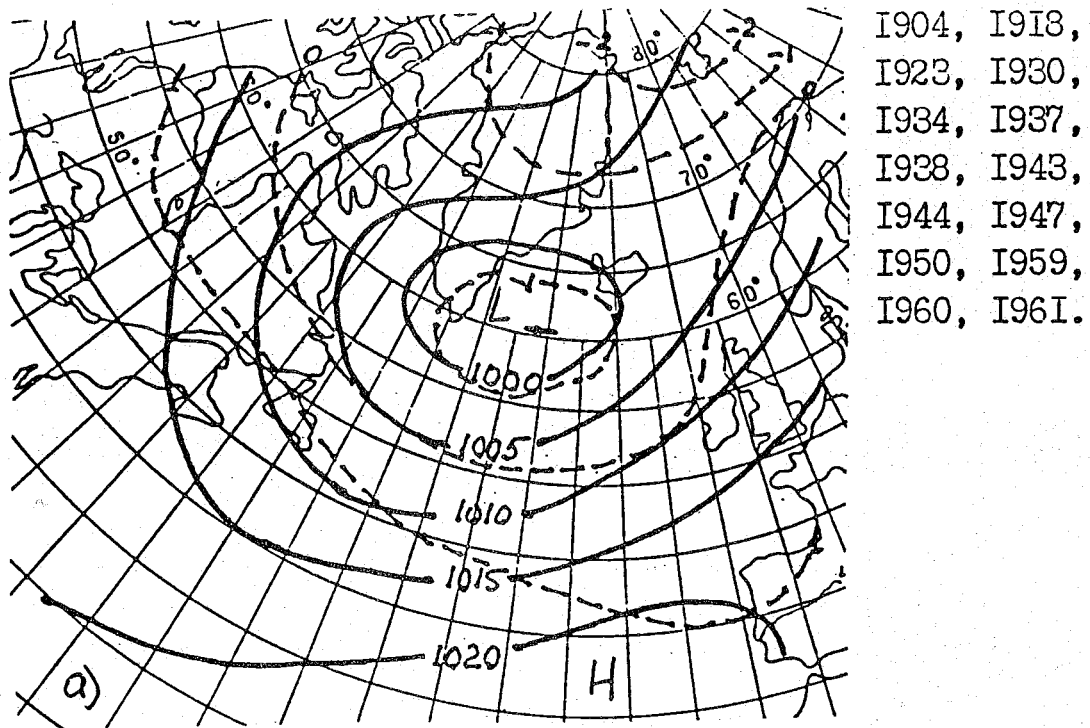
Fig. 1 Mean winter sea level pressure isobars (solid lines) and
      departures from normal (broken lines) (1901-1980) averaged for
      years when rich (a) and poor (b) year classes occurred.
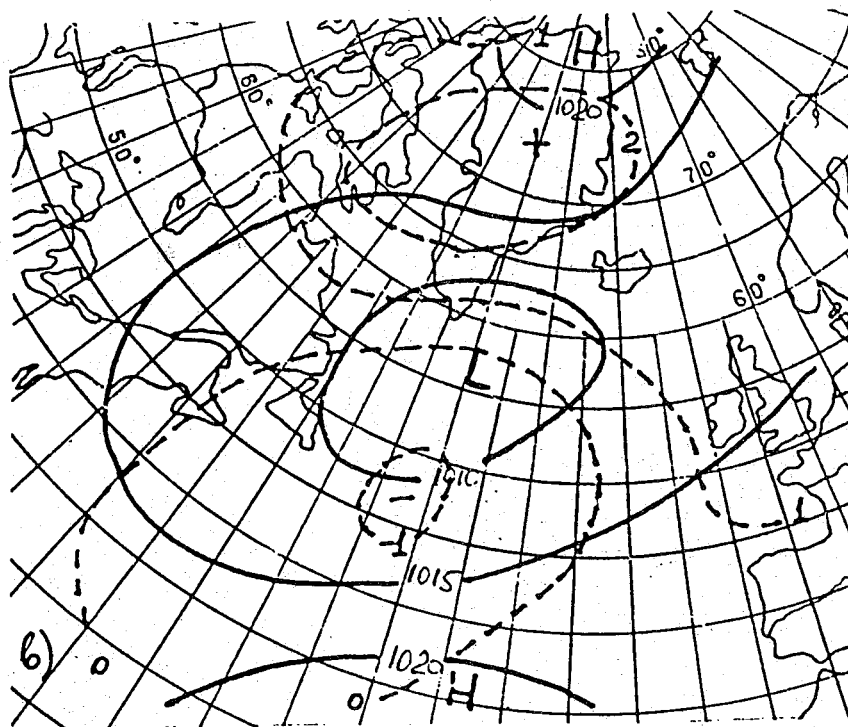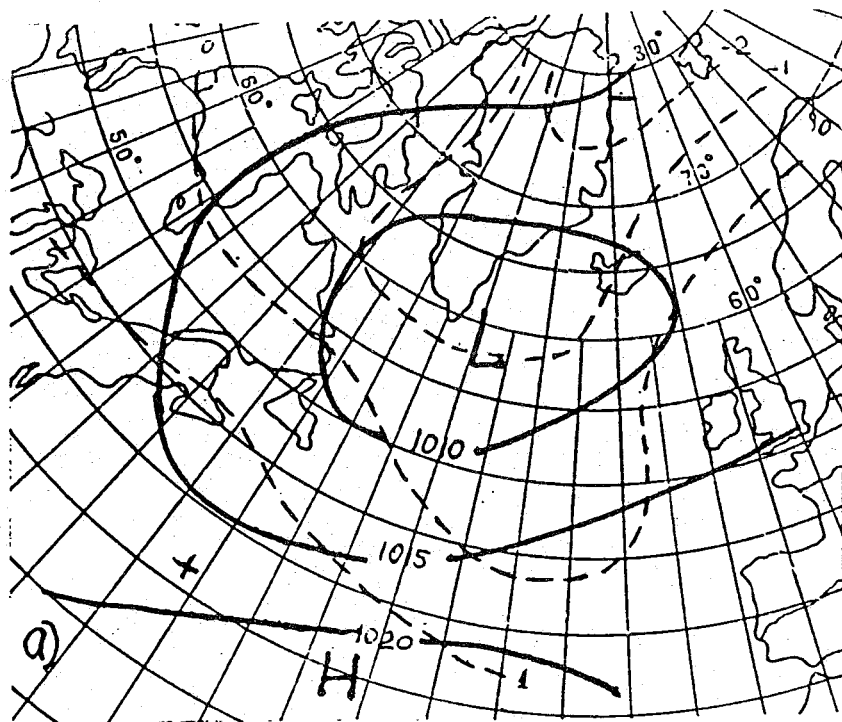
Fig. 2 As in Fig. 1 but for spring.

(Figs. 1a and 2b) a deep Icelandic low is associated with the developed Azore high, which is the evidence of the intensification of zonal circulation over the North Atlantic. The distribution pattern of SLP anomalies indicates the increased heat transport to the Northeast Atlantic. The principal feature of the atmospheric circulation in the years when the pure year classes occur, is the formation of a positive anomaly cell over Greenland, and as a result an increased frequency of northerly winds over the Northeast Atlantic region.
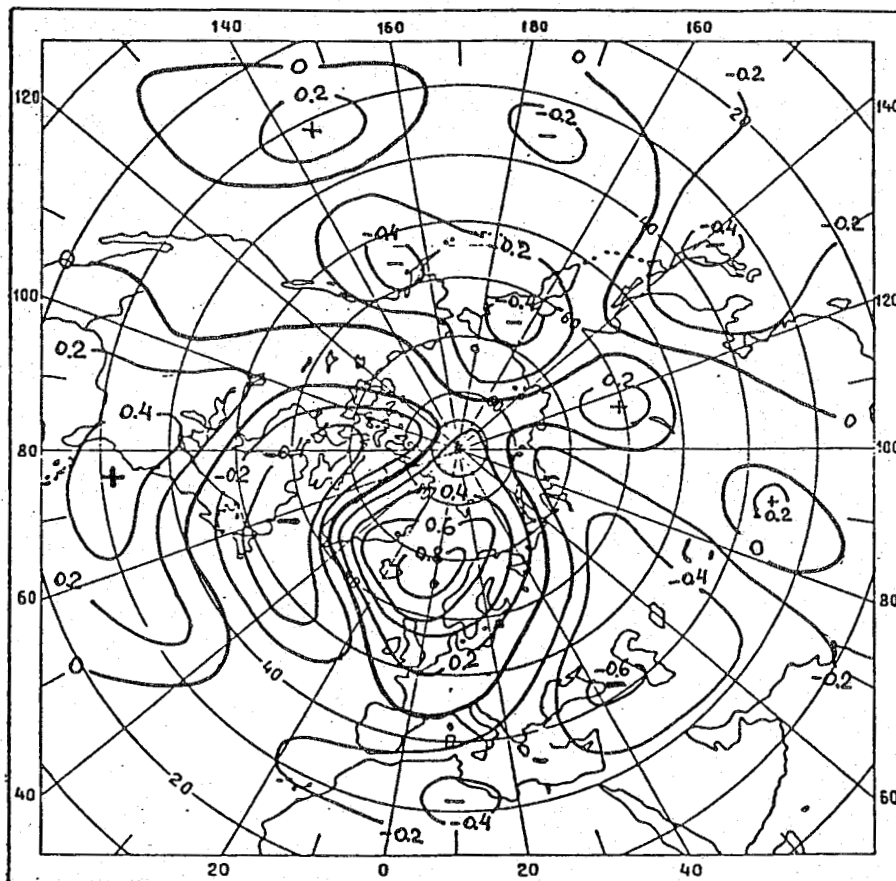
Fig. 3 Correlation coefficients between mean monthly air temperature in grid point at 65^0N on Greenwich meridian and elsewhere in January (data for 1951-1980). The absolute values of correlation coefficients exceeding 0.35 are significant at the 5% level.

The teleconnections for the surface air temperature in the Northeast Atlantic region is shown in Fig.3. One can distinguish three regions with high level of correlation with the Northeast Atlantic region: 1) the Northwest Atlantic and Northeast Canada, 2) the Sargasso Sea and the Southeastern United States, and 3) the Southern seas of the Soviet Union.

The location of the regions with high positive and negative correlation coefficients is interpreted fairly well by means of North Atlantic oscillations. Types of the atmospheric circulation associated with the seesaw in air temperatures between the Northeast and

Northwest Atlantic regions were described in detail by van Loon and
Rogers (1978). They used the difference between air temperature in
West Greenland (Jakobshavn) and Northwestern Europe (Oslo) as the NAO
index. The similar reverse relationship in water temperatures is also
well known (Cushing, Dickson, 1976).

Climatic changes in the Northeast Atlantic region are highly dependent
on features of the strong baroclinic zone along the eastern coast of
North America. According to Dickson and Namias (1976), during warm
winters over the southeastern United States, storm activity is
concentrated along the U.S-Canadian border, with a nearly normal
progression of storms to full development at Iceland. In other cases
when winters are cold, the zone of enhanced baroclinicity along the
Atlantic seabord is drawn southwards with a corresponding shift of
storm tracks. The positive SLP anomaly cell developing over Greenland
leads to recurrent outbreaks of cold air masses along its easterly
flank, and thus an unfavourable climatic regime in the Northeast
Atlantic region is established.

The reverse relationship of hydrometeorological and biological
processes in the Northeast Atlantic and in the Soviet Southern seas
was discussed in detail by Izhevsky (1961). It is worth noting that
the environmental characteristics of the Northeast Atlantic region is
well correlated not only with corresponding characteristics in the
continental region, but also with such an important indicator of
climatic changes as the Caspian sea level. It should be stressed that
this link is significant not only for the interannual time scale, but
also for secular variations (Fig.4).
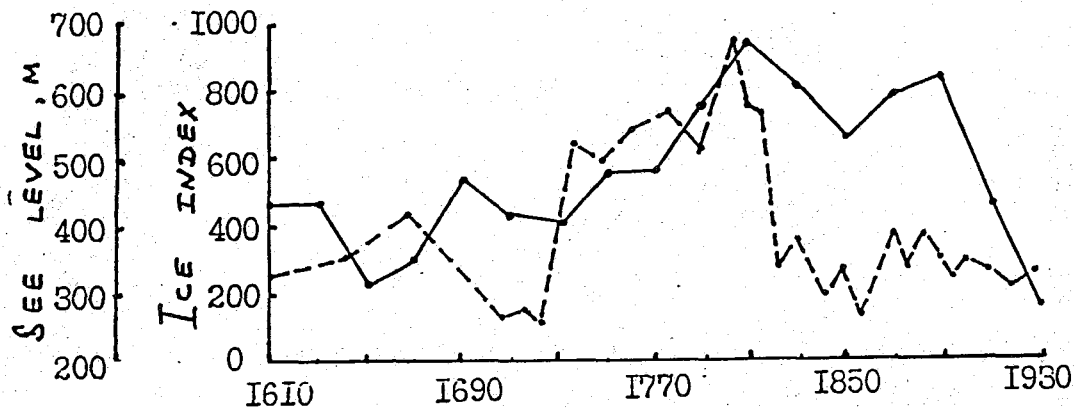
Fig. 4 Comparison of secular changes in the ice condition off Iceland
       (solid line) and the Caspian Sea level (dashed line) from 1610
       to 1930 (after Maksimov, 1954).

By comparing climatic changes in the Northern Hemisphere (and in the
three above-mentioned regions in particular) with the year class
strength of herring, it is possible to distinguish two types of
climatic regime, with favourable and unfavourable environmental
factors:

1. A warm regime favourable for herring. It is accompanied by a deep
Icelandic low and a developed Azore high. Westerlies between these two
centers of action become stronger. Principal trajectories of cyclones
is shifted polewards. As a result of frequent penetration of
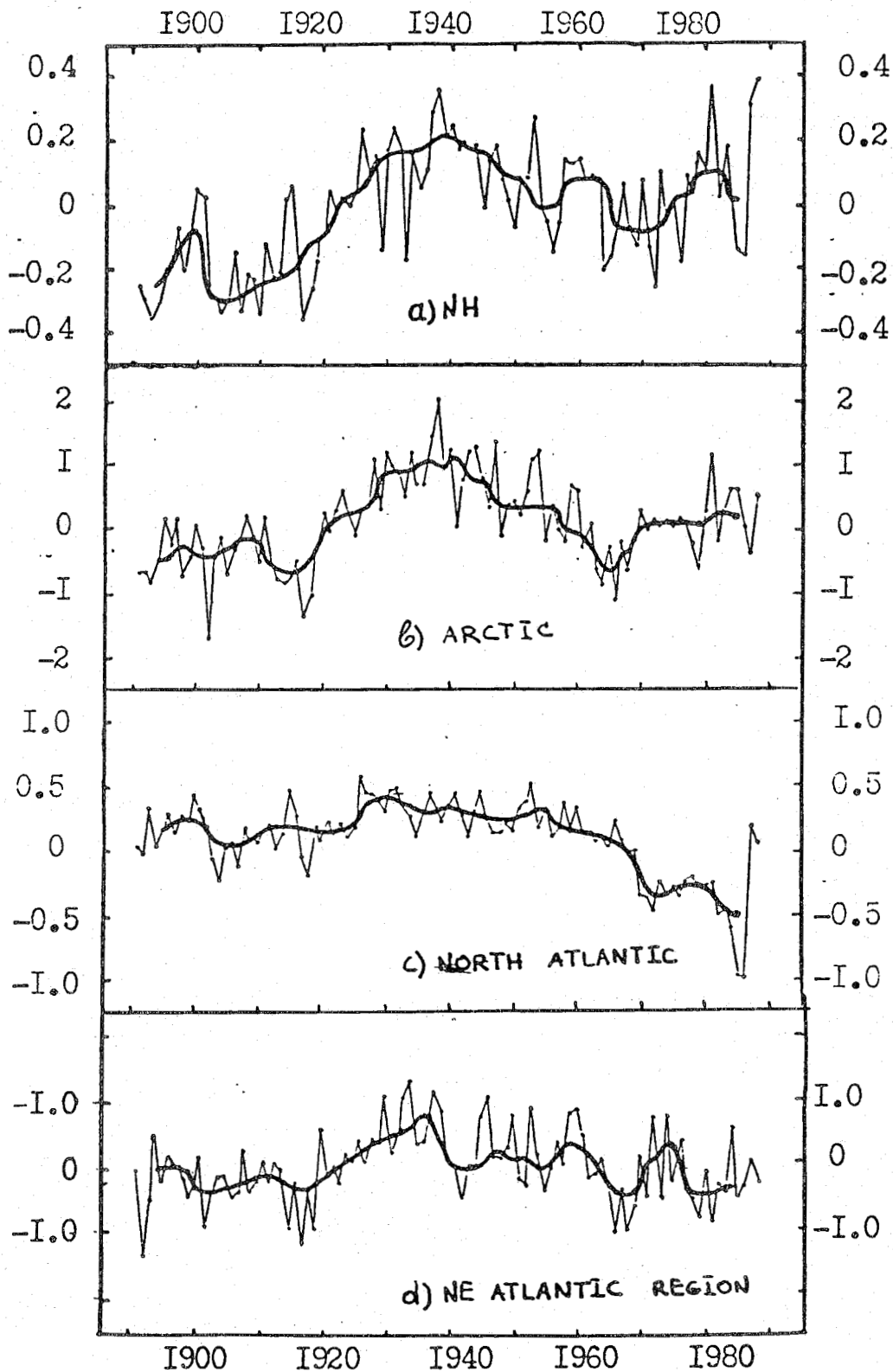
Fig. 5 Annual surface air temperature for (a) the Northern Hemisphere
(2.5-87.5°N); (b) Arctic regions (67.5-87.5°); (c) North
Atlantic; (d) Northeast Atlantic. Data are expressed as
departures in degrees Celsius from 1951-1980 reference period.
Heavy line shows the data after application of the 7-point
median filter.
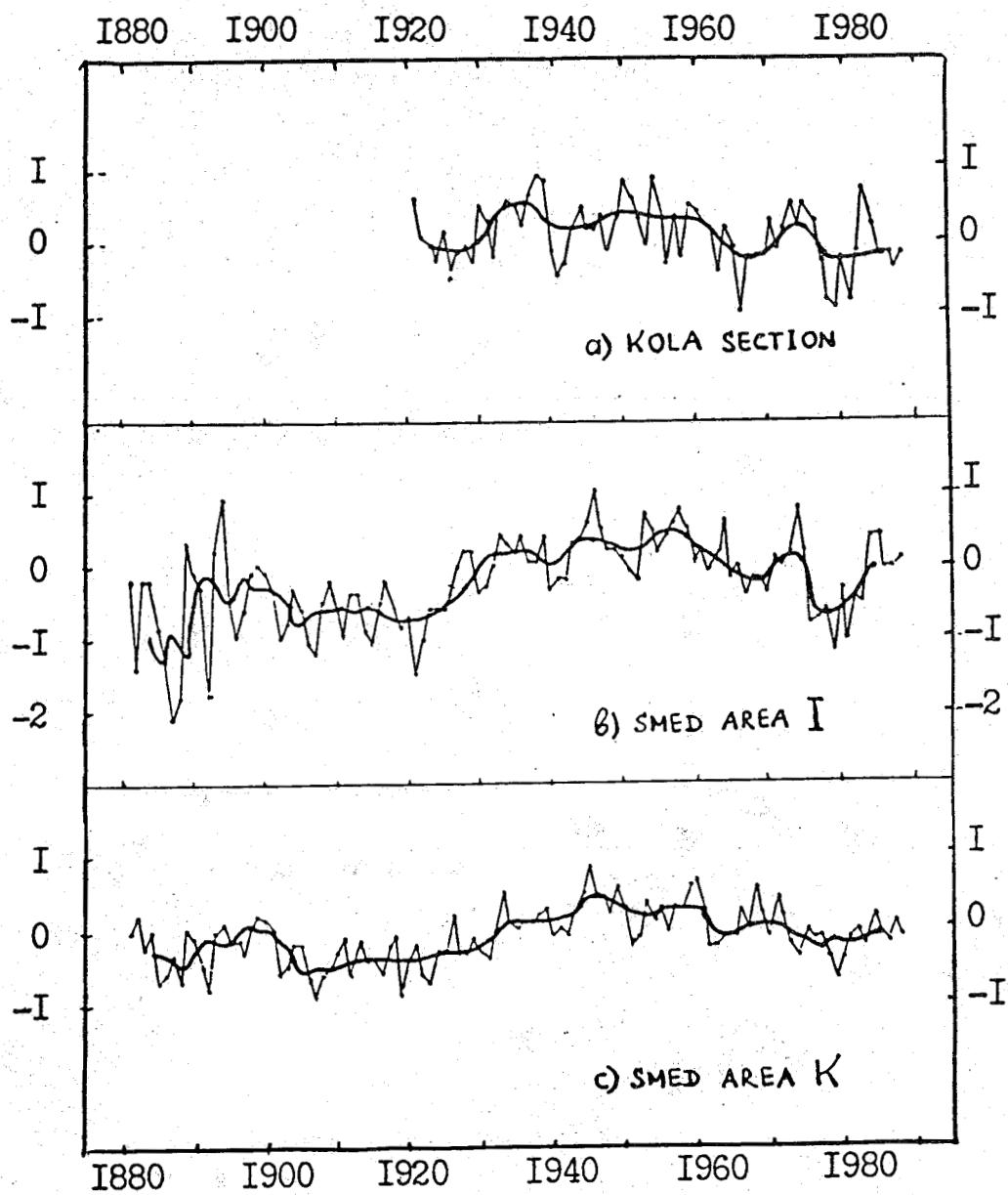
Fig. 6 Annual water temperatures (a) integrated over the 0-200 m depth
       layers on the Kola section (70°30'N,33°00'E - 72°30'N,33°00'E)
       and on the sea surface in the standard Smed area (b) "I" and
       (c) "K".

depressions to high latitudes, air temperature in Arctic regions rises, as well as the average temperature of the Northern Hemisphere. Negative air sea surface temperature anomalies are observed in the Northwest Atlantic region and in the Southern seas of the Soviet Union. The Caspian sea level gets lower.

2. A cold regime unfavourable for herring. It is accompanied by a weakening of westerlies over the North Atlantic. Meridional forms of atmospheric circulation prevail. Blocking anticyclones are formed more frequently. Positive anomalies of the air and sea surface temperatures are observed in the Northwest Atlantic region and in the Soviet Southern seas. The Caspian sea level rises. The deepening of the upper trough along the eastern coast of North America leads to a cooling in the Southeastern part of the United States and adjacent waters. The storm tracks shift southwards. The positive SLP anomaly cell is formed over Greenland.

The question arises whether a relatively cold climatic period has been replaced by a warmer one, or if the cooling trend which began in the 1940's will develop.

In 1988 the annual surface air temperature of the Northern Hemisphere was the highest ever measured. The warming of the hemispheric climate in the 1970's and 1980's is usually associated with the enhanced "greenhouse" effect caused by rising levels of atmospheric carbon dioxide. But some researchers express doubts concerning the decisive role of CO_2 (Wigley et al., 1981). According to Lamb (1984),it seems likely that changes in the climate due to natural causes may lead to conditions resembling a little ice age.

There is a significant difference between the climatic warming in recent decades, and the one which took place in the first half of the current century. In the 1920's and 1930's the rise in temperature was clearly expressed at high latitudes, while the present warming belongs to temperate latitudinal phenomena (though it is assumed that the influence of CO_2 should have been reflected first of all at high latitudes. Besides, changes in the average temperature of the Northern Hemisphere indicate primarily processes on land. The mean North Atlantic air temperature illustrates a clear negative trend (Fig. 5). Data on air and sea surface temperature in the Northeast Atlantic region (Figs. 5 & 6) also indicate the cooling. Besides the sharp rise in the Caspian sea level observed for about ten years also points to climatic deterioration. There are reasons to believe that the Caspian Sea level is likely to rise until the end of this century (Rodionov, 1989). The important feature of the climatic situation in the recent decades is the increase in variability of hydrometeorological characteristics from year to year as well as from one group of years to another (Bajdal, Neushkin, 1987), which usually occurs in periods of climatic cooling (Lamb, 1972).

CONCLUSION

Proceeding from the above said, we may conclude that despite the uncertainty of the situation, climatic deterioration and unfavourable environmental conditions for the Atlanto-Scandian herring could exist till the end of this century.

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Section III: Fecundity, larvae and juveniles

DISTRIBUTION AND DRIFT OF ATLANTO-SCANDIAN
HERRING LARVAE IN THE NORWEGIAN AND LOFOTEN
SHALLOWS IN 1983-1987

by

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ABSTRACT

The main spawning grounds of Atlanto-Scandian herring in the Norwegian
Shallows are affected by the Atlantic waters of the Norwegian Current
Eastern branch and freshened coastal waters. Essential year-to-year
variations in environmental conditions on the spawning grounds,
peculiarities of distribution and larval drift depend on these waters
dynamics: anticyclonic circulation of water masses retains larvae in
hatch area and promotes their localization in the coastal area;
cyclonic moderate circulation and southwesterly winds favour
scattering of larvae along the coast and their transport to the
northeast.

Rise in the heat content of waters on the spawning grounds and in the
routes of herring larval drift and predominance of southwesterly
winds determine the appearance of abundant year classes.

Periods of hatch and abundance of larvae are affected by essential
year-to-year variations. No relationship between the variation in
larval abundance and size and abundance of spawning stock was found.

INTRODUCTION

Annual observations of Atlanto-Scandian herring on the spawning
grounds in the Norwegian an Lofoten Shallows have been carried out by
the Polar Institute since 1959 (Yudanov, 1960, 1962; Zadorin, 1962;
Ydanov, 1964, 1966; Benko, Seliverstov, Zilanov,1966; Benko,
Seliverstov, 1969, Seliverstov, 1966, 1970 1974; Seliverstova, 1983;
Borkin, Krysov, Mukhina, 1987 Seliverstova, 1984; Krysov et al., 1985,
1986, 1988).

The aim of these investigations was to determine spawning grounds and
estimate spawning efficiency. In 1966-1967 (Seliverstov, Penin, 1969)
an attempt to determine an influence of hydrometeorological conditions
upon the distribution and drift of larval herring across the Norwegian
and Lofoten Shallows was undertaken for the first time.

Similar observations, studying the mechanism of herring stock
recruitment are carried out by the Institute of Marine Research
(Bergen) Bjørke, Fossum, Saetre, 1987,1988).

Peculiarities of distribution, drift of larvae and abundance of
herring year classes in 1983-1987 were emphasised in the paper on the
basis of analysis of hydrometeorological factors. In this case much
prominence was given to the temperature, salinity and dynamics of
waters in the area of hatch and drift routes of larval herring.

MATERIAL AND METHODS

Data on ichthyoplankton surveys carried out in 1983-1987 in two legs
(in March-April - in the Norwegian Shallows and in May-June - in the
Lofoten Shallows) were used in the paper. In 1987 three legs were made
in the Norwegian Shallows: one leg - in late March and two others - in
April. Data for 1988 are being processed.

Distribution of herring larvae was determined by sampling of the
depths 0. 25, 50, 100 and 150 m (or mear-bottom layer) according to
standard grid of stations using the IKS-80 nets. Herring larvae were
fixed in 2% formalin after morphometric measurements and visual
analysis using the MBS-I binocular. Temperature and salinity were
measured at all stations in standard depths from surface to the bottom
simultaneously with the ichthyoplankton investigations. Mean water
temperature in the 0-50 and 0-200 m layers in the coastal shallow
waters on standard sections along $63^{0}00$ N, $65^{0}45$ N, $67^{0}30$ N and $71^{0}10$
N was used to determine hydrographic conditions and to draw charts of
dynamic topography of 200 dB relative to the surface of 0-200 m layer.

The recurrence of winds of various directions was estimated to
characterize the meteorological conditions by the data on observations
from each survey.

Abundance of 0-group is given according to the data from the ICES
Working Group on herring and capelin (Anon., 1989).

Stratification of the Norwegian Shallows by Subareas is given
according to I.G.Yudanov (1962). Positions of banks in the Norwegian
Shallows and herring spawnings grounds are presented in Fig.1.
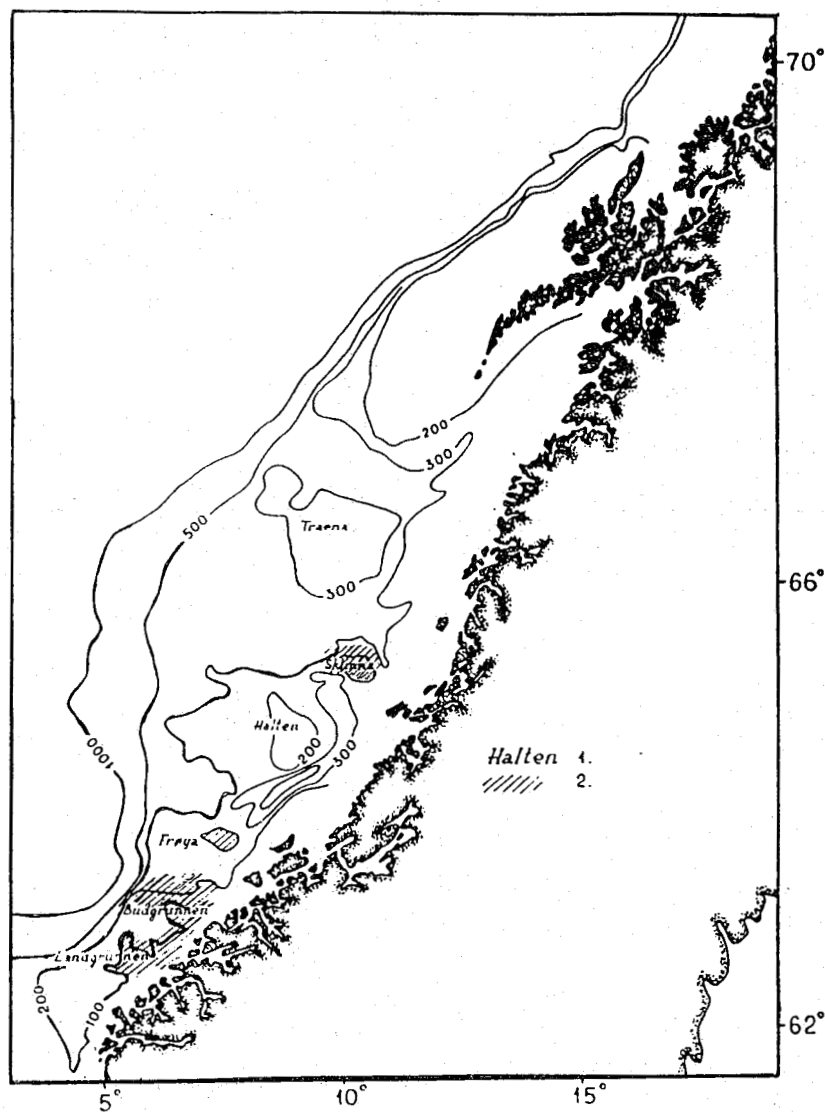
Fig.1. Banks of the Norwegian Shallows and herring spawning grounds:
I- Names of banks; 2 - herring spawning grounds.

RESULTS

Hydrometeorological conditions. Hydrographic regime of the Norwegian
shallow waters is formed under the influence of Atlantic waters with
high salinity and freshened coastal ones. In this case, coastal waters
from the southern area may occupy the whole water column and in the
central and northern ones - the upper 50-70 m layer. Direction of
winds influences greatly upon the dynamics of waters from the area.
These factors specify the variability of oceanographic conditions in
the area of main herring spawning grounds and determine the
peculiarities of larval drift from the hatch area.

The highest values of water temperature and salinity - 6.5 - 7.0^{0}C and
34.5 - 35.1 $^0/_{00}$ in the surface were registered in 1983 (Fig. 2A).

In 1984 (in the 1st leg of the survey) coastal waters with the
temperature 4-5^{0}C were distributed in the surface layer in the
southern area of the shallows, the area of which was reduced in the
2nd leg, since they were pushed aside to the coast by the Atlantic
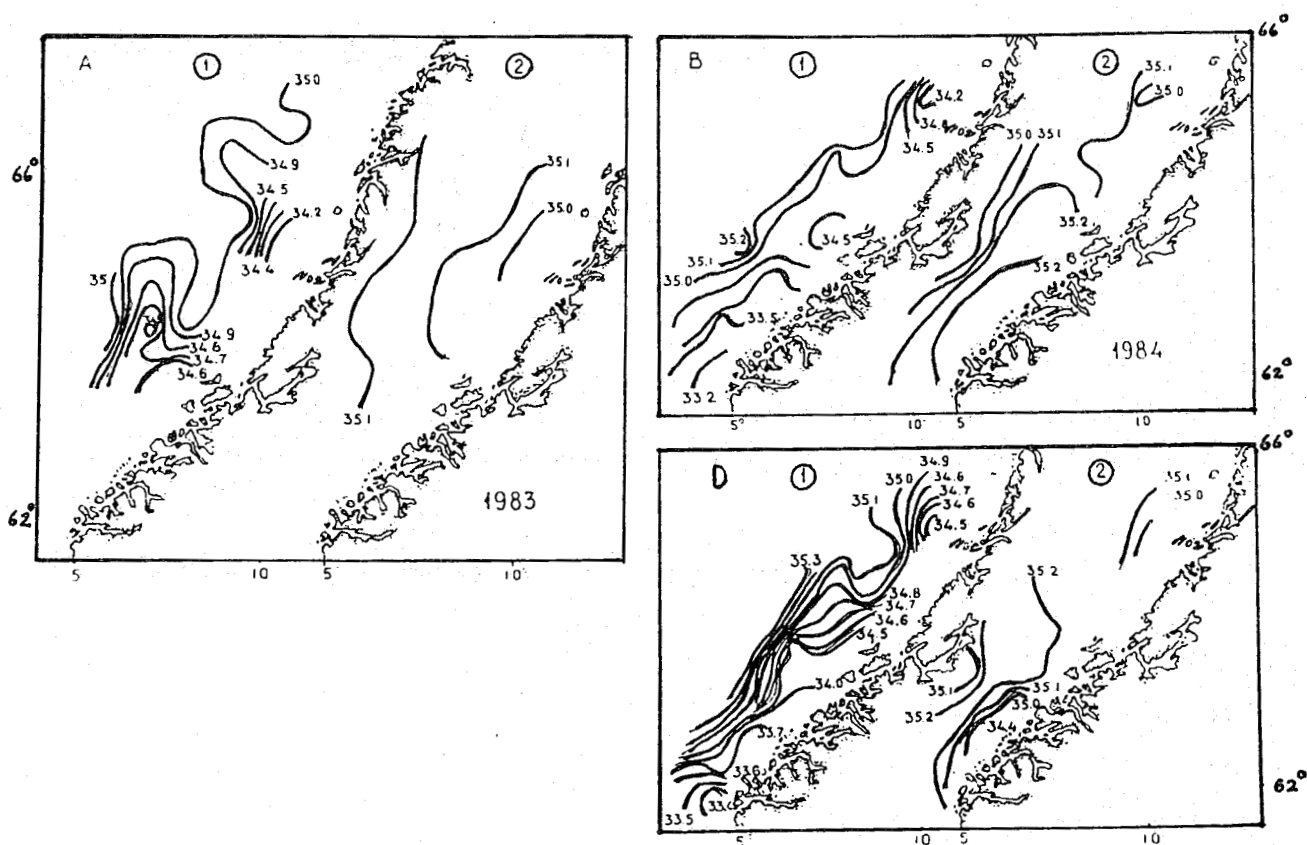
Fig.2. Distribution of water salinity in the Norwegian Shallows in
March 1983 (A) and in the 1st (B), 2nd (D) legs of survey in
April 1984: I - in the surface; 2 - in a near-bottom layer

waters with the temperature over 7^{0}C. Water temperatures in the
surface made up 5.3 - 5.6^{0}C on the Buagrunnen Bank in the 1st and 2nd
legs. Salinity in the surface waters on the Buagrunnen and Landgrunn
varied from 33.2 to 34.0 $^{0}/_{00}$ (Fig.2 B, D).

In 1985 cold waters with temperatures $4-5^{0}$C and salinity 33.0-33.5$^{0}/_{00}$
were observed on both banks. It should be noted that these waters are
widely distributed along the coast (Figs. 3A, c).

In 1986 (in the 1st leg) coastal waters with the temperatures $4-5^{0}$C
and salinity 33.2 - 34.0 $^{0}/_{00}$ were observed in the surface of layers
on the Buagrunnen and Landgrunn Banks. In the 2nd leg an intensive
transport of these waters into the off sea area was registered and the
area of their distribution increased considerably (Figs. 3B, D).

In late March 1987 (in the 1st leg) the coastal waters with salinity
33.8-34.0 $^{0}/_{00}$ and temperature $4-5^{0}$C occupied the whole sea surface
from the coast to the slope of depths. Their distribution in the north
was restricted by 64^{0}N. In the 2nd and 3rd legs (April) the area of
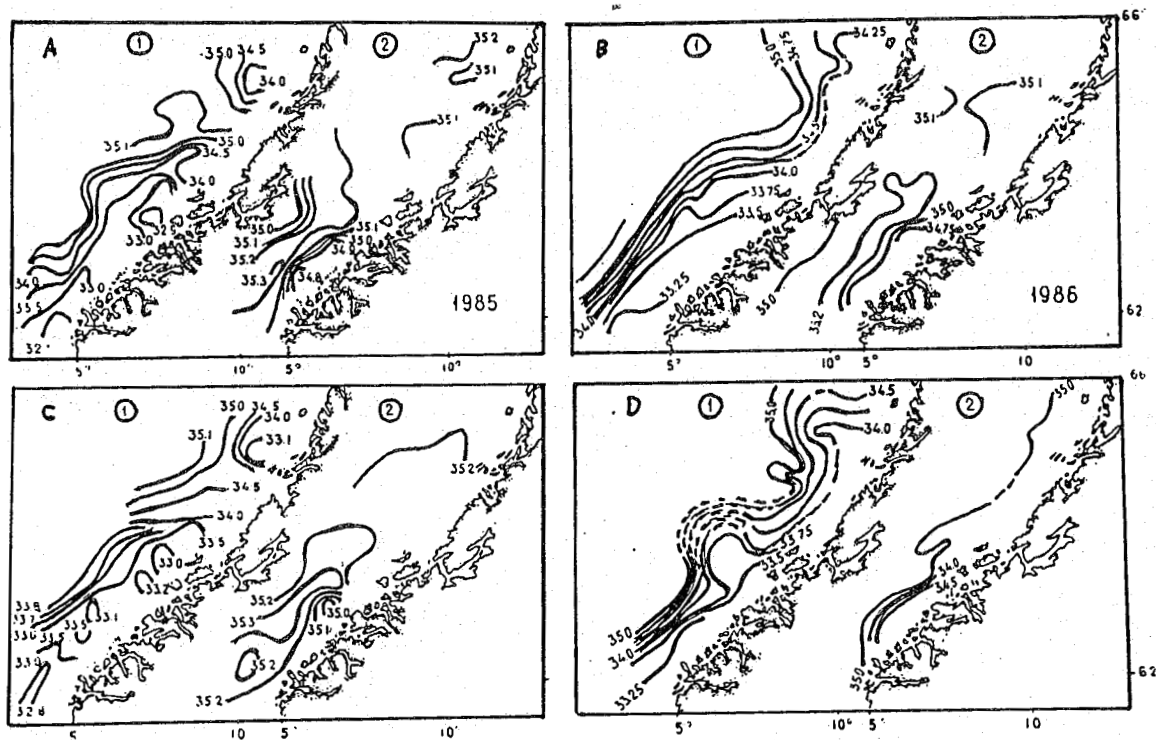
Fig.3. Distribution of water salinity in the Norwegian Shallows in the
1st (A, B) and 2nd (C, D) legs of survey in April 1985, 1986:
I - in the surface; 2 - in a near-bottom layer

distribution of these waters was reduced noticeably as a result of the
inflow of Atlantic waters with the temperature $7-8^{0}$C and salinity
$35.0-35.2$ $^{0}/_{00}$ in the shallows (Figs. 4A, B, C).

Warm Atlantic waters with the temperature $6-7^{0}$C and salinity $35.0-$
35.1 $^{0}/_{00}$ were observed in a surface layer in the central part of the
shallows practically during all years, except for the 2nd leg in 1985
when notably wide distribution of cold and freshened waters was
registered along the Norwegian coast (Fig. 3C).

The northern section in the shallows was constantly occupied by cold
freshened waters in the surface layer compared to the central one. The
range of temperature variations there varied from 4.6 to 6.0^{0}C and
salinity from 33.0 to 34.5 $^{0}/_{00}$. A decrease in thermohaline structure
was also registered on that section in 1985.

A decrease (by 1.0^{0}C) in temperature regime in the sea-surface was
observed in the Lofoten area from 1983 to 1987.

Analysis of the mean water temperature in the 0-50 and 0-200 m layers
on standard sections on the shelf (Table I) indicated its increased
values to be observed practically in all sections in 1983. A stable
trend of decrease in the heat content of the shelf waters was noted
after 1983. Compared to the previous years in 1986-1987 the intensity

Distribution and drift of Atlanto-Scandian herring larvae ....
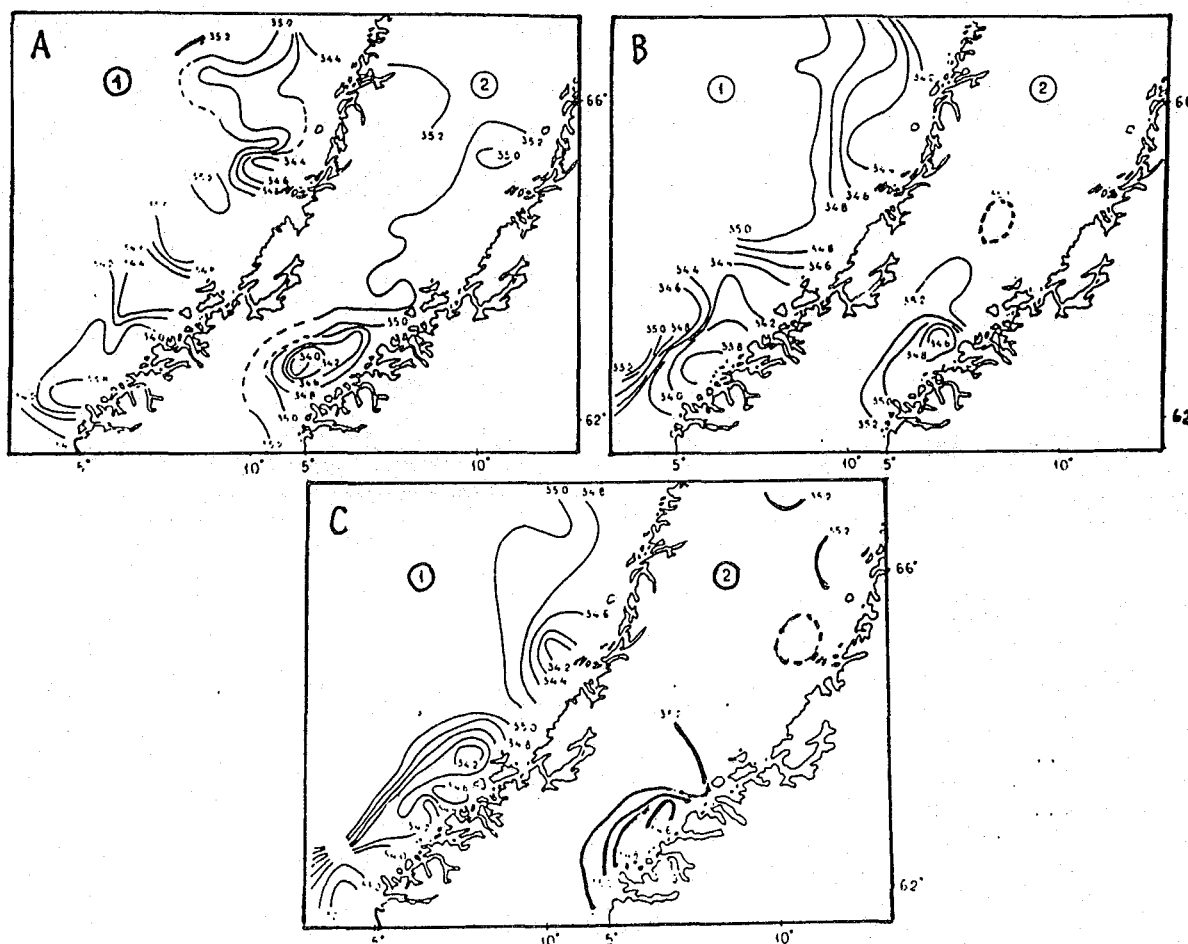
Fig. 4. Distribution of water salinity in the Norwegian Shallows in the 1st (A), 2nd (B) and 3rd (C) legs of survey in March-April 1987: I: = in the surface; 2 = in the near bottom layer.

of these waters was higher in the long-term variations of distribution of the coastal waters in a near-bottom layer in the southern Norwegian Shallows (in 1983-1987 surveys).

The 1983 was anomalously warm, something which is well confirmed by a mean water temperature in the 0-200 m layer on the section along 63^{0}N (Table I) and a distribution of temperature and salinity in the surface and near-bottom layer in March. Coastal waters were driven close to the coast under the influence of the Atlantic waters.

In the 1st leg of the survey (1984) the Atlantic waters with a high salinity were predominant in a near-bottom layer in the southern Norwegian Shallows, but already in the 2nd leg, in mid-April, the water masses with salinity below 35 $^{0}/_{00}$ appeared on the Landgrunn Bank (Figs. 2B, D). Water temperature on the bank made up 6^{0}C and was about 1^{0}C lower compared to the Buagrunnen Bank.

In the 1st leg of the survey (1985) the near-bottom layers on the Landgrunn and Buagrunnen Banks were occupied by waters with salinity below 35 $^{0}/_{00}$ and temperature 6.3-6.7^{0}C. In the 2nd leg the Atlantic waters with high salinity and temperature over 7^{0}C were already noted.

In 1986 the near-bottom layers on both banks were occupied by the coastal waters with salinity 34.4-34.7 $^{0}/_{00}$ and temperature 6.7^{0}C.

Table 1. Biomass of herring spawning stock, index of 0-group abundance catch of larvae in the Norwegian and Lofoten Shallows and mean temperature in the 0-50, 0-200 m layers on standard stationes and re-currence of the southwesterly winds 1983-1987.

Year	Spawning stock biomass * t x 10^{-3}	Index of 0-group abun-dance	Catch of larvae in Norwegian Shallows in April Nos.	Catch of larvae in Lofoten Shallows in June Nos.	Mean water temperature of the Norwegian Current Eastern branch on standard section								Mean water temperature on the North Cape-Bear Island section		Recur-rence of south west winds April %
					layer m	$63^{0}00$ N Feb	$63^{0}00$ N March	$65^{0}45$ N Feb	$67^{0}30$ N April May	$67^{0}30$ N July	$71^{0}10$ N May	$71^{0}10$ N June	May	June	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1983	613.3	1.77	4407	293	0-50	7.50	6.31	6.99	6.03	7.46	5.84	6.91	4.86	6.54	26.6
					0-200	7.51	6.39	7.18	6.32	6.91	5.72	5.95	4.78	5.51	
1984	635.7	0.34	1362	168	0-50	6.97	5.51	6.85	5.57	7.32	5.75	7.12	4.65	6.28	23.3
					0-200	7.23	6.25	6.89	5.92	6.69	5.75	6.35	4.58	5.14	
1985	573.7	0.23	7735	48	0-50	6.31	6.84	6.94	-	7.04	-	6.57	4.29	6.03	6.3
					0-200	-	7.51	6.93	-	6.57	-	5.74	4.19	4.80	
1986	526.3	0	5588	3	0-50	7.15	7.06	-	5.29	7.22	5.26	6.97	4.34	6.16	11.1
					0-200	-	7.24	-	5.77	6.56	5.01	5.78	3.66	4.99	
1987	491.2	0	2473	31	0-50	5.85	5.84	6.34	5.43	6.83	5.25	6.25	4.29	5.27	2.4
					0-200	6.73	6.20	6.52	5.88	6.56	5.09	5.65	4.46	4.38	

* Anon., 1988
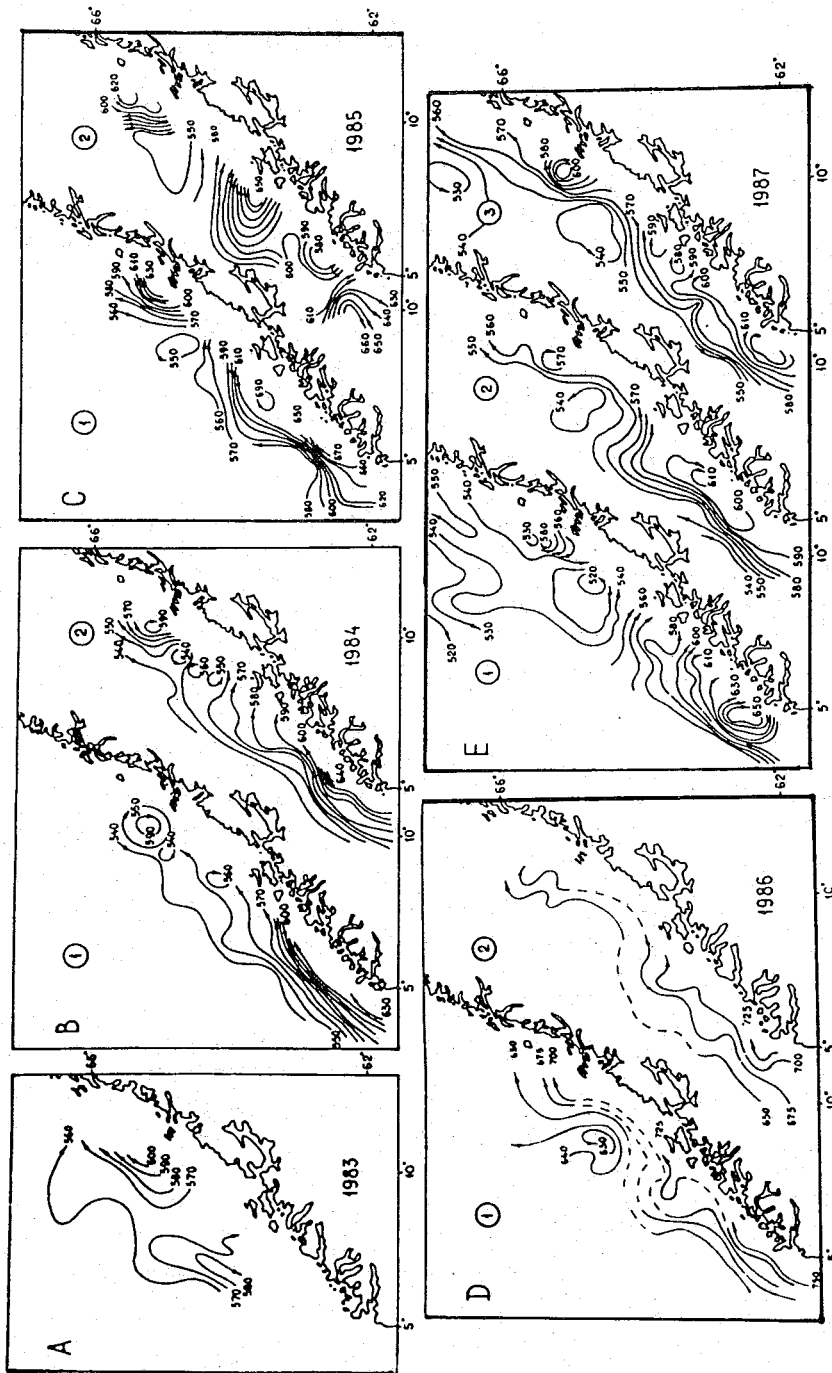
Fig. 5. Charts of dynamic topography of 0-200 dB in the Norwegian
Shallows in March 1983 (A), April 1984 (B), April 1985 (C)
April 1986 (D), March-April 1987 (E): I = in the 1st leg;
2 = in the 2nd leg; 3 = in the 3rd leg of the survey.

The widest distribution of the coastal waters was observed in 1987 when the isohaline of 35 $^{0}/_{00}$ in a near-bottom layer was registered west of the Buagrunnen and Landgrunn and the temperature varied from 5 to 7^{0}C.

The Atlantic waters with temperature $6-7^{0}$C and salinity over 35 $^{0}/_{00}$ were distributed in the near-bottom layer in the northern and central areas of the Norwegian Shallows in the years of our observations.

Charts of dynamic topography (Figs. 5A, B, C, D and E) including the data from 1983-1987 surveys allowed to elucidate some peculiarities of circulation.

In 1983 a relatively smooth surface with a minor rise of the level in the central part of the area and on the Sklinna Bank was noted in the Norwegian Shallows. The most intensive transport of water masses took place from the Sklinna Bank area to the northeast (Fig. 5A).

In 1984 a narrow stream of waters was registered in the coastal area in the south of the shallows. To judge by the thickness of isolines a maximum velocity of transport was registered in the southern area. An anticyclonic gyre, nearly broken down by the end of the survey, was observed over the Sklinna Bank. Transport of water masses had a north-eastern orientation (Fig. 5B).

In the 1st leg of the survey (1985), because of a difference in the level observed from off sea to the coast, the velocity of the stream increased in a similar direction. An intensive transport of water masses along the coast was also noted. In the 2nd leg the whole stream of water along the coast was split into separate eddings and the velocity of transport of water masses decreased (Fig. 5C).

In 1986 the velocity of water masses transport was not high. In the south of the shallows some localization of watermasses was registered in the coastal area (Fig. 5D).

In late March 1987 two circulations of different directions were formed in the Norwegian Shallows (Fig. 5E). An anticyclonic gyre was registered in the south and the poor cyclonic one - in the north. This promoted a delay of water masses in the south of the shallows. In April small anticyclonic gyres were formed over the Landgrunn, Buagrunnen and Sklinna Banks. Due to the numerous eddings the velocity of water masses transport was not high.

In 1983 and 1984 the predominance of the southwestern winds promoted the northeastern transport of water masses (Table I), since they coincided with a general direction of transport of waters by the Norwegian Current Eastern branch.

Distribution and drift of larvae. Figs. 6-8 present the distribution of larvae with length 9 mm and larvae 9mm in the Norwegian and Lofoten Shallows in 1983-1987. The larvae were separated into two length groupings due to the fact that 80-86 % of larvae from the 1st length group (small 9 mm) had yolk sacs and occurred mainly in the hatch area. Larvae from the 2nd length group (large 9 mm) may also occur in the hatch area in case of delays related to peculiarities of circulation of water masses on the spawning grounds, but most commonly these larvae fall into the drifting currents. Charting of larval distribution according to the principle mentioned, in our opinion,

allows to elucidate the areas of numerous larvae hatch and obtain the
more detailed description of their transport.

In 1983-1987 the main areas of herring spawning and its larvae hatch
in the Norwegian and Lofoten Shallows were relatively stable, however,
the importance of separate sites of hatch was far unequal. Thus, if in
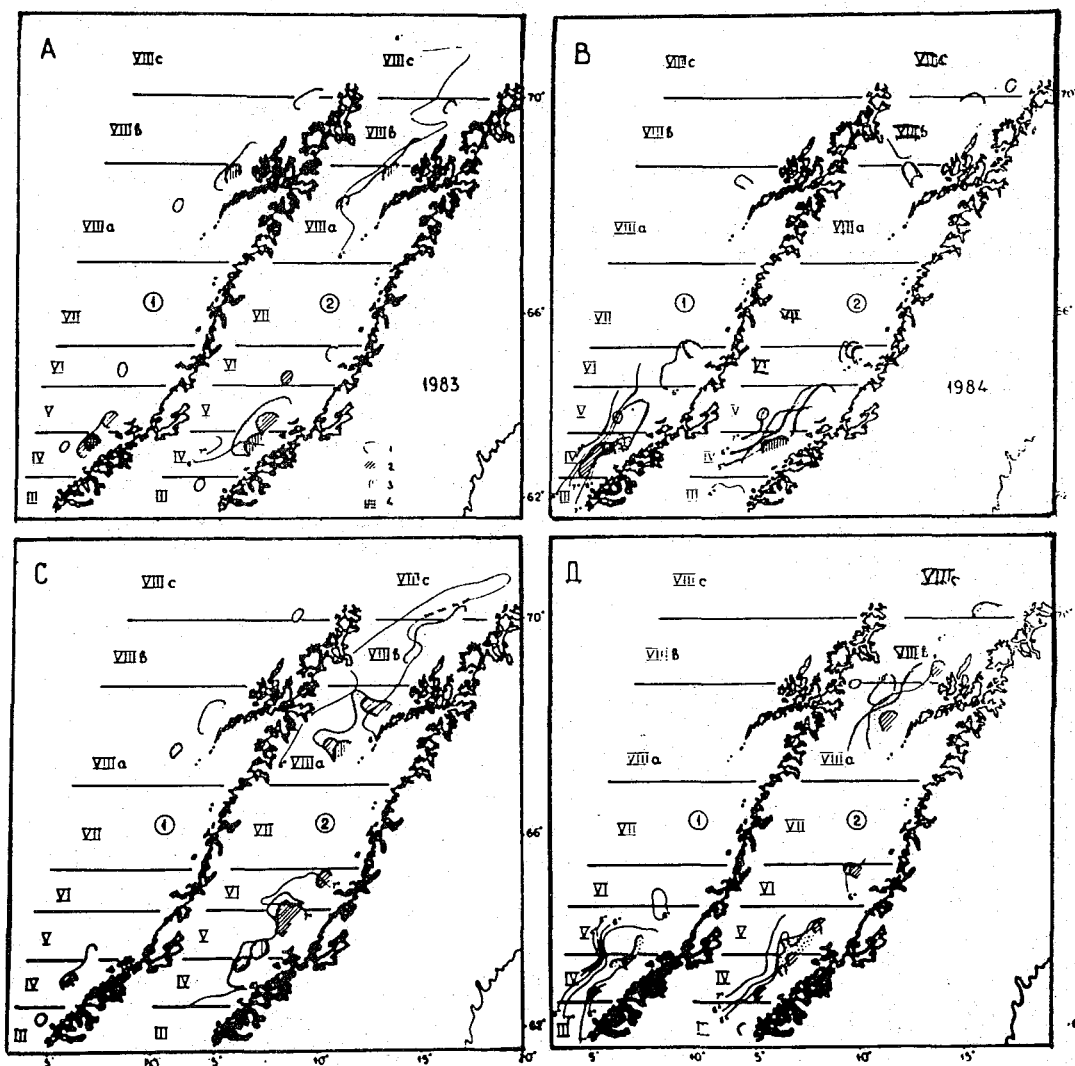
Fig.6. Distribution of larvae with length 9 mm and 9 mm and water
temperature in a near-bottom layer (I) and in the surface (2)
in the 1st (A, B) and 2nd (C, D) legs of ichthyoplankton survey
in March-April 1983, 1984. Density of larvae distribution in
Nos./catch: 1 - 1-10; 2 - 11-100; 3 - 101-1000; 4 - over 1000;
III-VIII - Subareas of the Norwegian Shallows according to
I.G.Yudanov

1983 the main hatch on the Norwegian Shallows, to judge by the
distribution of small larvae, took place on the Buagrunnen and,
partially, Frøya Banks (Figs. 6A, C) then in 1984-1985 the larvae
hatch was observed on the Landgrunn and Buagrunnen Banks (Figs 6B, D
and Figs. 7A, C) and already in 1986-87 a more hatch of larvae was
noted on the Landgrunn (Figs. 7B, D and 8A, B, C), compared to that on
the Buagrunnen Bank. During the years of investigations, except for
1983, a poor hatch of larvae was registered on the Sklinna Bank. Small
larvae were caught on the Halten Bank only in 1987.
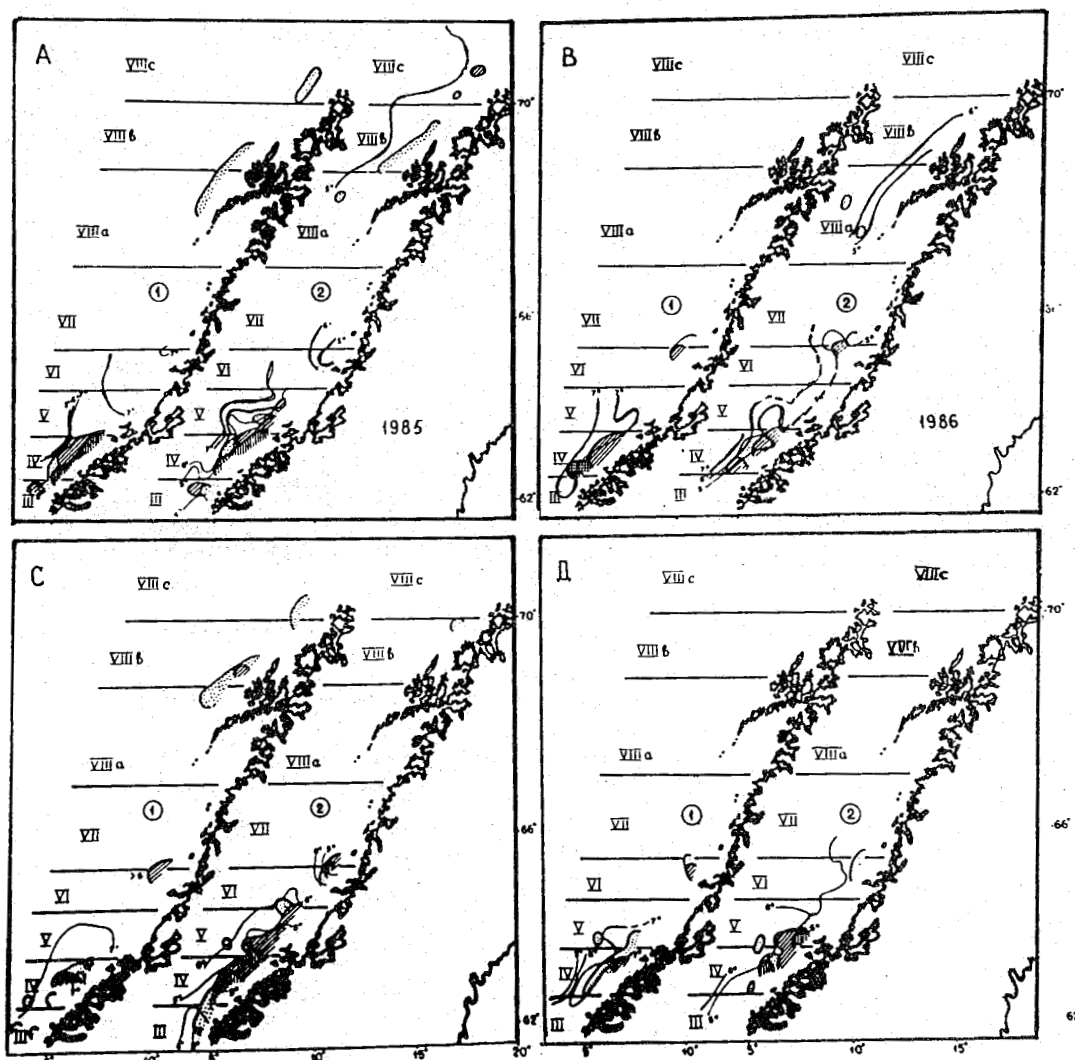
Fig.7. Distribution of larvae and water temperature in the 1st (A, C)
and 2nd (B, D) legs of ichthyoplankton survey in April 1985,
1986: 1 - in a near-bottom layer; 2 - on the surface. For
symbols see Fig.6.

In the Lofoten area small larvae occurred only in May 1984 (Fig. 6B),
however, in 1984 the larvae density (in Nos./catch) in the Lofoten
area was low.

Analysis of distribution of large larvae in the Norwegian and Lofoten
Shallows according to the data from 1983-1987 ichthyoplankton surveys
indicated the general scheme of their distribution and drift to be
relatively stable. In addition to that its definite peculiarities,
which are, in our opinion, of great importance for the year classes
abundance, differ from the general presentation in separate years.

In the 1st leg of the survey (1983) large larvae were found
distributed along the boundary between Subareas IV and V in the.
Norwegian Shallows A poor transport of larvae into the off shore was
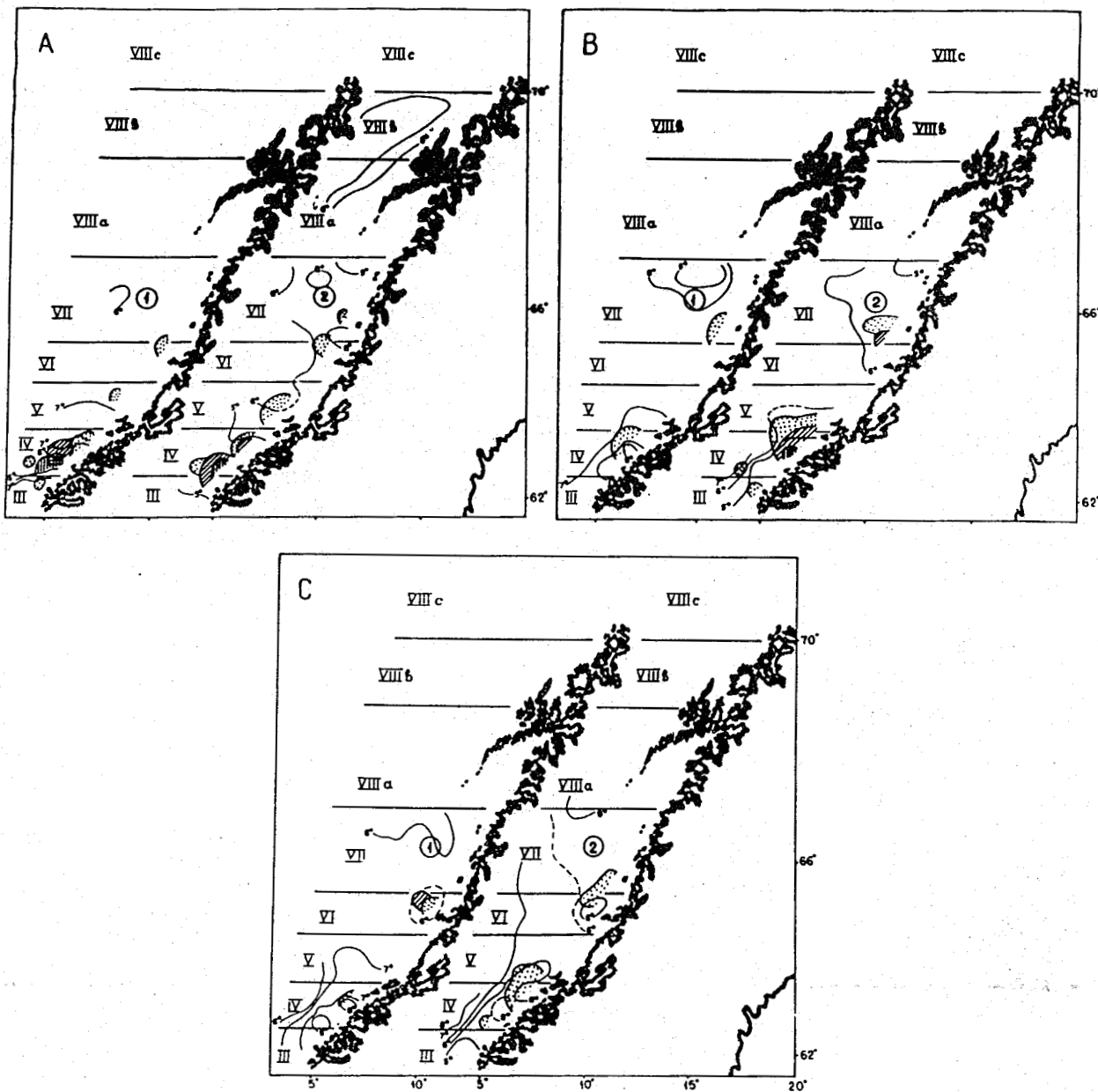
Fig. 8. Distribution of larvae and water temperature in the 1st (A),
2nd (B) and 3rd (C) legs of ichthyoplankton survey in March-
April 1987: 1 - in a near-bottom layer; 2 - on the surface.
For symbols see Fig.6.

observed in this section. A small "patch" of larvae was observed in
Subarea VI and on the Sklinna Bank. In the 2nd leg, made 6 days after
the 1st one, area of larval distribution increased almost by 1.5 times
in the northeastern direction. A large "patch" of large larvae was
noted along the boundary between Subareas V - VI. Compared to that in
the 1st leg the larvae density on the Sklinna Bank increased.

During the 1st leg of the 1984 survey the highest density of larvae
(101-1000 Nos./catch) was registered in the northern part of Subarea
IV and on the Sklinna Bank. The density of larvae was not high (1-10
Nos./catch) in Subarea V. In 12 days during the replicated
investigations in the shallows the area of larvae distribution in the
south of the shallows practically did not vary, and the density
decreased to 11-100 Nos./catch, which apparently related to a

transport of larvae to the coast. The density of larvae on the Sklinna
Bank in the 2nd leg increased as a result of accumulation of larvae,
related to the peculiarities of circulation of water masses on the
bank and transport of larvae from the south.

In 1985 (Figs. 7A, C) in the 1st leg the bulk of large larvae was
distributed in the northern part of Subarea IV where their density
reached 101-1000 Nos./catch. Transport of larvae into the Subarea V
took place along the coast and was poor. 6 days after the 1st leg an
increase of the area of larvae distribution in Subarea IV and along
the boundary of Subarea V took place. That was related to a retention
of larvae in this area due to the peculiarities of circulation. In the
northeastern direction the larvae were distributed as a narrow strip
to the boundary of Subarea VI. Small "patch" of large larvae was
observed on the Sklinna Bank.

In 1986 (Figs. 7B, D) in the 1st leg large larvae were distributed
within Subareas IV and the density of this larvae concentration did
not exceed 11-100 Nos./catch. Small "patch" of larvae with a similar
density was noted on the Sklinna Bank. The replicated investigations
carried out in the Norwegian Shallows 11 days after the 1st leg indi-
cated the large larvae to be distributed to the boundary between
Subareas IV and V. This larvae concentration density was higher (10-
1000 Nos./catch) compared to that observed in the 1st leg. Increase of
larvae concentration in the south of the shallows in the 2nd leg was
related to a localization of water masses in the area above mentioned.
In the 2nd leg larvae density decreased to 1-10 Nos./catch which was
associated with a transport of larvae and a lack of recruitment from
the south.

In 1987 (Figs. 8A, B and C) the bulk of large larvae was distributed
in Subarea IV, with the density being 101-1000 Nos./catch in the
southern area and 11-100 Nos./catch in the northern one. The density
of larvae was low in Subarea V and on the Sklinna Bank. During the
replicated investigations carried out 6 days after the initial ones
large larvae were already distributed along the boundary between
Subareas IV- and V, in this case their highest density (101-1000
Nos./catch) was registered in Subarea IV. The density of larval
"patch" increased compared to that one of the 1st leg and made up
10-100 Nos./catch. The 3rd leg of the survey was made 11 days after
the 2nd one. In this leg the area of larvae distribution in the south
of the shallows did not practically change, but the density of their
concentrations decreased to 1-10 Nos./catch. The density of larvae
also reduced on the Sklinna Bank. In 1987 a transport of larvae in the
northeastern direction was poor. The main portion of larvae was
transported to the coast.

A comparison of mean length of larvae caught in Subareas IV and V in
the 1 and in the 1, 2 and 3 legs - in 1987 confirms the facts of
retention of large larvae in the south of the Norwegian Shallows in
1986-1987 and their more intensive transport in the northeastern
direction in 1983-1985 (Table 2).

Table 2. Mean length (mm) of herring larvae caught in Subareas IV and
          V in 1983-1987.

Sub area	Year				
	1983	1984	1985	1986	1987
IV	9.1- 9.7	10.3-10.8	9.7-10.8	8.0-12.5	9.2-11.7-13.6
V	10.9-12.4	12.3-14.8	11.4-12.9	-- 12.8	11.0-13.6-17.3

In 1986 and 1987 when retentions of large larvae were well pronounced,
their mean length varied considerably compared to 1983-1985 when their
drift was more active.

In 1983-1985 (Figs. 6, 7A, C) the highest density of large larvae was
registered in the Lofoten area. In our opinion it is related to both
the local larvae hatch in this area and a transport of larvae from the
Norwegian Shallows area. In 1986-1987 the hatch of larvae in the
Lofoten area was minor.

Table 3. Numbers (%) and mean length (mm) of herring larvae caught in
          the 0-50 and 50-200 m layers in the Norwegian Shallows 1983-
          1987.

Leg of survey	Layer m	Year									
		1983		1984		1985		1986		1987	
		catch %	mean length	catch %	mean length	catch %	mean length	catch %	mean length	catch %	mean length
1	0-50	49.2	9.4	82.7	11.2	57.9	9.8	58.3	9.2	10.1	9.6
	50-200	50.8	8.8	17.3	10.0	62.1	9.4	41.7	7.9	89.9	8.9
2	0-50	93.8	12.1	31.2	12.7	70.4	9.5	78.9	11.9	85.6	12.6
	50-200	6.2	9.9	68.8	12.1	29.6	9.5	21.1	10.7	14.4	10.6
3	0-50									82.2	17.6
	50-200									17.8	12.4

Analysis of Table 3 indicates that the larvae caught in the upper 50-m
layer were larger than in the 50-200 m layer. Catch of large larvae
(%) from the upper 50-m layer increased in the 2nd leg, excluding 1984
when they were caught deeper, compared to other years.

Fig.9 presents catch (%) of larvae from the 0-50 and 50-200 m layers
in the Norwegian Shallows waters with varying salinity.

As can be seen in Fig.4 in 1984-1987 the larvae were distributed in
the 0-50 m in the coastal freshened water with the salinity 33.5- 34.5
$^0/_{00}$ and in the 50-200 m layer with saltier mixed and Atlantic waters
with the salinity 34.5-35.2 $^0/_{00}$. The observations indicated the
transport of larvae in the Norwegian Shallows in 1985-1987 (the obser-
vations were not conducted in 1983) to be mainly observed in the 0-50
m layer in the freshened coastal waters. 1984 was an exception when
the larvae were found distributed in saltier waters.

Periods of spawning and larvae hatch. Periods of larvae hatch were
determined by the methods described in A.S.Seliverstov (1969). Data on
direct observations over the spawning in the near-bottom layer when
incubating were also used.

The curves of larval hatch (Fig.10) indicate that year-to-year
variations make up 10-25 days in the larvae hatch peak in 1983-1987.
Compared to other years more prolonged larvae hatch in 1984, probably,
was related to that the period of incubation took place in the waters
with a low temperature (6-7^{0}C).
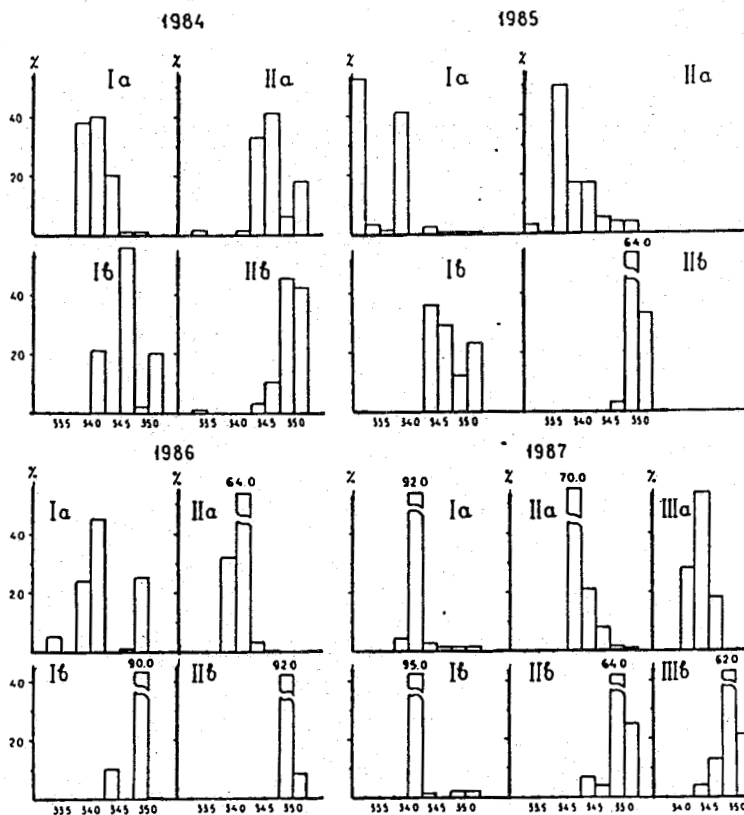
Fig.9. Catch of larvae (%) in the 0-50 (a) and 50-200 m (b) layers
in the 1st (I), 2nd (II) and 3rd (III) legs of ichthyoplankton
survey (1984-1987)

In this paper the reasons for fluctuations in spawning periods are not
elucidated. In our opinion they may be associated with the
peculiarities of maturation of herring reproductive products and
periods of its transport to spawning grounds which, in their turn,
depend on winter-spring redistribution of Atlantic and coastal water
masses.

DISCUSSION

Data on thermal state of water and salinity in the near-bottom waters
on the Landgrunn and Buagrunnen Banks areas indicated the variations
in oceanographic characteristics on these banks to be minor in 1983-
1985. In 1986-1987 high variations in temperature and salinity, which,
probably, influenced the survival of eggs and larvae at early stages
of ontogeny, were registered there.

Passive drift of larvae with water masses starts in several days after
a hatch with an ascent of larvae into a mid-water (Zadorin, 1962;
Seliverstov, 1969).

Gradually increasing importance of herring spawning grounds on the
Landgrunn Bank has been observed from 1983 to 1987. In 1986-1987 an
essential portion of herring larvae started their drift from that
area. As a result of that an extent of their migration across Subarea
IV has increased.
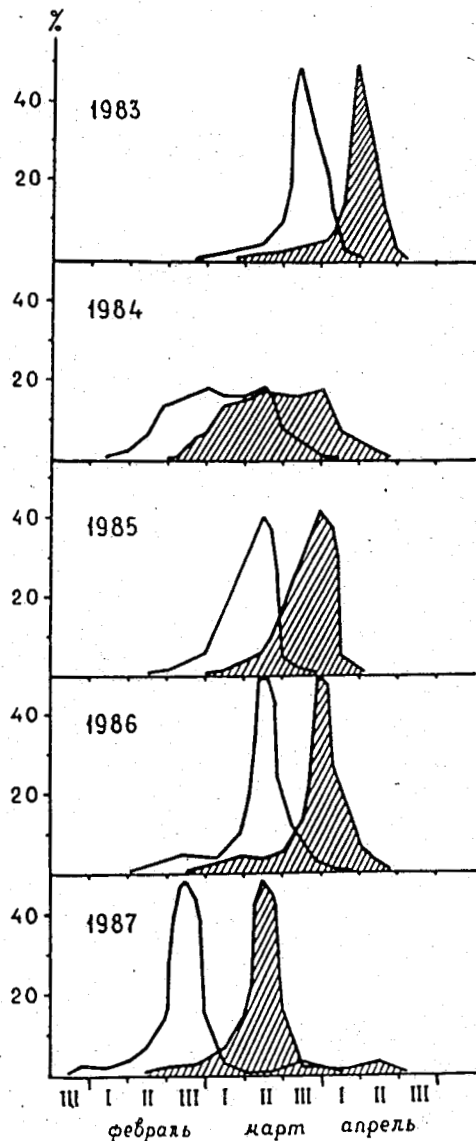
Fig.10. Curves of herring spawning (%) - (unshaded) and larvae hatch
(%) - (shaded) in the Norwegian Shallows in the I, II and III
decades of February-April 1983-1987

Charts of dynamic topography of waters from the Norwegian Shallows
area and larvae distribution showed that in 1986-1987 the zones of
retention related to the peculiarities of circulation of water masses
were formed in the south of the shallows. Drift of larvae from these
zones had easterly orientation. In 1983-1985 their northeasterly drift
was observed along the coast.

In the period of years considered   herring larvae in numerous
quantities were observed in the Lofoten area only in 1983 and 1984.
Transport of larvae from the Norwegian Shallows areas into the Lofoten
area is real under favourable conditions of the drift, as noted by
A.S.Seliverstov (1969). In 1983-1984 an intensive inflow of warm
Atlantic waters with high salinity promoted a drift of larvae from the
southern spawning grounds into the Lofoten area.

The results from the investigations conducted on the Norwegian and
Lofoten Shallows in 1983-1987 also showed that the most favourable
conditions for eggs development, hatch and drift of herring larvae
were registered only in the warm 1983. The 1983 herring year class was
estimated a rich one (Anon., 1983, 1984). The subsequent year classes
(1984-1987) were estimated poor. The size of the herring spawning
stock in 1983-1987 varied slightly (Anon., 1988). This indicates that
the main factors specifying the appearance of the 1983 abundant year
class were abiotic.

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HERRING AND BLUE WHITING REPRODUCTION CAPACITY

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ABSTRACT

Reproduction capacity is a very important parameter of a commercially exploited population.   One of the essential criterion of this parameter is population fecundity (PF). PF was determined in spring spawning Norwegian herring and blue whiting. In herring it varied significantly within the range of more than two orders. In blue whiting the highest PF exceeded the lowest one only by a factor of 3,5. Fluctuations of the survival index (S), i.e. percentage of eggs spawned to survive to the age of 3 were also significantly different. In herring, fluctuations of S of above two orders were recorded, whereas in blue whiting less than 0.5 orders.   Comparative retrospective co-analysis of PF, year-class strength and S has resulted in establishing three levels of reproduction capacity:

1. Safe PF guaranteeing the emergence of an abundant year class under moderate ambient conditions of survival, 2. Minimal safe allowable (implying natural year class abundance fluctuations), 3. Critical population fecundity posing a danger of long-term   decline   in abundance.   In herring these levels were estimated as 1346×10^{12}, 577 $\times 10^{12}$ and 175×10^{12} eggs correspondingly. In blue whiting 2759 x 10^{12}, 1739 x 10^{12} and 978,4 x 10^{12} eggs correspondingly. A slow recovery of the spring spawning Norwegian herring induces a hope that herring PF could restore to critical PF and even surpass it one day. Blue whiting reproduction capacity varied within the natural range. Still the 1984-85 sharp decline in PF could be accepted as a warning not to neglect reproduction capacity estimation when TAC is calculated.

INTRODUCTION

Population fecundity or, in other words, the total amount of eggs
spawned by the spawning female component of the population throughout
the spawning period during the year considered (Anokhina, 1969;
Polyakov, 1971) is the original value of the year class abundance. The
importance of determining this value in order to appraise the
dependence of recruitment on the stock size is obvious.

The estimation of population fecundity requires data on the overall
abundance, individual absolute fecundity, the share of mature fish,
and sex ratio in each age group. Such a detailed characteristic of
population status becomes possible only after a long period of
studies, and under a well-established supply of fishing statistics.

The broad application in fisheries biology of the technique of
assessment of the overall population abundance and of the abundance of
age groups which make up the spawning part of population has made it
possible to evaluate the population fecundity and survival rate of
year classes during their early life history.

This paper outlines the results of attempts to determine the
population fecundity and to retrospectively analyse the variations in
population fecundity and year class strength in herring and blue
whiting.

MATERIAL AND METHODS

Material on the individual absolute fecundity of the spring-spawning
Atlantic herring was collected at the Polar Fisheries Research
Institute between 1951 and 1975. the fecundity of fish of each group
was detected annually throughout this period. Three gram portions
were taken from three parts of gonade of the IV Stage of maturity,
eggs were counted in each portion and extrapolated to the weight of
the whole gonade. Individual absolute fecundity in 4474 individuals
of the Atlantic spring-spawning herring was determined by E.A.
Seliverstova. the results were kindly offered to me prior to being
published, which is sincerely appreciated.

The population fecundity is defined as the total of contributions of
each age group to the overall amount of eggs which is to be shed by
the population:

$$E_p = \sum_{i=3}^{n} C_E$$

E_p - is the population fecundity, in number of eggs;

$i = 3$ - is the age at recruitment into the spawning
                     population
n -   is the number of age of age groups;
C_E - is the contribution to population fecundity made by
                   fish of the same age groups determined as follows;

$$C_E = E \cdot N \cdot m \cdot R$$

where   E - is the mean individual absolute fecundity of
                              the given age group;

                         N - is the abundance of fish in the given age
                              group obtained through VPA, or by other
                              methods of determination of overall
                              abundance;

                         m - is the proportion of mature fish of the
                              given age group appearing on the ogive of
                              maturation

                         R - is the proportion of females, i.e. sex ratio
                              in the given age group

Data on the age composition, abundance and biomass of the spawning
population, maturation ogive sex ratio of the spring-spawning Atlantic
herring and Barents Sea capelin were obtained from material of Working
groups of the International Council for the Exploration of the Sea
(Anon., 1970, 1975, 1983, 1984, 1986, 1987), as well as from other
publications (Dragesund, et al. 1980).

Abundance index of fish aged 3 or more was used as criterion. In the
case of spring-spawning Atlantic herring a year class is regarded to
be strong if the abundance of three-year olds exceeds 7000×10^6
individuals, medium if the three-year olds are within 2000 to 7000 x
10^6 individuals, and poor if their number is less than 2000×10^6 fish
(Table 1). The year class strength estimated by those criteria
virtually coincides with the strength estimates obtained from the age
composition of catches of adult herring. For blue whiting these
criteria where as follows: strong year class: more than 10×10^9
three year olds, medium one: from 5×10^9 to 10×10^9, and poor year
class: less than 5×10^9 three year olds.

Year class survival rate is found as percentage of three-year old fish
from the total amount of eggs laid during the year of birth of this
generation

$$S = \frac{N_i \cdot 10^2}{E_{pi}}$$

where: S -   is the survival rate up to three year olds of the
                        given generation (percent);

                  N_i - is the number of three-year-olds of the
                        given generation;

                  E -   is the population fecundity in the given year;

Year class survival rate can be regarded as an integrated index of
survival conditions in the early life history.

Terms denoting various levels of population fecundity were used in the
analysis of the relationship between the year class strength of
commercial fish species and the spawning stock. "Safe guaranteeing
population fecundity" (GPF) is the level of population fecundity when
the emergence of a rich (strong) year-class is guaranteed thanks to a
sufficient amount of eggs laid by the entire spawning population,
under average survival conditions of the year class at its early life
history. "Minimum safe allowable population fecundity" (MAPF) secures
the appearance of strong year classes under propitious survival
conditions, medium year classes in average ecological conditions, and

only poor year classes in unfavourable survival conditions at early
life. "Critical population fecundity" (CPF) is the total volume of
eggs shed by the given population which provides for the appearance of
strong year classes only in the best survival conditions at their
early ontogenesis. A lower CPF would deprive the population of the
opportunity to produce a strong year class even with the very best
survival conditions.

The following procedure was used to find these three estimated levels
of population fecundity:

$$E_{gar} = N_{ab} / S_{med}$$

$$E_{minal} = N_{av} / S_{med}$$

$$E_{cri} = N_{ab} / S_{max}$$

where: E_{gar} is GPF

            E_{minal} is MAPF

            E_{cri} is CPF

            N_{ab} is the juvenile abundance of a strong
                          year class aged 3 years

            N_{av} is the juvenile abundance of a medium
                          year class of the same age.

            S_{med} is the survival rate of a medium year
                          class in its early life history

            S_{max} is the maximum survival rate for the
                          period of observations of a year
                          class in its early life history.

RESULTS

Spring-spawning Atlantic herring. Year class abundance fluctuations
of spring-spawning Atlantic herring are exceptionally great. For
example, the strong year class of 1959 at age 3 exceeded the poor year
class of 1956 by 125 to one as far as its abundance goes (Table 1,
Fig.1) On the other hand, the total amounts of eggs shed, i.e. the
population fecundity at the years of birth of these year classes were
nearly equal. The poor year class of 1968 was over a thousand times
less abundant than the good 1959 generation!

Strong year classes would appear both in years of exceptionally high
population fecundity, e.g. in 1951, and in relatively low years, e.g.
in 1963. Poor year classes come about both during high population
fecundity years, as was the case in 1955, and in low years as was
observed annually since 1965. The emergence of generations of medium
abundance follows a similar pattern.

Year class survival till age 3 varied quite significantly through the
period of studies, in fact by nearly three orders of magnitude. The
survival conditions of the 1951 year class were worse than those of
1973 by an order of magnitude (Table 1).

Herring and blue whiting reproduction capacity.

Table 1.   Population fecundity (PF), year class strength (R) and
           survival index (S) of the Norwegian spring spawning herring.

Year	PF eggs x 10^{12}	R x 10^6 age 3 number of fish	Year class strength	S in %
1951	1167.4	7380	strong	0.000630
1952	1075.9	3448	medium	0.000320
1953	899.5	3820	medium	0.000358
1954	946.2	600	poor	0.000063
1955	1446.1	494	poor	0.000034
1956	880.2	169	poor	0.000019
1957	1256.2	252	poor	0.000020
1958	1303.1	241	poor	0.000018
1959	879.2	21175	strong	0.002408
1960	658.0	7337	poor	0.001150
1961	573.3	2175	medium	0.000379
1962	464.1	203	poor	0.000044
1963	208.7	8281	strong	0.003968
1964	375.2	3832	medium	0.001021
1965	500.6	107	poor	0.000021
1966	343.3	230	poor	0.000067
1967	192.1	33	poor	0.000017
1968	43.3	16	poor	0.000017
1969	12.3	375	poor	0.000866
1970	7.03	13	poor	0.000180
1971	-	6		?
1972	4.7	30	poor	0.000640
1973	12.4	748	poor	0.006030
1974	9.9	421	poor	0.004250
1975	11.4	58	poor	0.000530
1976	7.8	410	poor	0.005260
1977	22.3	180	poor	0.000810
1978	32.5	257	poor	0.000790
1979	40.4	1217	poor	0.003100
1980	47.1	122	poor	0.000260
1981	48.0	89	poor	0.000180
1982	56.8	602	poor	0.001060
1983	81.4	10000	strong ?	
1984	105.0			

Possessing a quantitative expression of survival conditions in the
form of survival percentage at the early life history one can
retrospectively evaluate the conditions of survival in the period of
studies.   Hence, there were four strong year classes recorded in 1951-
1981 (Table 2) while year class strength facilitating conditions
occurred 8 times.

The overexploitation of strong year classes in the 1960's coupled with
the unfavourable survival conditions observed in 1965-1968 made the
spawning population of herring in the early 1970's consist of
individuals from poor year classes. Their population fecundity was
very low: two to three orders of magnitude less than the level
observed in the 1950's and early 1960's (Table 1). Even under the best
survival conditions, the emergence of a strong year class is
theoretically improbable, given such a population fecundity. To attain
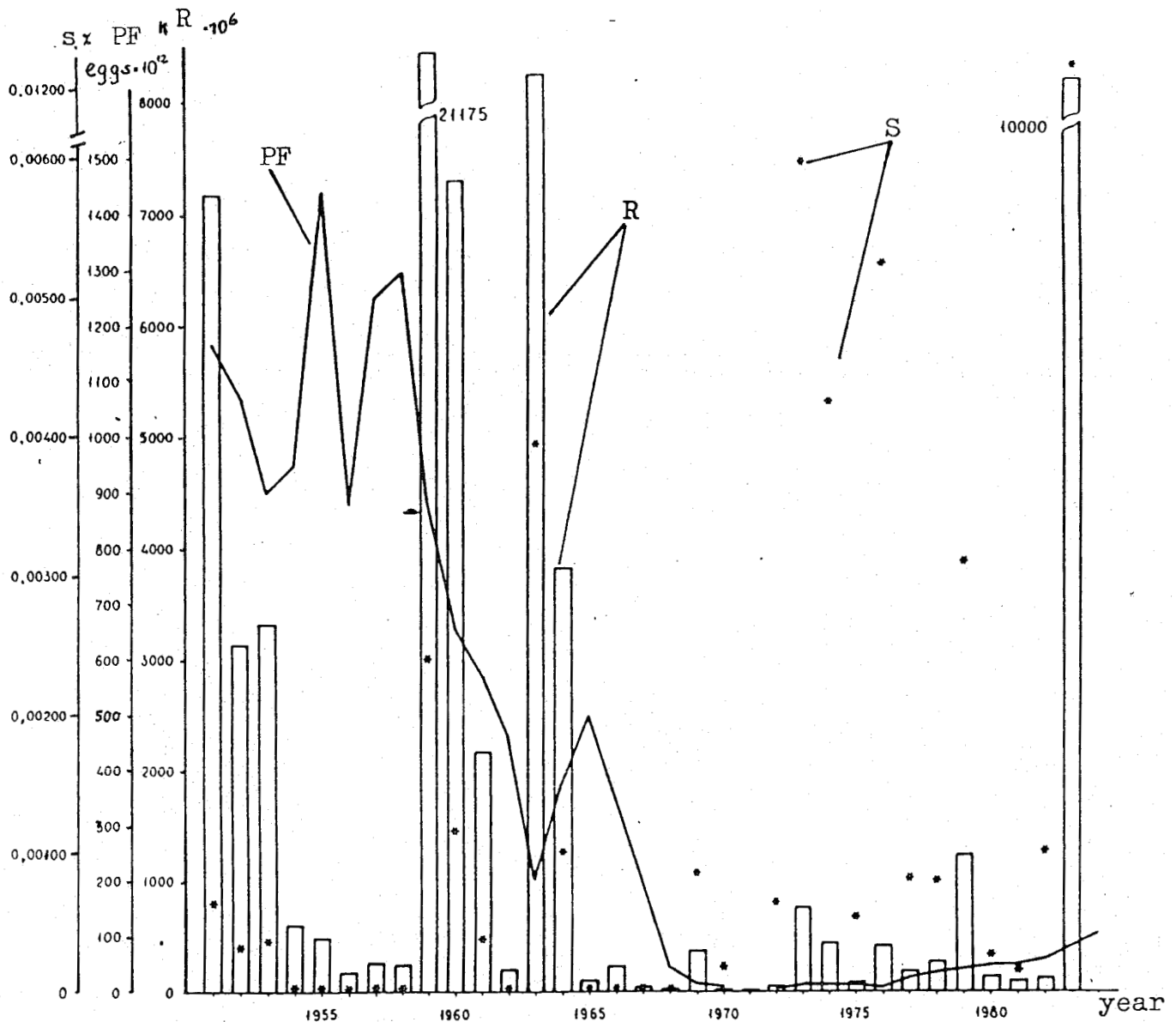
Fig. 1. Population fecundity (PF), year class strength (R),
at age 3 and survival to age 3 (S) in Norwegian
spring-spawning herring.

that, one has to have a population fecundity of at least 175×10^{12}.
The maximum favourable conditions (0.006 % survival) have occurred
only throughout 30 years.

Let us take the range of 175×10^{12} eggs for the critical population
fecundity. Theoretically, there is still hope under CPF to have a
strong year class under the most favourable conditions. However, one
should not expect already a generation of medium abundance in
"average" conditions. Such a critical population fecundity had been
"passed" in 1966-1967 when the maximum contribution into the
population fecundity was made by the fish of the strong 1959 year
class. Not later than the next year this generation contributed less
than half the fish to the population fecundity because of a too
intensive elimination of this year class by the fishery. This also led
to a drop in the 1968 population fecundity level below the critical

Herring and blue whiting reproduction capacity.

Table 2. Norwegian spring-spawning herring year class graded
by strength.

Number at age 3 x 10^6	PF eggs x 10^{12}	Survival %	Year
	RICH		
21175	879.2	0.002408	1959
8281	208.7	0.003968	1963
7380	1167.4	0.000630	1951
7337	658.0	0.001115	1960
10000	81.4	0.012000 ?	1983
	MEDIUM		
3832	375.2	0.001021	1964
3448	1075.9	0.000320	1952
3220	899.5	0.000358	1953
2175	573.3	0.000379	1961
		0.000520	
	POOR		
1217	40.4	0.003010	1979
748	12.4	0.006030	1973
600	946.2	0.000063	1954
494	1446.1	0.000034	1955
421	9.9	0.004250	1974
410	7.8	0.005260	1976
375	12.3	0.000866	1969
257	32.5	0.000790	1978
252	1266.2	0.000020	1957
241	1303.1	0.000018	1958
230	343.3	0.000067	1966
203	464.1	0.000044	1962
180	22.3	0.000810	1977
169	880.2	0.000012	1956
122	47.1	0.000260	1980
107	500.6	0.000021	1965
102	56.8	0.001060	1982
89	48.0	0.000180	1981
58	11.4	0.000530	1975
33	192.1	0.000017	1967
30	4.7	0.000640	1972
16	43.3	0.000008	1968
13	7.0	0.000180	1970
6	?	?	1971

point. The spawning population biomass under the CPF was 1.4 mill. tonnes which is probably to be regarded as the critical biomass of the spawning population for the case of the Norwegian spring-spawning Atlantic herring.

Safe guaranteed population fecundity (1346 x 10^{12} eggs) is of practical value. The level of population fecundity close to this value is found in five cases (Table 1). It was exactly under a similar level of population fecundity that a strong year class appeared in 1951 under survival conditions that would only be good for the birth of a generation of medium abundance.

The minimum safe allowable population fecundity must be 577 x 10^{12} eggs. A close or a higher population fecundity had occurred repeatedly. Yet it declined in 1962 never to return to the MAPF later.

The decrease in the spawning population biomass and in population
fecundity of the spring-spawning Atlantic herreing below the minimum
allowable level as early as 1962 offset considerably the chance for
strong and medium year classes. Moreover, the fall in the population
fecundirty below the critical level in 1967-1968 in fact eliminated
even the theoretical possibility of the appearance of strong or at
least medium year classes.

Only in 1983, when population fecundity recovered to 81.4 x 10^{12}, the
appearance of a medium or even a strong year class became possible
under the extremely favourable environmental conditions, and with no
fishery for juvenile herring.

Blue whiting. The blue whiting strength of the year class fluctuations
were not as significant as were the case for herring, for the period
1970-1985. The richest blue whiting year class (1982) exceeded the
poorest one (1980) by a factor of 4.7 (Table 3, Fig.2). The changes of
population fecundity have not been great in either case. The maximal
population fecundity of 1982 was 2.5 times higher than the minimal one
of 1980. Survival index fluctuations were significantly greater - from
0.00011 in 1980 to 0.0011 % in 1982.

Table 3. Population fecundity (PF), year class strength (R) and
         survival index (S) of blue whiting.

Year	PF eggs x 10^{12}	R x 10 at age 3 N x 10^6	Year class strength	S %
1970	2318	13057	strong	0.00056
1971	1983	11897	strong	0.00060
1972	2334	11602	strong	0.00050
1973	2030	9797	medium	0.00048
1974	3147	7331	medium	0.00023
1975	3384	6568	medium	0.00019
1976	2598	5796	medium	0.00022
1977	2351	5259	medium	0.00022
1978	2047	7502	medium	0.00037
1979	3042	4199	poor	0.00014
1980	2803	3121	poor	0.00011
1981	1794	4392	poor	0.00024
1982	1340	14741	strong	0.00110
1983	1616	10762	strong	0.00066
1984	1364	6599	medium	0.00048
1985	1956	6860	medium	0.00035
1986	2479			
1987	1796			
1988	1838			

Safe guaranteeing population fecundity calculated is to be equal to
2759 x 10^{12} eggs, minimal safe allowable equal to 1739 x 10^{12} and
critical population fecundity was found to be 978.4 x 10^{12} eggs.

The blue whiting population fecundity never lowered down to the
critical level during the investigation period, 1970-1985. Moreover,
this population parameter has reached the guaranteeing level of
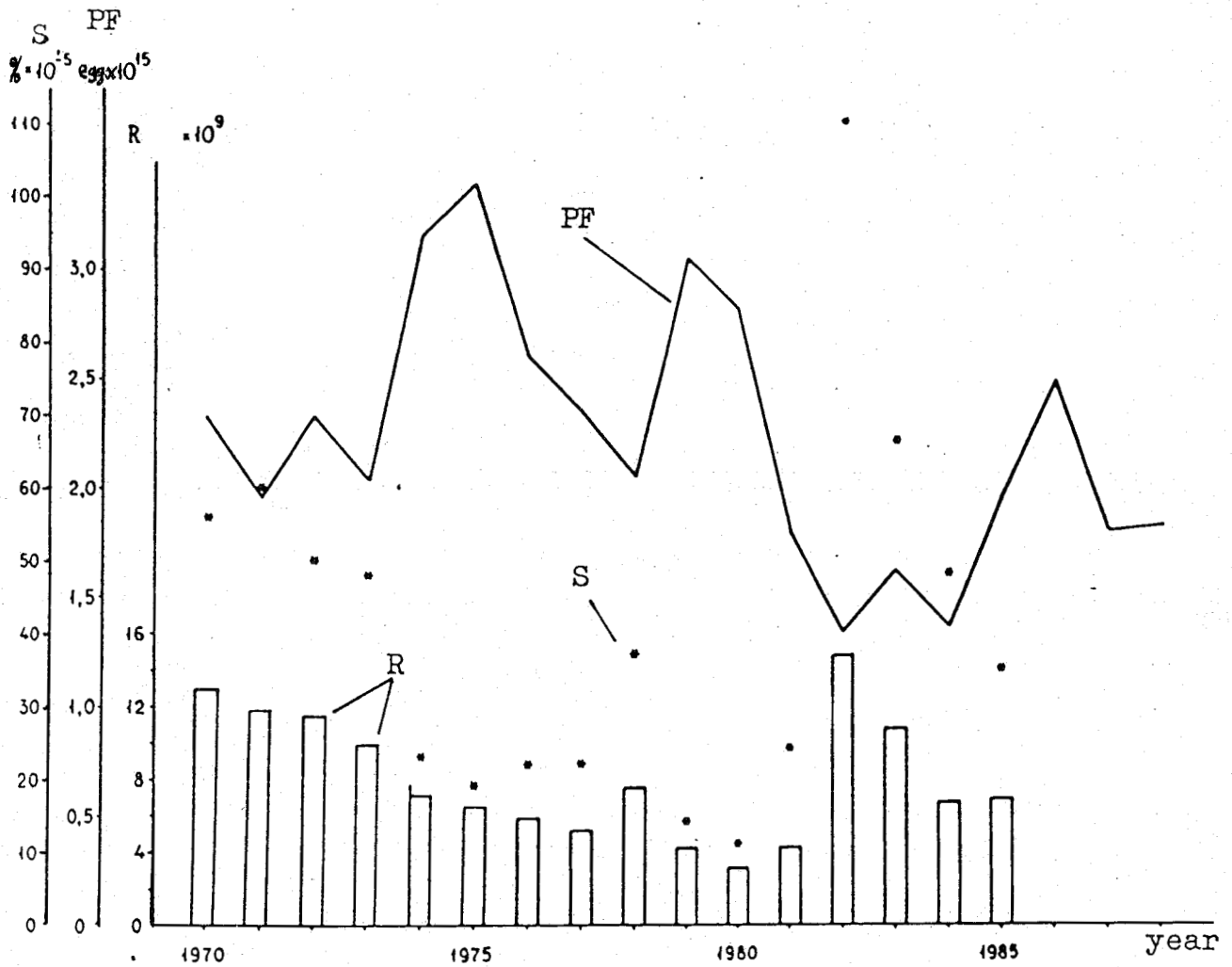
Fig. 2. Population fecundity (PF), year class strength (R)
at age 3 and survival to age 3 in blue whiting.

population fecundity several times. The blue whiting population
fecundity was at the minimal safe allowable level in 1986-88 and will
stay at this level in 1989. This last fact encourages theoretically
founded expectations of abundant year classes emerging under
favourable survival conditions.

DISCUSSION

Population fecundity of herring and blue whiting is quite comparable.
Maximal blue whiting population fecundity is 3040×10^{12} eggs, for
herring it is 1446.1×10^{12} eggs. However, the herring year class
strength and survival fluctuations exceeded the blue whiting ones by
2-3 orders of magnitude. The three levels of the blue whiting and
herring population fecundity when considered as reproduction capacity
levels could be compared. The blue whiting critical population
fecundity of 1345×10^{12} eggs is equal to the guaranteeing population
fecundity for herring (Table 5). Cri_{PF} for herring is less than
the same parameter for blue whiting by an order, but the highest
survival rate for a herring year class is by far greater that that of
blue whiting.

Herring and blue whiting reproduction capacity.

Table 4. Blue whiting year class graded by strength.

Number at age 3 x 10^6	PF eggs x 10^{12}	Survival %	Year
	RICH		
14741	1340	0.00110	1982
13057	2318	0.00056	1970
11897	1983	0.00060	1971
11602	2334	0.00050	1972
10762	1616	0.00066	1983
	MEDIUM		
9797	2031	0.00048	1973
7502	2047	0.00037	1978
7331	3147	0.00023	1974
6860	1956	0.00035	1985
6599	1364	0.00048	1984
6568	3387	0.00019	1975
5796	2598	0.00022	1976
5259	2351	0.00022	1977
	POOR		
4392	1794	0.00024	1981
4199	3042	0.00014	1979
3121	2803	0.00011	1980

The spring-spawning Norwegian herring population fecundity was reduced below the critical level as early as 1968 on account of a too high fishery elimination. The latter deprived that population of even the theoretical possibility of producing another abundant year class for 15 years. The blue whiting population fecundity never lowered to such a critical and catastrophic level. However,that fact should not be a basis for too optimistic hopes of increasing the fishery elimination.

The blue whiting reproduction capacity is influenced by the same features as that of the Atlanto-Scandian herring. These are a) low individual fecundity, which gives the age composition an important role, b) long life cycle of mature fish (Marti, Fedorov, 1963).

Under natural conditions the spawning stock consists of 10-12 year classes, and this ensures the reproduction capacity stability even when sharp year class fluctuations happen. Therefore the high stable blue whiting and herring reproduction capacity could be substantially changed only when the age composition of the stock is affected by intensive fishing. Yu. Marti warned that such a danger existed already in 1963 (Marti, Fedorov, 1963). Unfortunately, that warning was neglected by the herring fishery and the spring spawning Norwegian population was driven into a deep and long term depression. Even nowadays, the abundant 1983 year class is not yet a guarantee for emerging from this depression. Hence this year class needs a thorough protection.

Table 5. Three levels of herring and blue whiting
population fecundity (eggs x 10^{12}).

	GPF	MAPF	CPF
Herring	1346	577	175
Blue whiting	2759	1739	978.4

For the sake of preventing such a catastrophe with the blue whiting
population, reproduction capacity must be kept and preserved at the
level of minimal safe allowable population fecundity. Allowable catch
should be established considering a spawning stock biomass estimation
safely ensuring the MSAPF.

Reducing the blue whiting population fecundity below the level of
MSAPF in 1982 and 1984 must be accepted as a warning. If the blue
whiting population is reduced below CRIPF, a single abundant year
class will not be able to restore the reproduction capacity of this
population.

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THE 1983 YEAR CLASS OF NORWEGIAN SPRING SPAWNING HERRING AS JUVENILES

AND RECRUIT SPAWNERS

by

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ABSTRACT

This paper gives the geographical distribution and the migrations of the 1983 year class of Norwegian spring spawning herring in the period 1983-1989. These migrations are compared with herring migrations of earlier periods. Further, the acoustic abundance estimates of this year class is reviewed.

INTRODUCTION

The stock of Norwegian spring spawning herring collapsed in the late
1960's (Dragesund et al. 1980). From a level of approximately zero in
1972 the spawning stock recovered in a slow but steady manner to a
level of about 0.5 million tonnes in 1983 (Hamre 1989). This was,
however, far below the average stock size in the period prior to the
stock collapse. The strength of the year classes in the period 1970-
1982 was also below the average year class strength of earlier
periods.

In 1983 large amounts of 0-group herring were recorded in the Barents
Sea, indicating favourable conditions for survival and growth of the
herring larvae and 0-group. Since then, information on this year class
has been obtained by:

1) Acoustic surveys
2) Sampling commercial catches
3) Tagging

Results from these surveys and investigations are given in papers
presented to the ICES Statutory Meetings by the present author
(Røttingen 1984,1985,1986,1987 and 1988), in ICES Working Group
reports (Anon. 1984,1985,1986,1987,1988 and 1989) and in unpublished
cruise reports to the Institute of Marine Research.

The aim of this paper will be the following:

1) To make a chronological review of the seasonal geographical
distribution and various aspects of the behaviour and biology of the
1983 year class from its birth in spring of 1983 to 1988/89 when the
bulk of this year class recruited to the spawning stock.

2) Discuss the abundance estimates obtained for the 1983 year class.

3) Outline the migration patterns which the 1983 year class has
undertaken, and compare these with migration patters from previous
time periods.

RESULTS

Geographical distribution

YEAR 1983

The spawning in 1983

At the end of the 1970's and beginning of the 1980's release and
recapture data showed that tagged herring did not mix randomly within
spawning stock of Norwegian spring spawning herring, but that the
spawning stock consisted of at least two units or "components" (Hamre
1989). In 1983, these units (one southern and one northern), were
estimated to be of approximately the same size. The southern unit
spawned mainly on the traditional spawning grounds on the coastal
banks south of 63^{0}N, the northern unit spawned north of 63^{0}N. The
Working group on Atlanto-Scandian herring has estimated the total
spawning stock to 615 thousand tonnes in 1983. This estimate was
derived from a VPA run which was tuned to the 1984 spawning stock
estimate obtained by tagging (Anon. 1988).
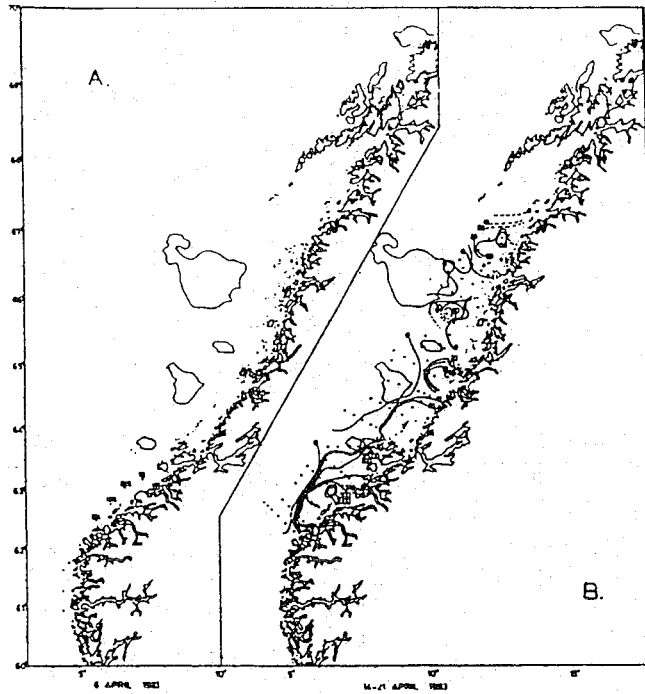
Fig. 1. Norwegian spring spawning herring.
         A. Number of larvae on Gulf III stations, April 6th 1983.
         B. Number of larvae per m^2 surface 14-21 April 1983.
         (Bjørke, unpublished data).
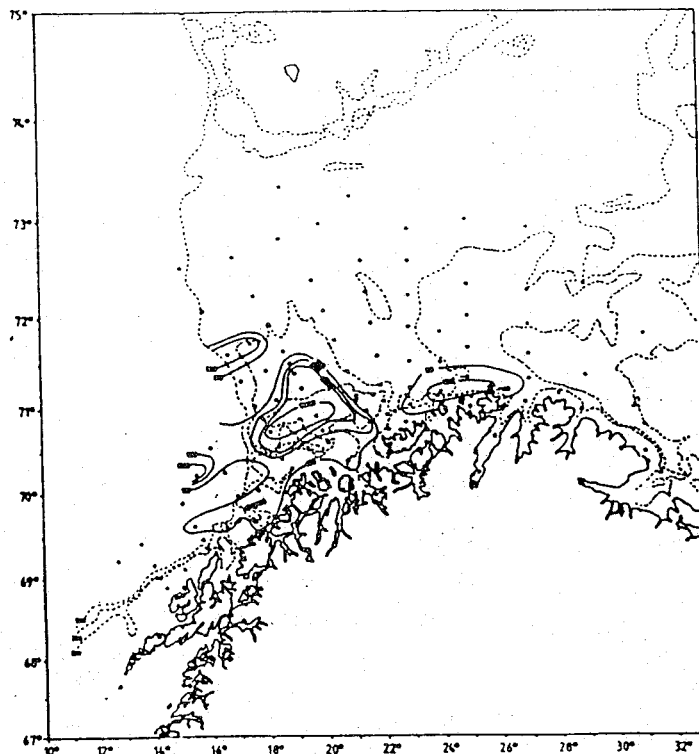
Fig. 2. Norwegian spring spawning herring
         Distribution of postlarvae 20 June-16 July 1983.
         (Bjørke, unpublished data).

April 1983 - herring larvae

The following paragraph on herring larvae in 1983 is a summary from
Bjørke (pers.com). On April 5 four stations using a Gulf III plankton
recorder were taken in the area from Statt to Smøla. The number of
larvae is shown in Fig 1a. Most of the larvae were newly hatched, but
there were observations of larvae up toward 14 mm. This indicates that
hatching took place on the spawning fields on Møre in last week of
March 1983. In the period 14-21 April herring larvae were recorded
from Statt to Bodø (Fig 1b). 5200 larvae, of which 390 were larger
than 12 mm, were taken in 1983. This was until then the largest number
of larvae observed since the stock collapse in the late 1960's.

The distribution of the herring larvae (Fig 1) may be taken as an
indication of the extent of the spawning in 1983. The general
conclusion is that there seems to have occured a widespread spawning
in 1983 from Statt and northwards to Bodø, but the main spawning seems
to have occured in the traditional spawning sites off Møre.

June-July 1983

Postlarvae off northern Norway were recorded on a survey in the period
20 June-16 July 1983. The sampling was done by pelagic trawl. Fig 2
shows the distribution of the herring postlarvae. (H. Bjørke,
unpublished data). The main concentrations were found off Tromsøflaket
(Approximately 71°N, 19°E). The western limit of the distribution is
not recorded. The main part of the postlarvae is found relatively
close to the shore.
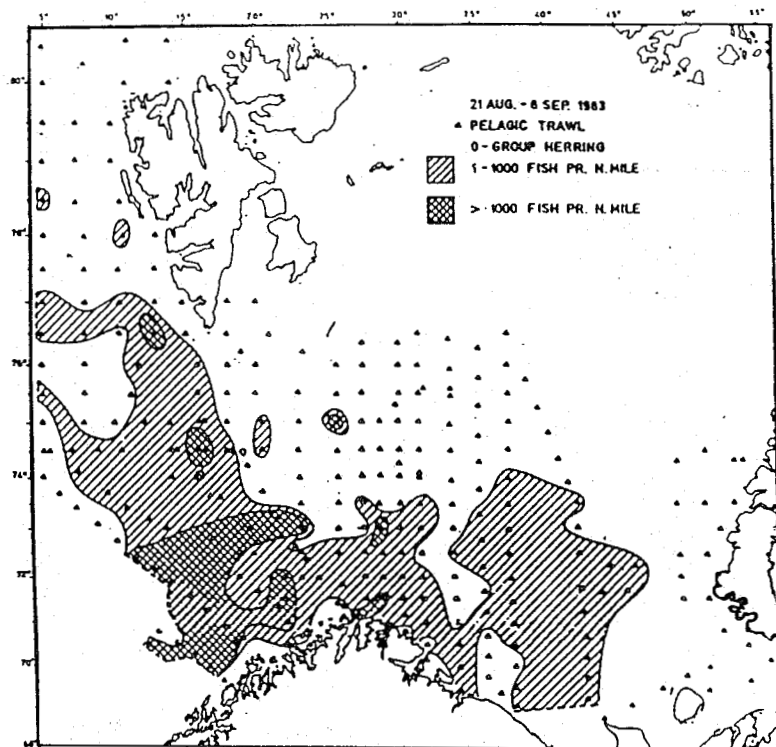
Fig. 3. Norwegian spring spawning herring.
        Distribution of 0-group, International 0-group survey
        August-September 1983 (Anon 1983).

August-September 1983

The distribution of the O-group recorded during the international
O-group cruise in the Barents Sea in the period 21 August-8 September
1983 is given in Fig 3 (Anon 1983).This is a trawl survey, the dense
and very dense areas shown in Fig 3 are defined according to the catch
of O-group herring in the trawl stations. The O-group herring have
now, compared with the postlarvae situation in June-July, a far more
offshore and eastern distribution. In 1983, O-group herring were found
on a larger number of stations and the number of specimens at each
station was higher than previously observed on the international
O-group surveys. These surveys started in 1965.

November 1983

Fig 4 shows the area where O-group herring was recorded in November
1983. Bad weather and some technical difficulties limited the
investigation area during this survey. There is therefore a
possibility that O-group herring were located in other areas of the
Barents Sea than shown in Fig 4. However, if the figure shows the main
distribution area, then a considerable east to southeast migration of
the O-group herring took place in the late autumn months of 1983.
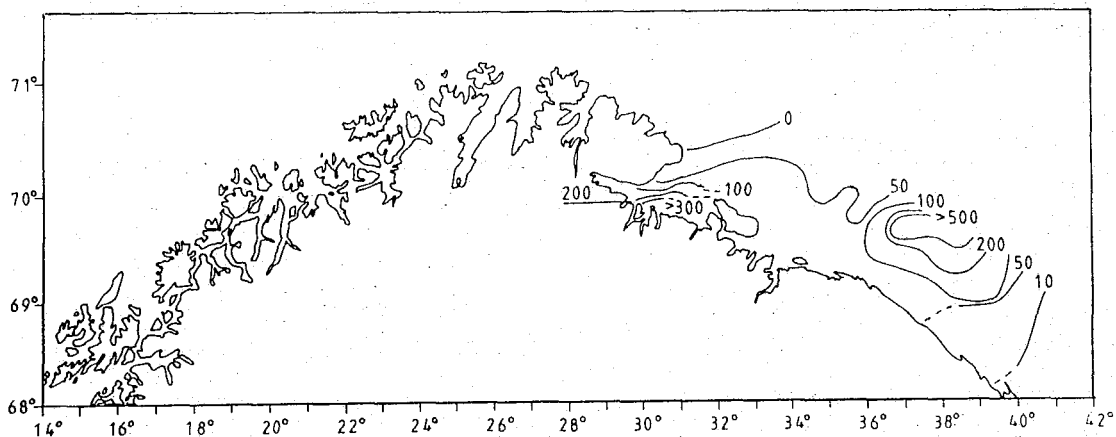
Fig. 4. Norwegian spring spawning herring.
Distribution of O-group November 1983. Integrator output
presented as total integrated scattering cross section per
nautical mile multilplied by 10.

A O-group herring survey was carried out in the fjord and coastal
areas of northwest and north Norway in November 1983. This was part of
a yearly investigation series that started in 1975 (Røttingen 1987a).
The abundance of O-group herring recorded in the fjord areas in 1983
was considerably higher than in the period 1975-1982.

Scenario at the end of 1983

By the end of 1983 it was clear that the 1983 year class of Norwegian
spring spawning herring was abundant and distributed over wide areas
in the Barents Sea and in the fjord and coastal areas of Norway. But
how strong was this year class? Was it comparable to the large year
classes of the 1950's and 1960's? Was it by the end of 1983 possible
to make any quantitative comparisons with other year classes?

Dragesund (1970) made investigations of the strength of the year
classes 1959-1965 as O-group, and he also measured the subsequent year
class strength at recruitment to the spawning stock. However, the

methodology, equipment and calibration methods used during these investigations were different from those applied in 1983. This makes a direct comparison between acoustic abundance estimates from the 1960's and 1980's impossible.

Based on the results from the international 0-group surveys in the Barents Sea the Working group on Atlanto-Scandian herring in October 1983 calculated an abundance index for the 0-group herring in 1979 and 1983. The result is given in the text table below:

	Year	
	1979	1983
Abundance index	8	431

The number of the 1979 year class as 4 year old fish was estimated by tagging to 1350 x 10^6 individuals (Anon. 1984). Assuming at least an equal abundance of 0-group herring in the coastal areas in 1983 as in 1979 the Working group stated:"The Working group concluded that the 1983 year class was very strong as 0-group compared to any year class since the collapse of the stock in the late 1960s, and that it could well turn out to be of the same order of magnitude as the year classes produced in the period 1961-66. These year classes had an avcerage strength of 17 x 10^9 individuals in terms of VPA estimates of 0-group fish (Dragesund and Ulltang, 1978). The corresponding average of 4 year old fish for the year classes 1961-1966 was 1507 x 10^6 individuals." (Anon 1984).

YEAR 1984

January 1984

Herring of the 1983 year class (now I-group) were recorded during the investigations of spawning capelin. Fig 5 gives the trawl stations taken during these investigations. The trawl stations with catches of I-group of herring are marked with filled symbols. If Fig. 4 is representative of the distribution in November 1983, the catches in January 1984 indicate that the herring had migrated northwards.

May-June 1984

Fig 6 gives the geographical distribution of the I-group herring in the Barents Sea in May-June 1984 (Toresen 1984). There were two main distribution areas. In the eastern part of the Barents Sea the I-group herring were distributed from north of the Rybachi peninsula (approx. $70^0 30'N$, $32^0,00'E$) to the Goose Bank area (approximately $73^0 00'N$, $48^0 00'E$). There were more or less continuous recordings of I-group herring as a scattering layer in 100-150m depth (Fig 7) over a distance of approximately 250 nautical miles. The other distribution area off the Finnmark coast to about 50 nautical miles offshore. In this area some of the I-group herring formed schools near the surface, and there were some mixing with adult capelin.

The 1983 year class of Norwegian spawning herring as......
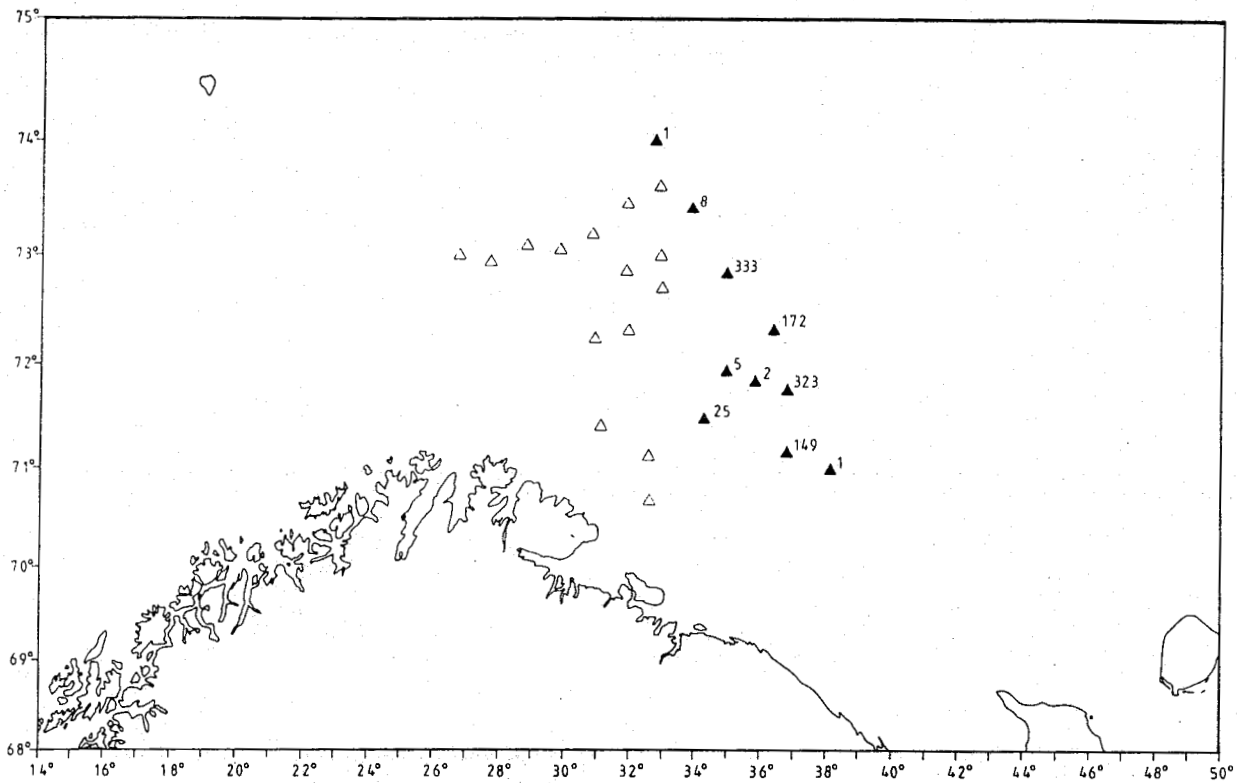
Fig. 5. Norwegian spring spawning herring.
Number of I-group per trawled nautical mile, January 1984.
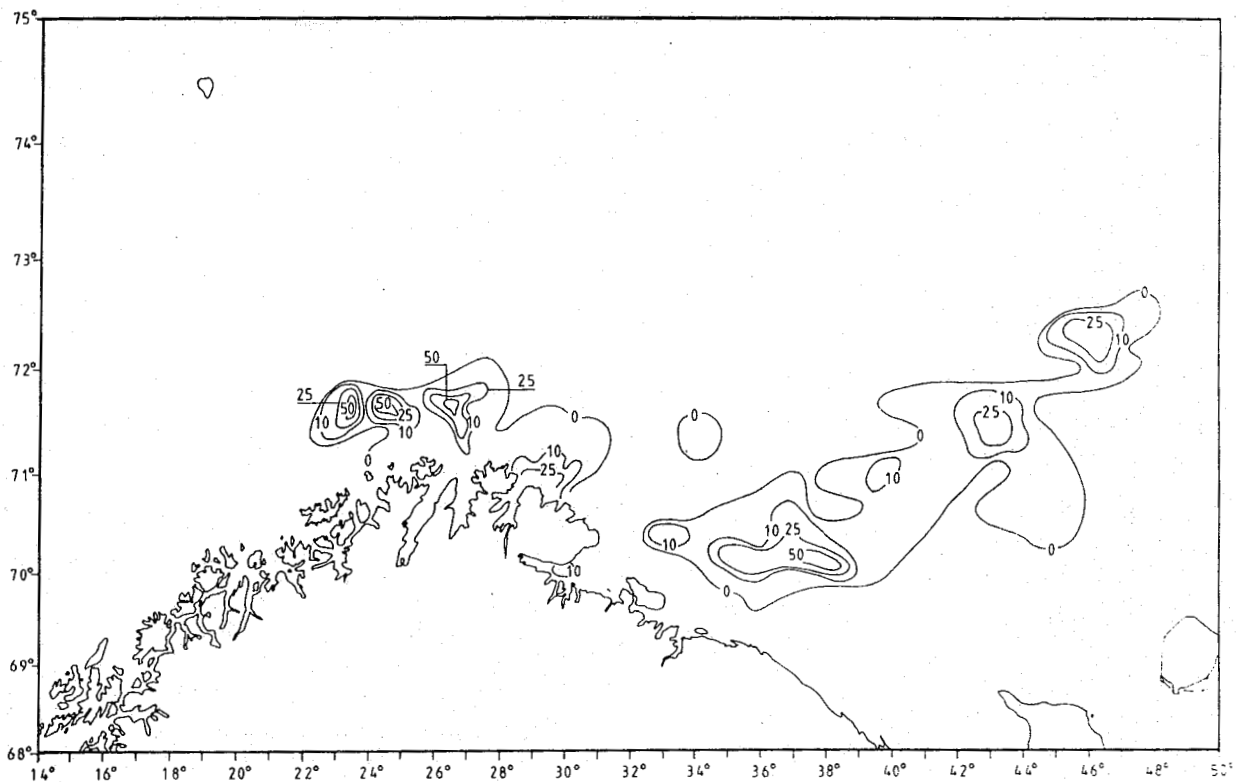
Fig. 6. Norwegian spring spawning herring.
Distribution of I-group in May-June 1984. Integrator output
as in Fig. 4. Modified from Toresen 1984.
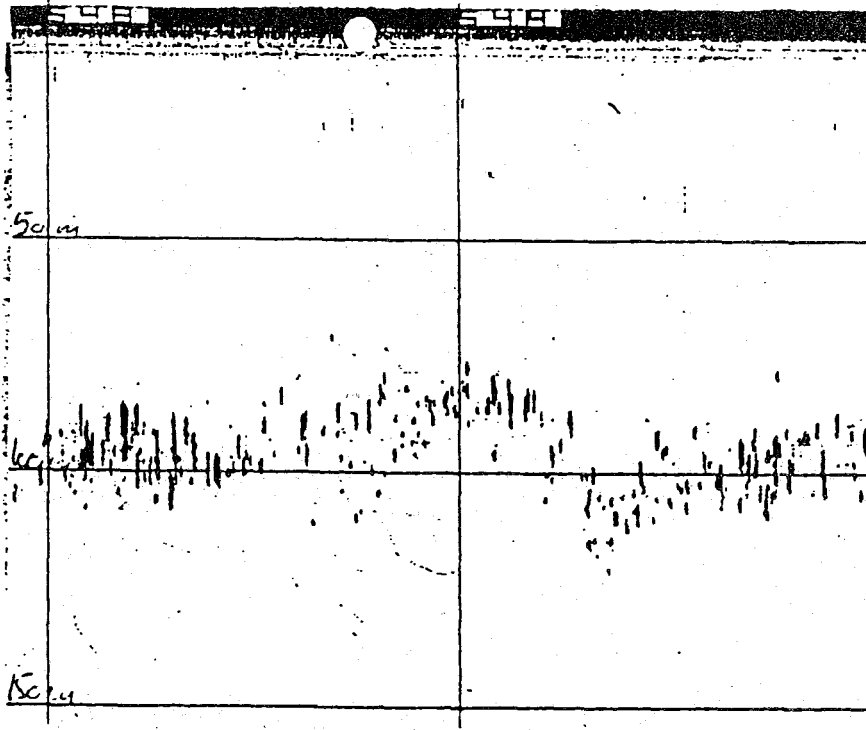
Fig. 7. Norwegian spring spawning herring.
         Echogram showing scattering layer of I-group at 100 m depth.
         Goose Bank. (Approx. 72°N, 47°E), May 1984 (Toresen 1984).

November-December 1984

A survey of the fjord and coastal areas of Norway, utilizing the same
course lines as the corresponding survey in November-December 1983,
showed that the 1983 year class was distributed over much smaller
areas than the year before. However,there still remained considerable
consentrations of this year class in some fjord areas, especially in
northern Norway. Fig 8 shows a typical recording of the I-group
herring from a fjord in northern Norway.

Scenario at the end of 1984

The corresponding surveys on the coast and fjord areas in November
1983 and November 1984 showed that the abundance (in numbers) and
geographical distribution area of the 1983 year class had decreased
considerably in these areas in this period. This was due to emigration
and/or mortality.

Unfortunately, it cannot be stated with absolute certainty if any of
the 0-group of the 1983 year class in the fjords of northern Norway
emigrated from the fjords and joined the offshore population in the
Barents Sea. Due to the possible underestimate of the 1983 year class
during the acoustic survey in November 1983, the abundance estimates
from the surveys in 1984 in the Barents Sea could not give any clear
answer to the question if the offshore part of the 1983 year class had
increased in 1984 due to emigration from the fjords. However, Fig 6
shows that I-group herring were distributed close to the entrance of
the fjords east of Sørøya (approximately 23°E) in June 1984. This may
be herring which has emigrated from the fjords. Although a major part
of the 0-group herring in 1983 were distributed in the fjords from
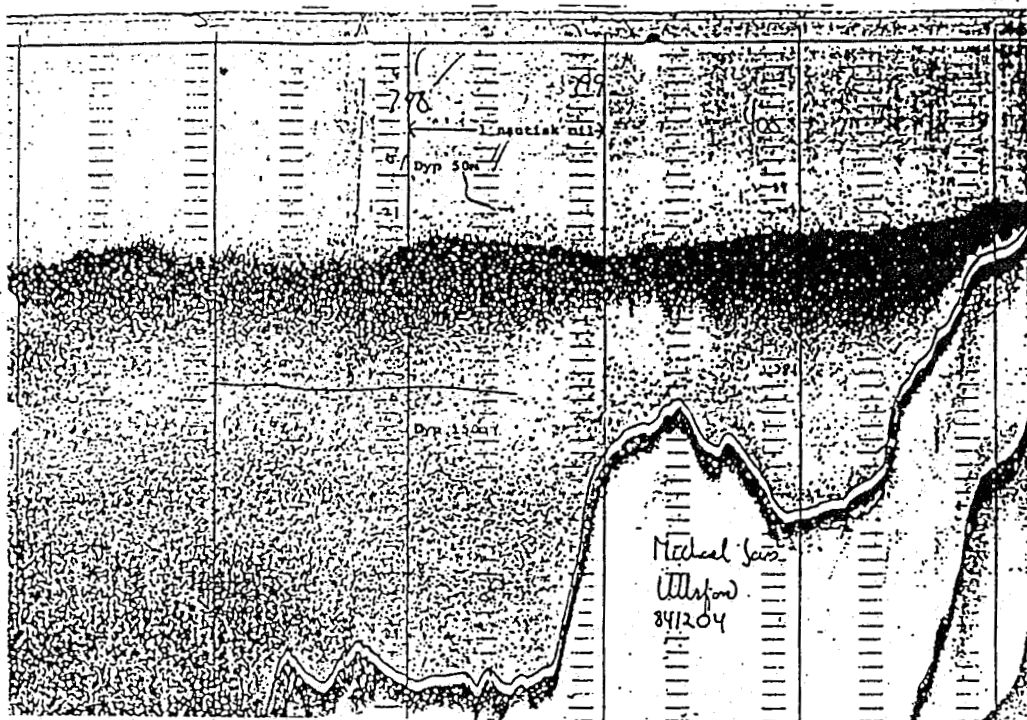
Fig. 8. Norwegian spring spawning herring.
         Echogram of I-group in Ullsfjord, northern Norway,
         December 1984.

Sørøya to Lofoten, there were no records of I-group herring in the
open sea outside this coastal area.

Based on the information available by October 1984, the Working Group
restated their opinion,in a more confident way, about the 1983 year
class in the following manner: "As observed last year, and confirmed
in this year's report, the 1983 year class is strong and in view of
the greatly improved prospects for recruitment to the spawning stock,
a fishing mortality on the adult component of the stock in the order
of F = 0.05 will have very little effect on the long-term development
of the stock." (Anon. 1985).

                              YEAR 1985

January 1985

Fig 9 gives an indication of the distribution of the 1983 year class
in the eastern part of the Barents Sea in January 1985. The acoustic
survey in January 1985 was designed to cover the distribution area for
cod, some areas where II-group herring may have been distributed may
not have been surveyed. This may particulary be the case for the
northern borders of the herring distribution.

However, taking the results from the January survey as an indication
of the general distribution, it can be seen that the distribution of
the herring is, in general, a little more to the east than the
distribution in June 1984 (Fig 6). The behaviour had changed, in
January the herring mostly occured in schools in contrast to the
scattering layers in June 1984. There were also concentrations of
capelin in the same area as the herring. The sonar and echo recordings
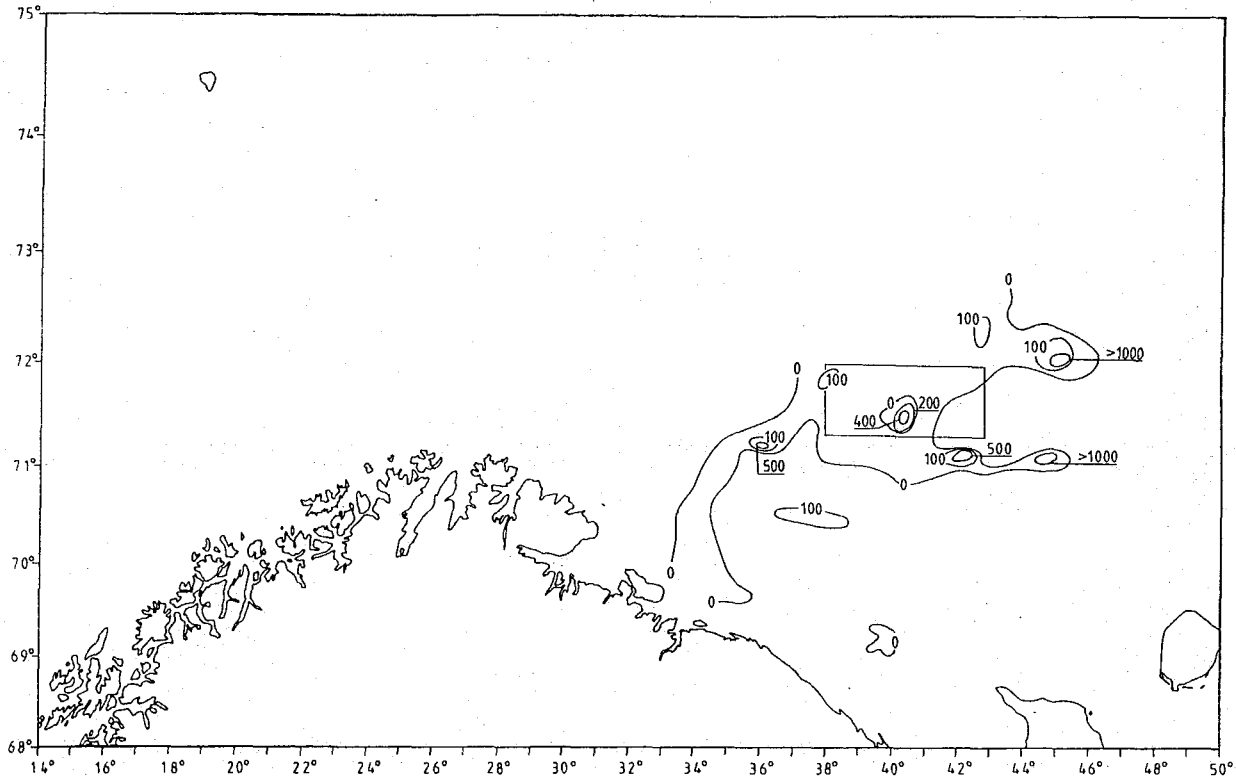
Fig. 9. Norwegian spring spawning herring.
          Distribution of 1983 year class in January 1985. Integrator
          output as in Fig. 4. The Norwegian capelin winter fishery
          took mainly place within the small frame shown in the figure.

of capelin and herring were difficult to discriminate and this caused
considerable difficulties in carrying out the Norwegian capelin winter
fishery in January 1985. The area where the capelin fishery took place
is within the frame included in Fig 9. A maximum by-catch of 10%
herring was enforced in the Norwegian capelin winter fishery in 1985.
The by-catch statistics show that approximately 2500 tonnes of II-
group herring were caught in the Norwegian and 1800 tonnes in the USSR
winter capelin fishery in 1985 (Anon 1986).

May 1985

Fig 10 gives the distribution of the 1983 year class in May 1985
(Hamre and Dommasnes 1985). Compared with January a westerly migration
has taken place, and the eastern border is now approximately at 40°E.
The herring was recorded both as small schools and as scattering
layers form 50 m to 100 m depth. In some parts of the distribution
area the herring was mixed with capelin, the capelin layer was usually
deeper than the herring recordings.

Returning to the coastal areas, a tagging survey was conducted on the
Norwegian coast south of 68°N in April-May. Small schools of herring
of the 1983 year class were recorded off Møre and Helgeland. This
herring had a far greater growth rate than the herring recorded in the
Barents Sea. (Fig 11).

The 1983 year class of Norwegian spawning herring as......
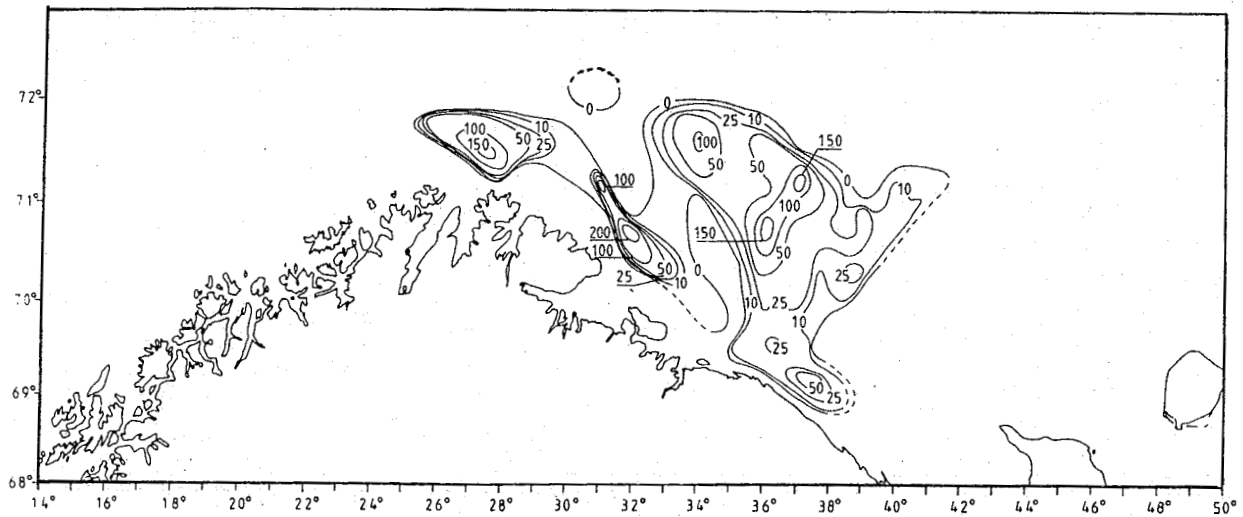
Fig. 10. Norwegian spring spawning herring.
Distribution of the 1983 year class in May 1985. Numbers
denote tonnes per naut. mile^2. (Hamre and Dommasnes 1985).
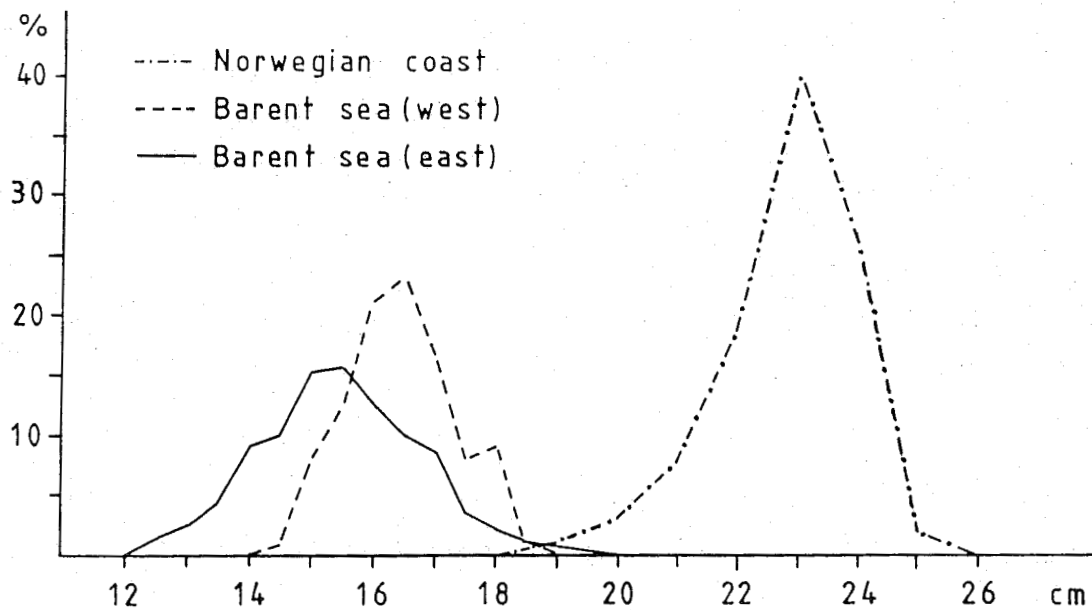
Fig. 11. Norwegian spring spawning herring.
Length distribution of the 1983 year class in May 1985).

September 1985

Fig 12 shows the distribution of the 1983 year class in September 1985
A comparison with Fig 10 (May 1985) shows that there was no major
change in geographical distribution of the 1983 year class in the
Barents Sea during the summer season of 1985. In September the herring
were mostly distributed in dense schools near the surface during
daytime, but there were also recorded schools of herring down to
100-150 m depth. During night time the schools were dissolved and the

The 1983 year class of Norwegian spawning herring as......
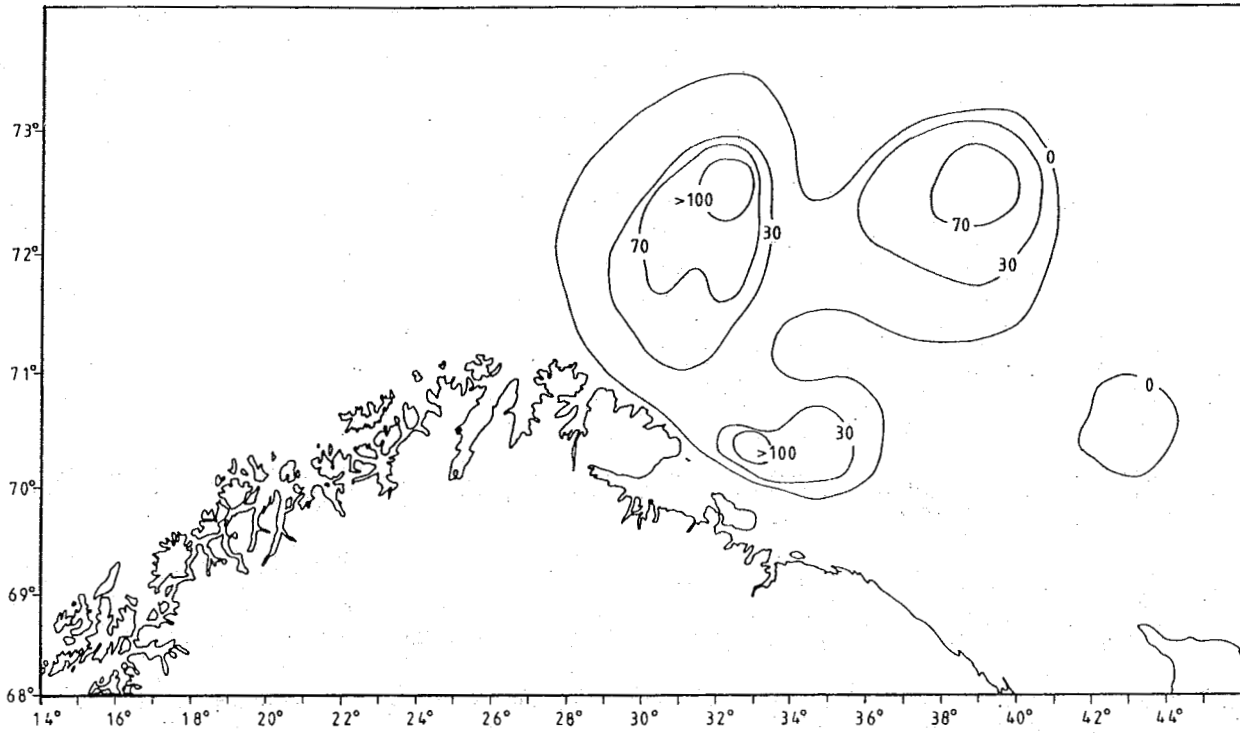
Fig. 12. Norwegian spring spawning herring.
         Distribution of the 1983 year class in September 1985.
         Numbers denote tonnes per naut. mile^2.
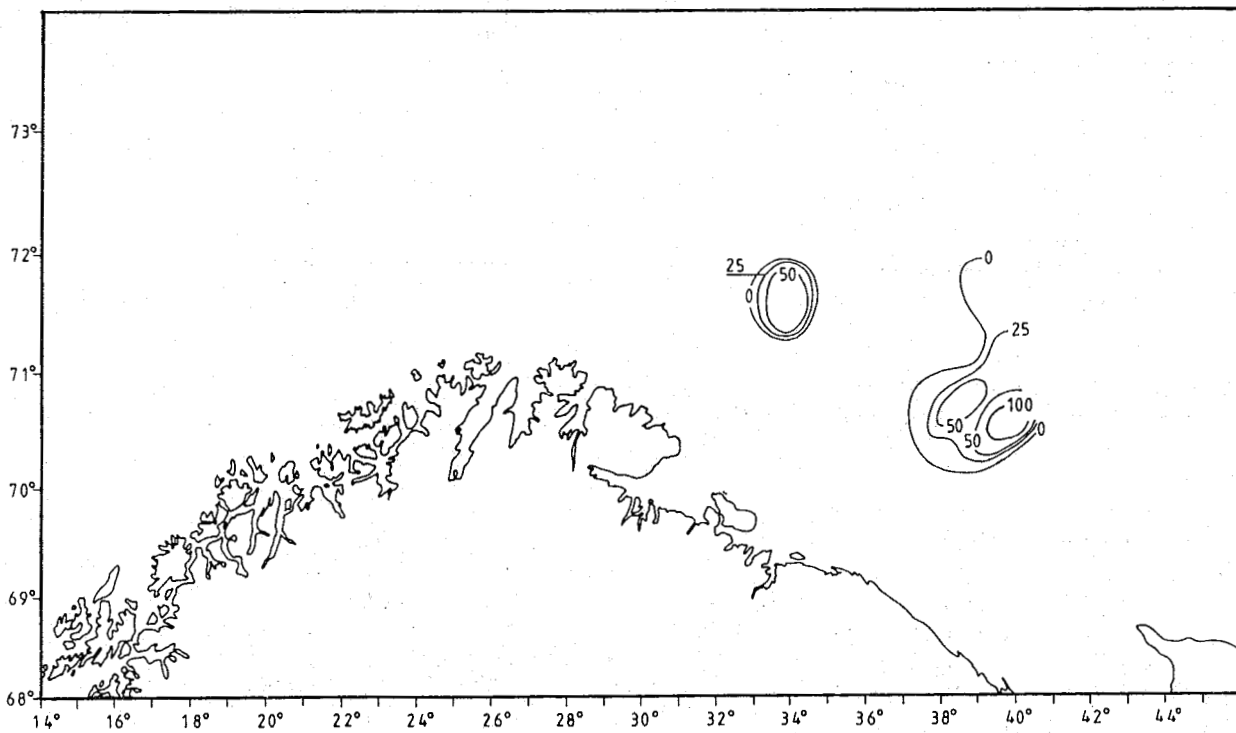
Fig. 13. Norwegian spring spawning herring.
         Distribution of the 1983 year class in November 1985.
         Numbers denote tonnes per naut. mile^2.

herring was recorded in scattering layers. Some 0-group herring and
juvenile cod and haddock were recorded together with the II-group
herring.

November 1985

Fig 13 shows the distribution of the 1983 year class in November 1985.
The herring of the 1983 year class occurred together with 0-group
herring. Only the area west of 41^0E was surveyed. Fig 11 and 13 show
that a comprehensive migration had taken place eastwards during a time
interval of 2 months.The herring in the eastern part of the
distribution area were mostly recorded as a scattering layer in the
upper 50m of the water masses.

In November 1984 considerable amounts of I-group herring were recorded
in the fjords of Northern Norway, especially north of 69^0N. Very
little II-group herring were recorded in these areas in November 1985,
by this time the far greater part of the herring of the 1983 year
class had migrated from this area. South of Lofoten (68^0N) no herring
of the 1983 year class were found in the fjord areas in November 1985.

Scenario at the end of 1985

Two different "populations" of the 1983 year class could still be
recognized:

A) In the Barents Sea, the main concentrations of the 1983 year class
undertook a western migration in the winter months, from an area
around 40^0E to an area off eastern Finnmark and Kola. In the summer
season the geographical distribution remained relatively constant, but
in October a migration to the eastern part of the Barents Sea took
place. In winter the herring in the Barents Sea occurred together with
capelin,in autumn the concentrations of the 1983 year class were mixed
with 0-group herring (1985 year class).

B) On the coast, herring of the 1983 year class migrated from the
inner part of the fjords where they were distributed as 0-group. Minor
parts of the herring were found in the outer coast areas south of 68^0N
in spring. Further,the 1983 year class began to appear in the coastal
herring fishery in autumn of 1985. This herring had a larger growth
rate than the herring distributed in the Barents Sea.

YEAR 1986

January 1986

Fig 14 shows the distribution of III-group herring in January 1986.
This was the most eastern distribution of the 1983 year class that had
been observed since June 1984. From about 38^0E and eastwards, the
herring was recorded as a "carpet"near the bottom. At some locations,
(approximately 72^0N, 46^0E), denser concentrations appeared as
"columns" rising up to 50m from the sea bed. West of 38^0E, some large
schools of herring were detected, particulary in the area north and
east of the Skolpen Bank. In the period January-April 1986 a fishery
on the 1983 year class of herring was carried out by USSR in ICES area
I (eastern part of the Barents Sea). The total catch in this fishery
was approximately 25 thousand tonnes.
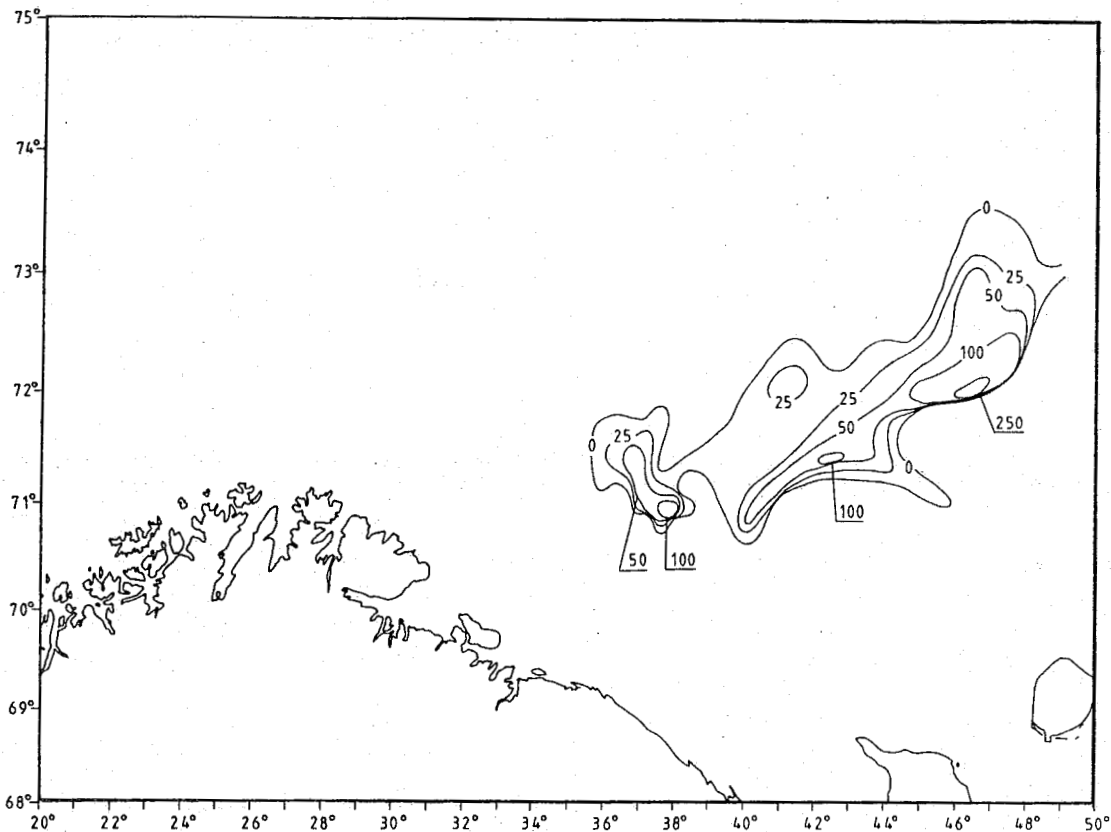
Fig. 14. Norwegian spring spawning herring.
        Distribution of the 1983 year class in January 1986.
        Numbers denote tonnes per naut. mile².

Spawning season, February-March 1986

In 1986 herring of the 1983 year class appeared for the first time on
the spawning grounds off Møre. About 7% of the herring in the spawning
areas (large variations from area to area) belonged to this year
class. This was herring with a larger growth rate than that of the
herring of the same year class in the Barents Sea. However, less than
10% of the 1983 year class which appeared on the spawning grounds had
maturing gonads and may therefore have been recruit spawners, the rest
were immature fish.

May 1986

Fig 15 gives the distribution in May 1986. There was now an extended
east-west distribution in a "belt" of approximately 40-50 nautical
miles width. The herring was mostly recorded as a scattering layer in
150-200 m depth. The density of the herring was much lower than
recorded during previous surveys.

Herring were also recorded in the coastal areas. During a tagging
survey in April 1986 schools consisting of 1983 year class herring
only were recorded in the outer coastal areas between 66°N and 67°N.
This herring had a larger growth rate than the herring in the Barents
sea (Fig 16).

The 1983 year class of Norwegian spawning herring as......
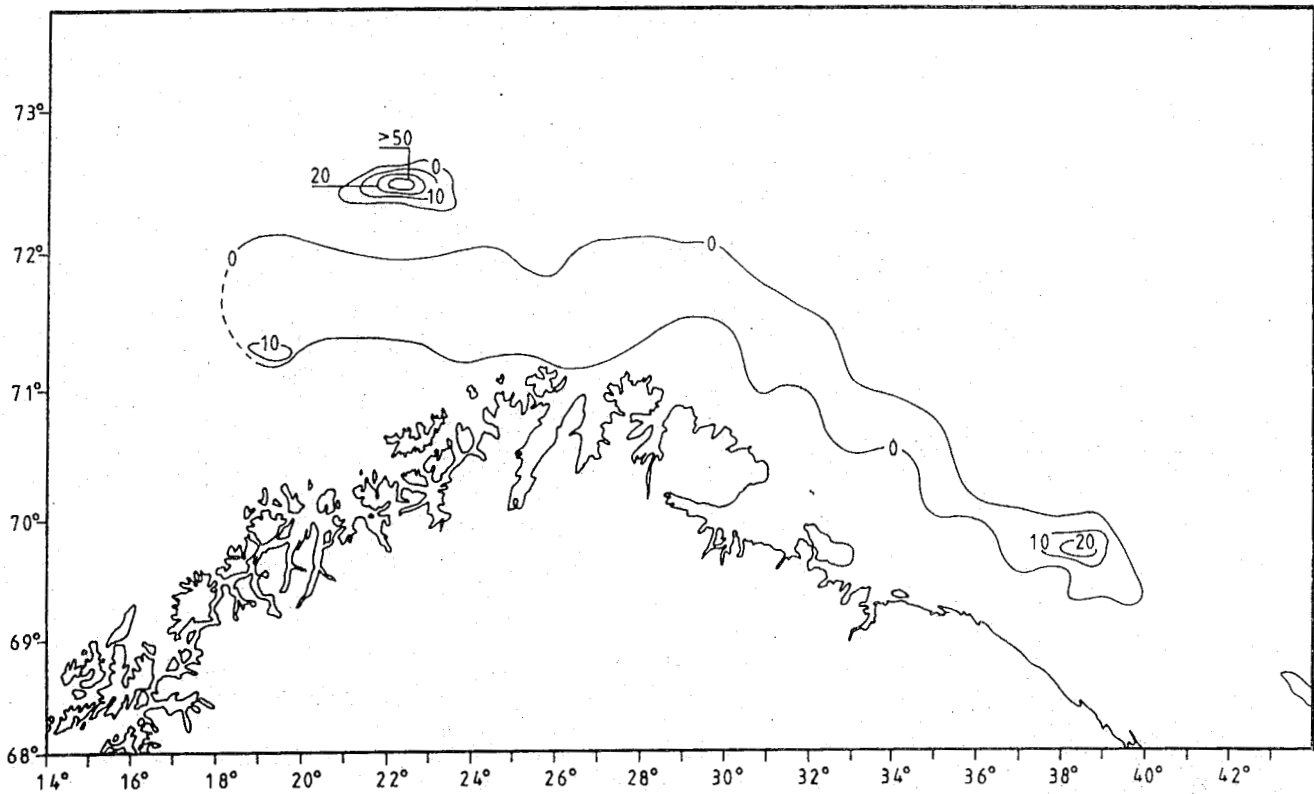
Fig. 15. Norwegian spring spawning herring.
Distribution of the 1983 year class in May 1986.
Numbers denote tonnes per naut. mile^2.
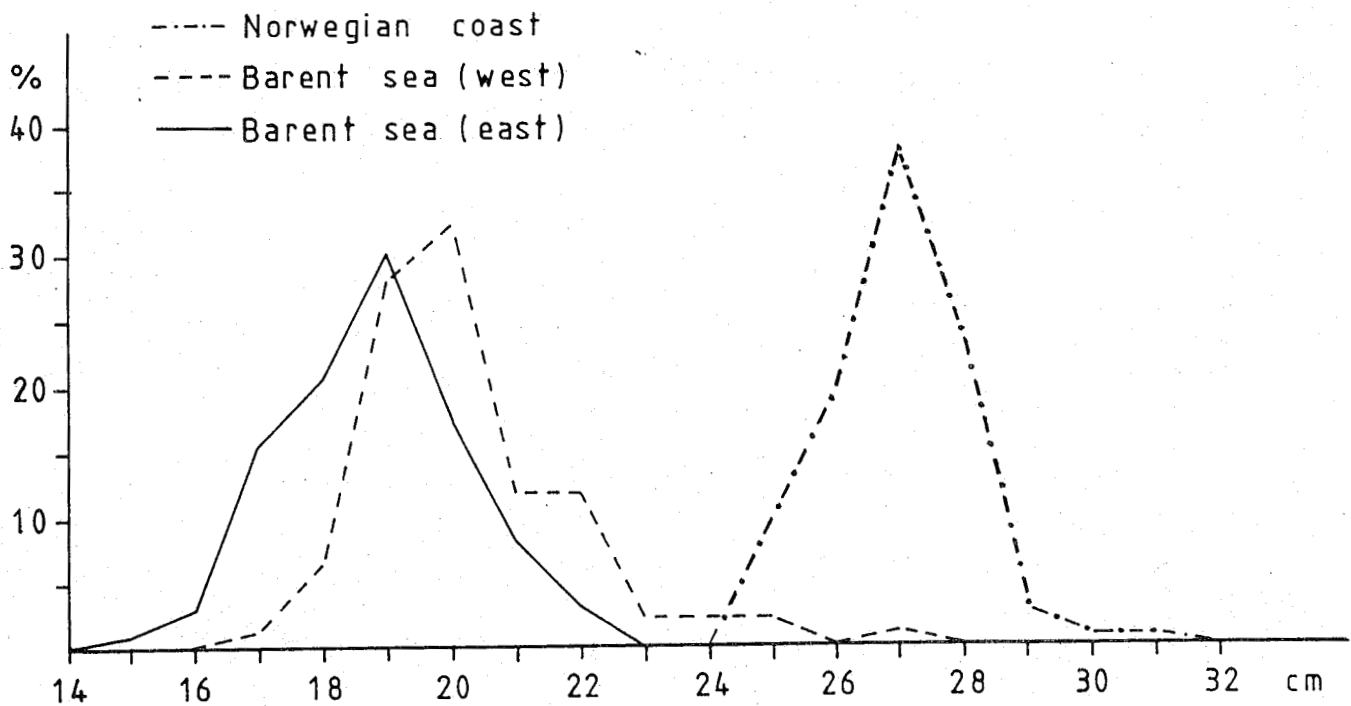
Fig.16. Norwegian spring spawning herring.
Length distribution of the 1983 year class in May 1986.

The 1983 year class of Norwegian spawning herring as......
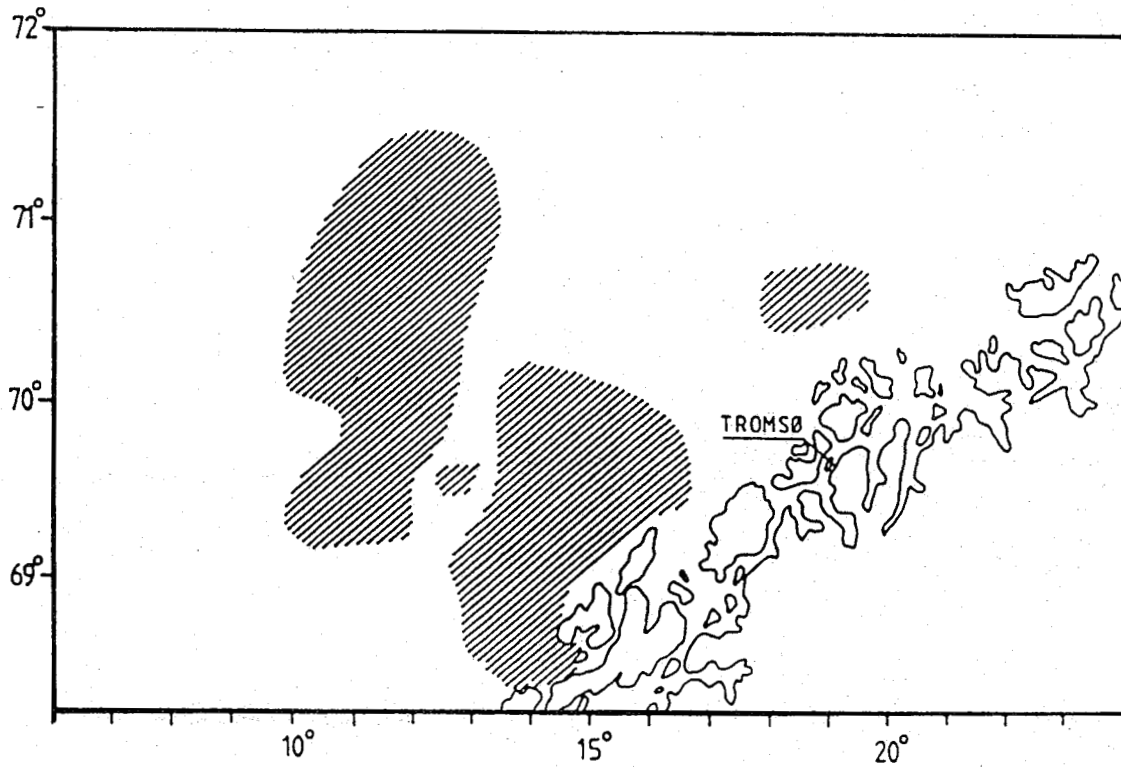
Fig. 17. Norwegian spring spawning herring.
         Distribution of the 1983 year class in August 1986.
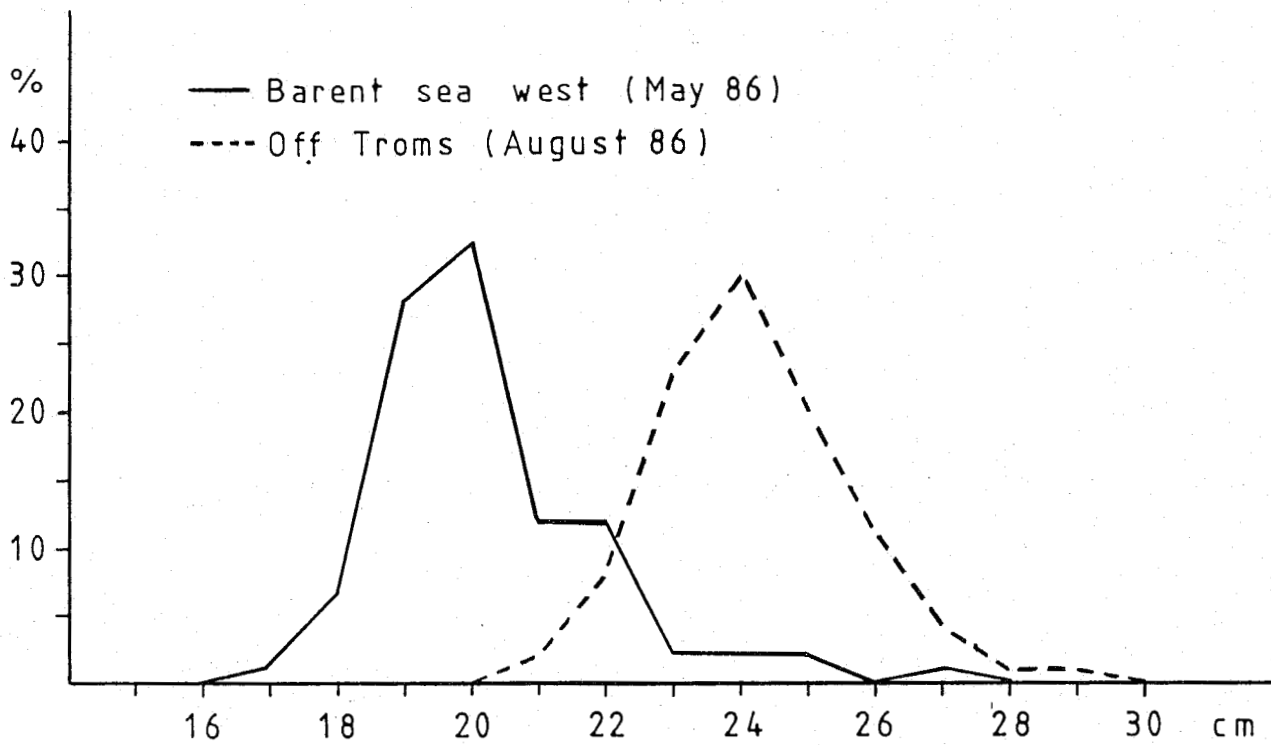
Fig. 18. Norwegian spring spawning herring.
         Length distribution of the offshore distributed herring
         in May 1986 (Barents Sea) and August 1986 (Norwegian Sea).

August 1986

By this time the 1983 year class had emigrated from the Barents Sea
and there were observations of scattered concentrations up to 150
nautical miles of the coast of Norway from 64°N to 70°N (Fig 17).The
main concentrations were found north of 68°N. In this period the
herring were located in various depths from near the surface to
depths of 200-300m. The sonar recordings near the surface consisted of
small schools, the larger schools were located in depths of 50m and
deeper. The mean length of the 1983 year class had increased
considerably since the herring left the Barents Sea (Fig 18).

November 1986

The herring in the offshore areas had concentrated nearer the coast,
between 66°N and 67°N. (Fig 19). The herring were now located in
schools near the surface during night time (0-50m) and near bottom or
down to 250-300m depth during daytime. The size of the schools showed
large variations, during night the herring often split into small
loose schools.

In autumn 1986 the 1983 year class became abundant in the catches in
Norwegian herring fishery. The fishery took place in the fjord areas
were the herring had wintered since the stock collapse and the
migration to the feeding and wintering grounds in the Norwegian Sea
terminated. The 1983 year class occurred together with older herring
on the wintering grounds.
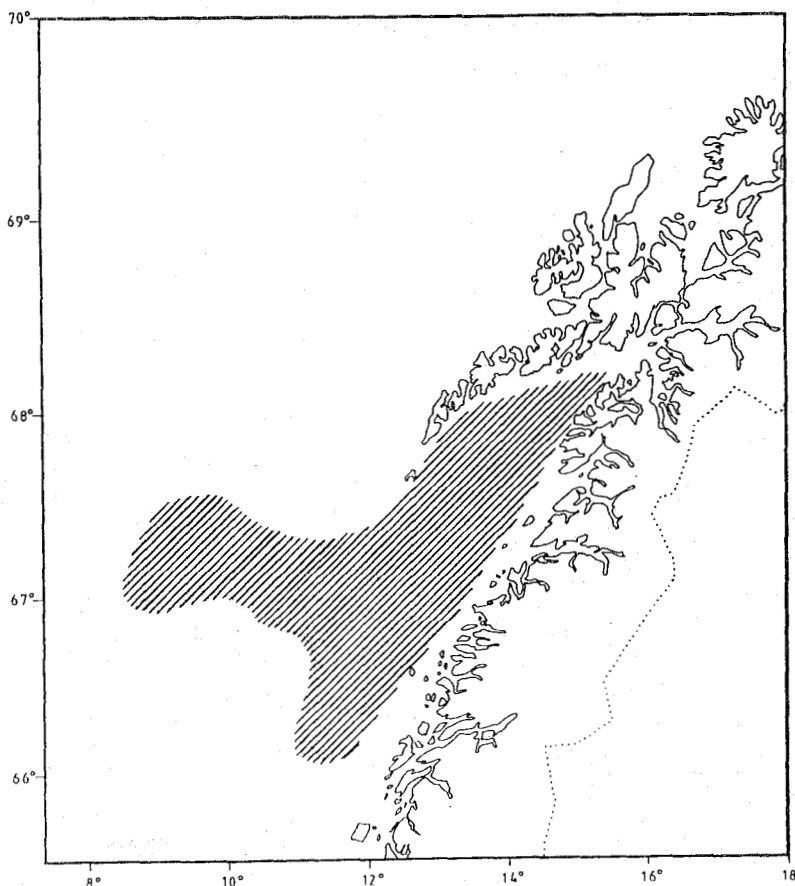
Fig. 19. Norwegian spring spawning herring.
          Distribution of the 1983 year class in November 1986.

Scenario at the end of 1986

A very small fraction of the 1983 year class (less than 1%) seemed to
be recruit spawners in winter 1986. These herring spawned on the
traditional spawning grounds off Møre. They were   not herring
originating from the Barents Sea nursery area.

In 1986 the two types of herring of the 1983 year class could still be
recognized. Some herring were recorded on the traditional spawning
sites off Møre in February-March,in the outer costal areas in spring
and in wintering areas in some fjords from October/Nowember. These
herring had a large growth rate.

But by far the larger part of the 1983 year class was in winter/early
spring of 1986 located in the eastern part of the Barents sea. In
spring of 1986 a fundamental change in the distribution of the 1983
year class took place. In May-June the whole offshore population of
the 1983 year class migrated westwards out of the Barents Sea and into
the Norwegian Sea off the Norwegian coast. The "stay" in the Barents
Sea nursery area had thus terminated.

YEAR 1987

January 1987

Fig 20 shows the wintering distribution area of the herring (January
1987). During day time the herring occurred in schools in 100-200m
depth, during night time the herring ascended to the upper 50m and
often occurred in large dense schools.
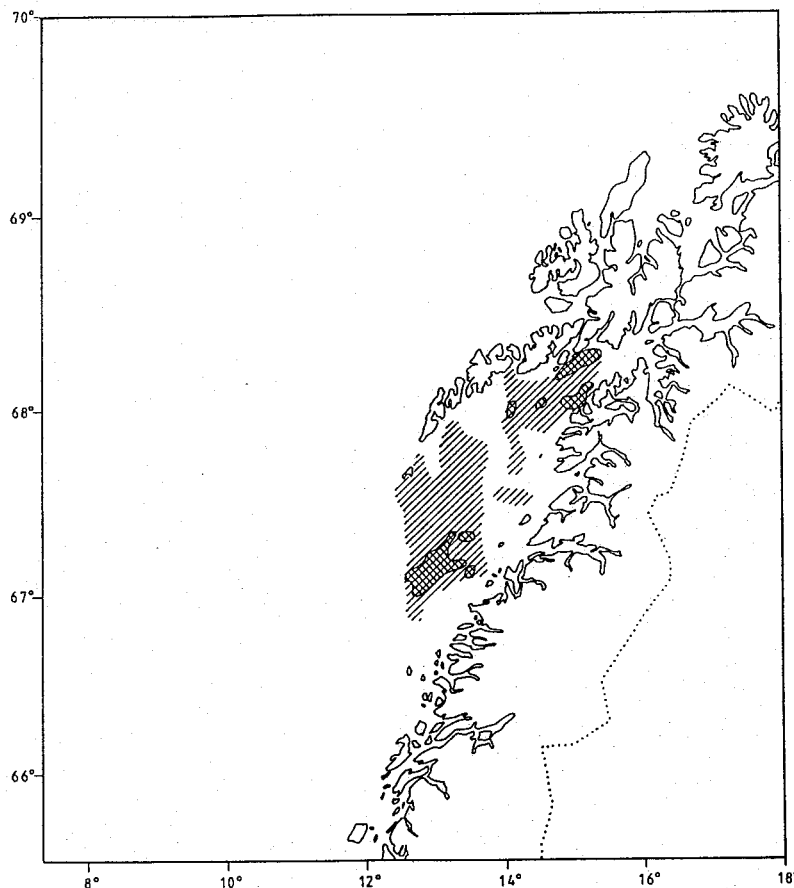
Fig. 20. Norwegian spring spawning herring.
         Distribution of the 1983 year class in January 1987.

Spawning season, February-March 1987

This year the 4 year old herring dominated the biological samples from
the traditional spawning sites off Møre. The geographical distribution
of the 1983 year class is given in Fig 21. On the spawning grounds the
herring mostly occurred in loose schools or in scattering layers.
There were observed only a few dense schools in February-March 1987.
The herring of the 1983 year class were mixed with older herring on
the spawning fields. About 40-60% of the 1983 year class which was
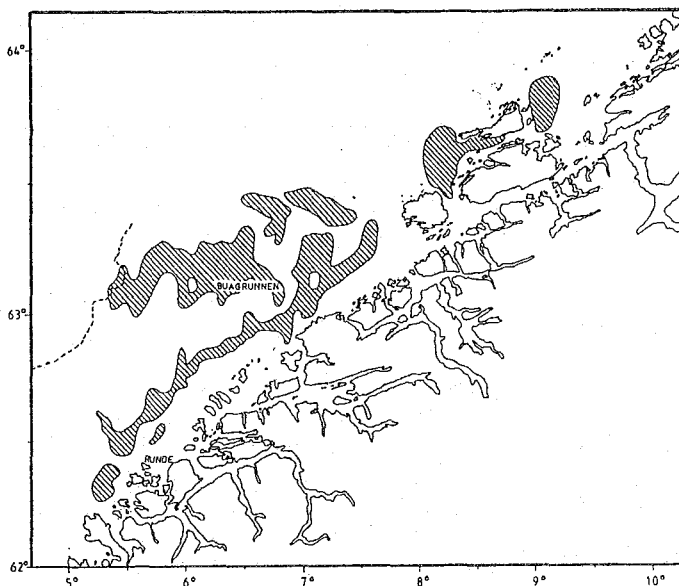
Fig. 21. Norwegian spring spawning herring.
          Distribution of the 1983 year class on the spawning sites
          off Møre in February/March 1987.

recorded on the spawning grounds were recruit spawners. But the
greater part of the 1983 year class were still immature and therefore
did not appear on the spawning grounds. The average length of the
herring of the 1983 year class in the spawning areas was approximately
28 cm. However, one sample from the southern part of the distribution
area had a mean length of 31 cm. This may have been herring of coastal
origin.

April-May 1987

The main offshore concentrations were now located to the north of the
spawning sites (Fig 22), and the extension of the distribution area
had increased.

In April-May 1987 schools consisting of 1983 year class of herring
were recorded in the outer coastal area between 66°N and 67°N.
However, according to the length distributions, this was obviously not
the same type of herring as was recorded in the same area in April-May
in 1985 and 1986. The mean length of the herring was actually greater
in 1986 than in 1987 (Fig 23), indicating that the fast growing
herring in this area in 1985 and 1986 had been replaced by a herring
with a slower growth rate in 1987. The "new" herring in this area
probably originated from the nursery areas in the Barents Sea.

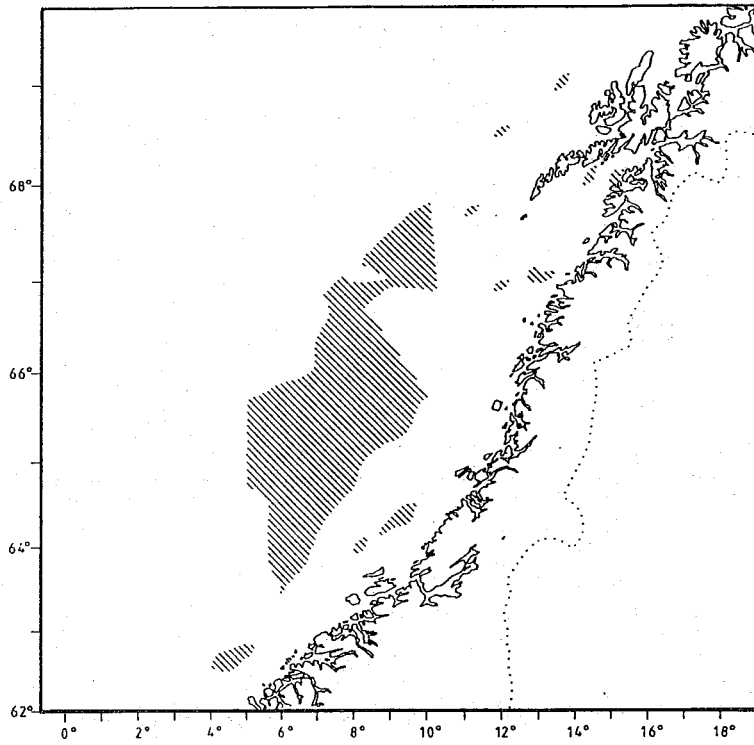The 1983 year class of Norwegian spawning herring as......
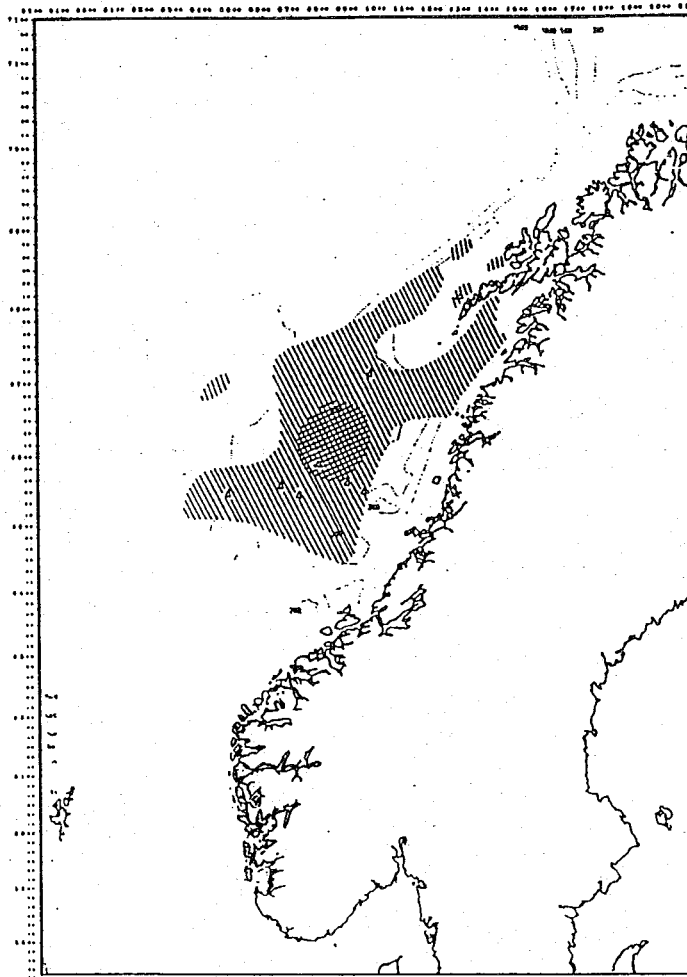
Fig. 22. Norwegian spring spawning herring.
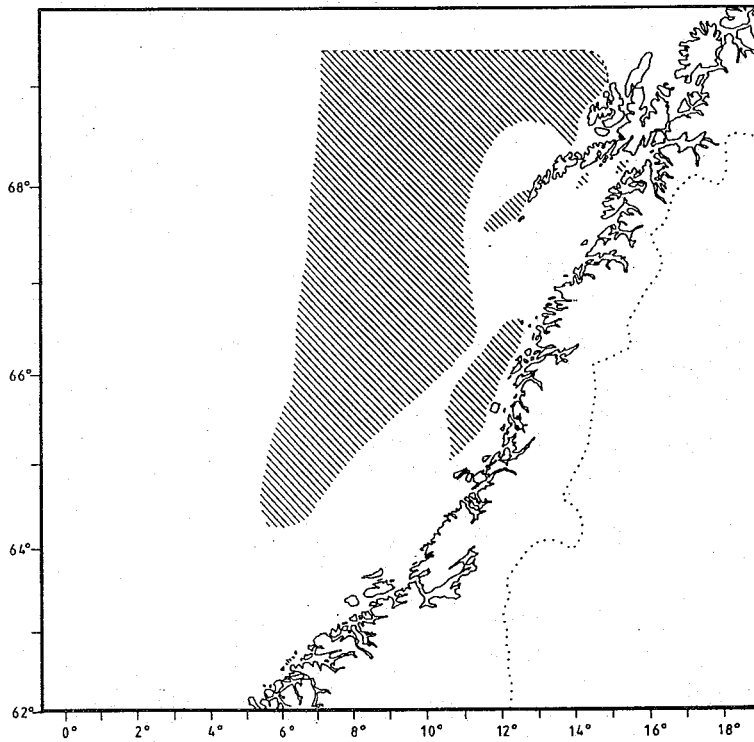   Distribution of the 1983 year class in May 1987.
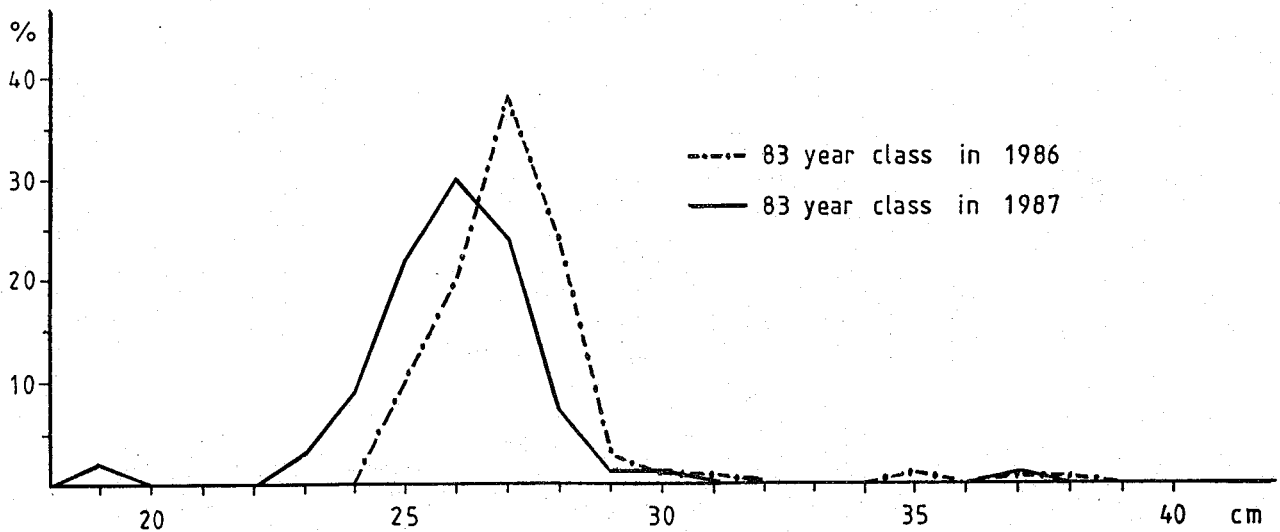
Fig. 23. Norwegian spring spawning herring.
         Length distribution of the 1983 year class in Norwegian
         coastal waters off Helgeland (between 65°N and 68°N) in
         April 1986 and April 1987).

June-July 1987

The migration of the offshore distributed herring continued
northwards; the distribution area for July 1987 is given in Fig 24. In
the period April-July 1987 the herring mostly occurred in small
schools near the surface. The herring recordings were mixed with
plankton recordings.
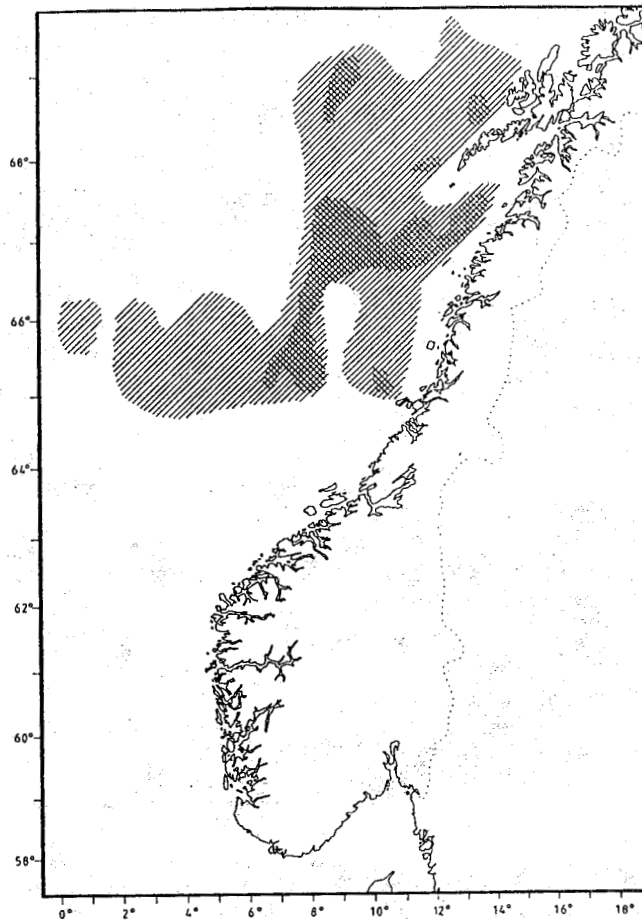
Fig. 24. Norwegian spring spawning herring.
         Distribution of the 1983 year class in July 1987.

August 1987

Medio August 1987 the 1983 year class concentrated in the area west of
Lofoten (Fig 25). Compared with the period April-July, the behaviour
of the herring had changed. The herring concentrated in a rather dense
scattering layer in about 10-20m depth during most of the day. This
was typical "fat herring", with a lot of fat in the intestine area.
The gonads were poorly developed.

September 1987

In September the main concentrations of herring had migrated into the
Vestfjord area (Fig 26). By this time the herring began to make
extensive vertical migrations. During day time the herring were
recorded in schools at 250 m to 300 m depth, rising towards the
surface and dispersing during night. The gonads were considerably more
developed than in August.
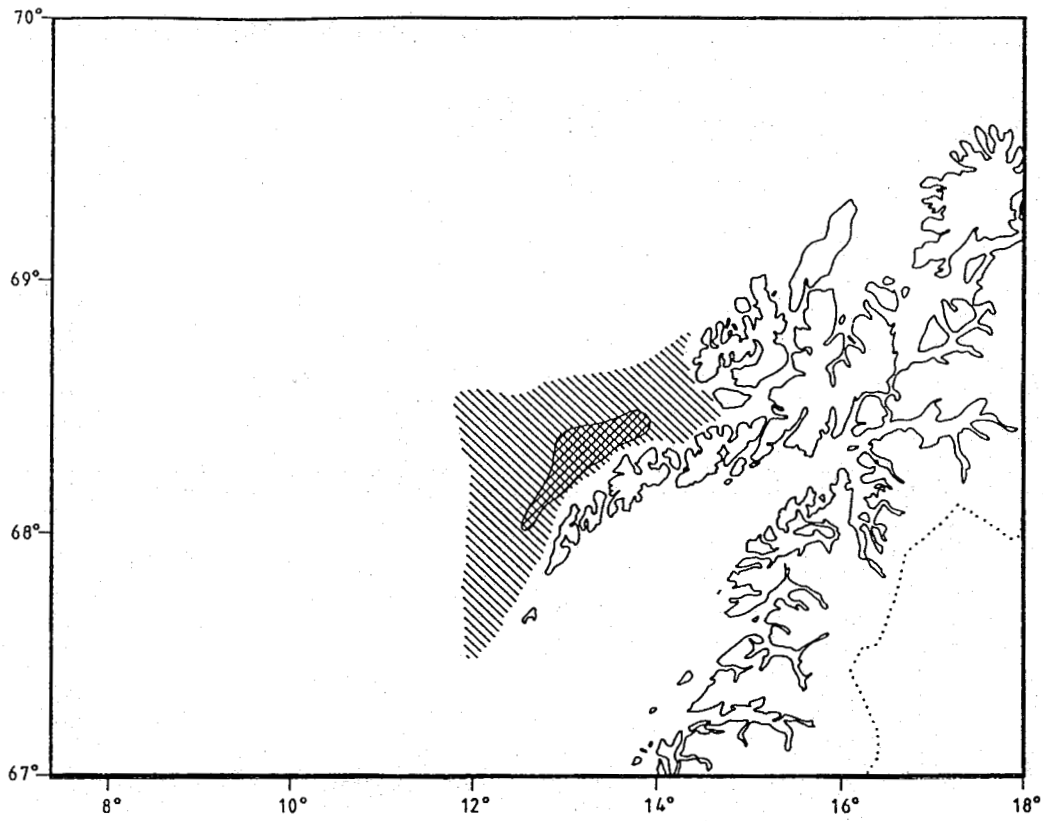
Fig. 25. Norwegian spring spawning herring.
        Distribution of the 1983 year class in August 1987.
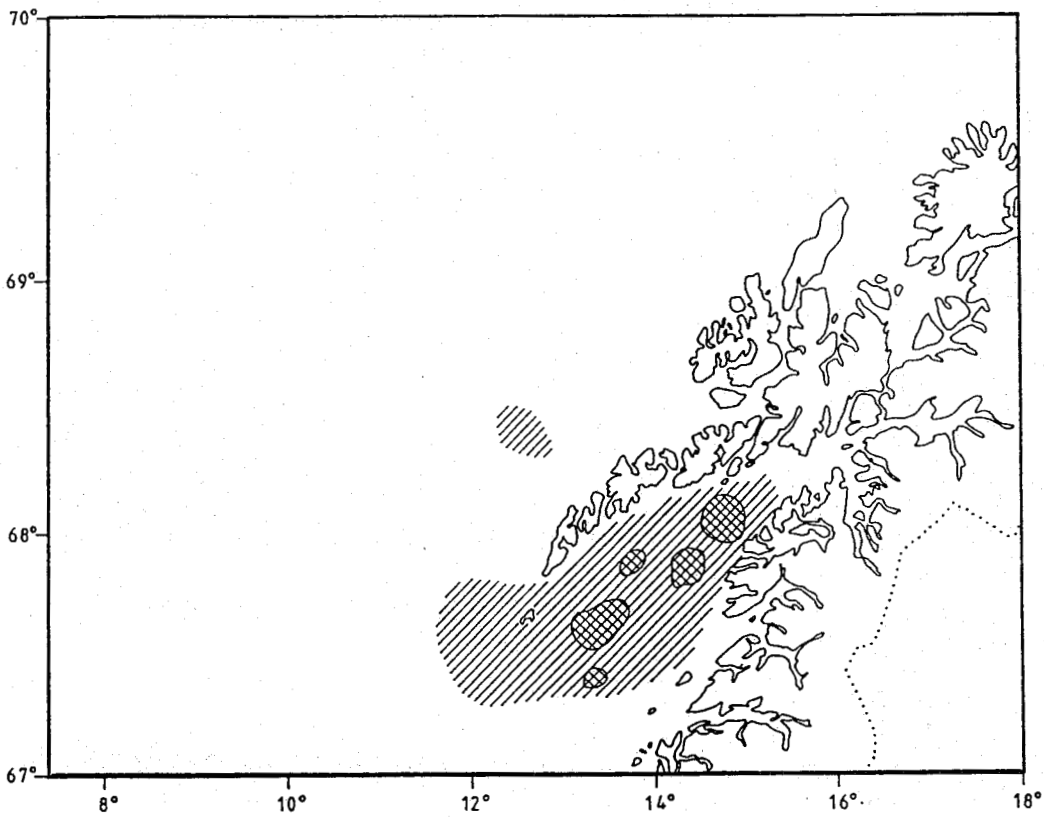
Fig. 26. Norwegian spring spawning herring.
        Distribution of the 1983 year class in September 1987.
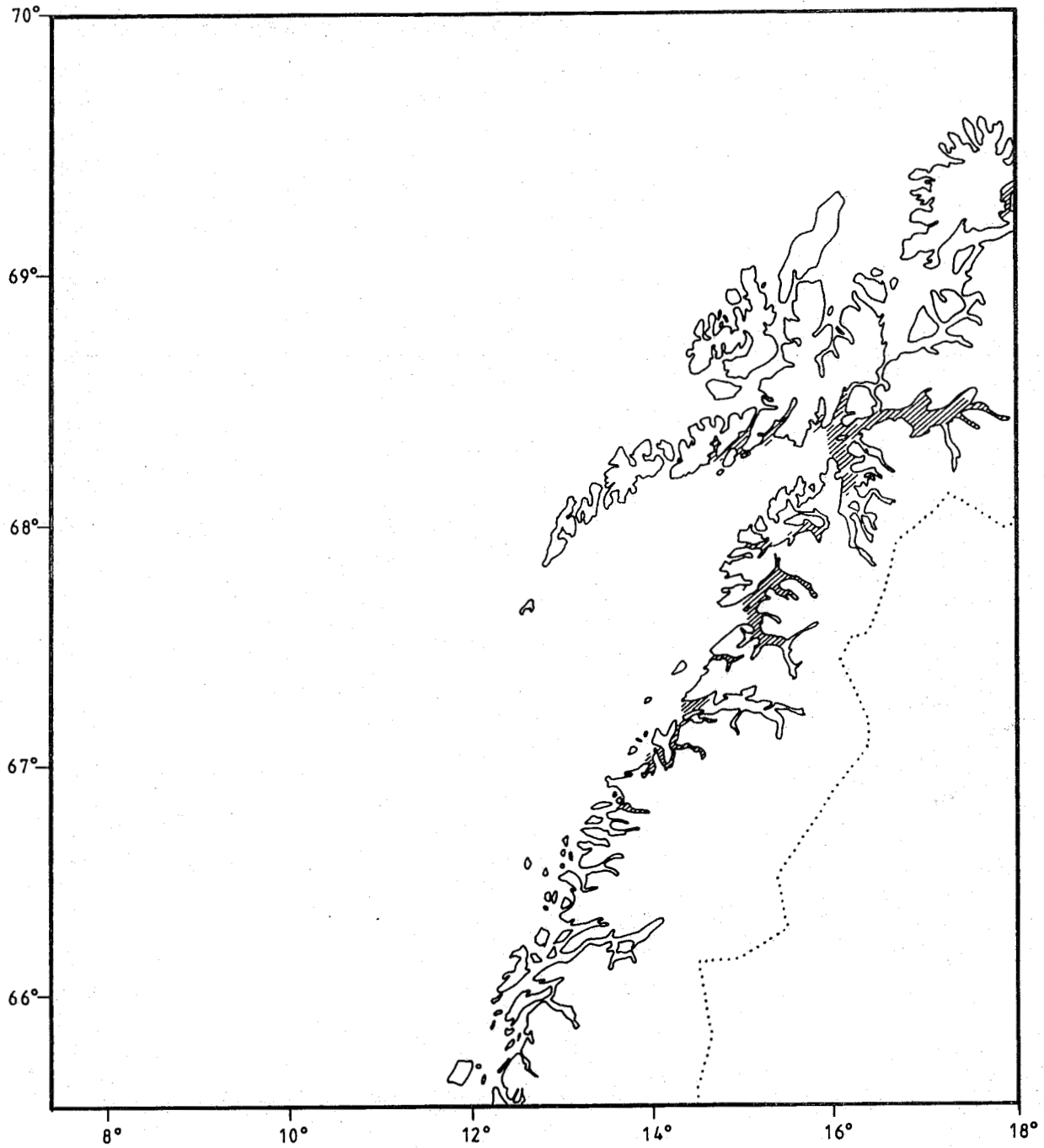
Fig. 27. Norwegian spring spawning herring.
        Distribution of the 1983 year class in November 1987.

November 1987

In October the herring migrated further into the Vestfjord, and by
November the herring which since 1983 had been distributed offshore,
were now located in the tributary fjords of the Vestfjord (Fig 27).
Here the herring occurred in enormous schools, often extending over
several nautical miles. The herring undertook vertical migrations (Fig
28). The gonads were further developed, and the amount of fat in the
intestine had clearly decreased compared with August/ September. The
herring wintered in the Vestfjord until the end of January 1988.
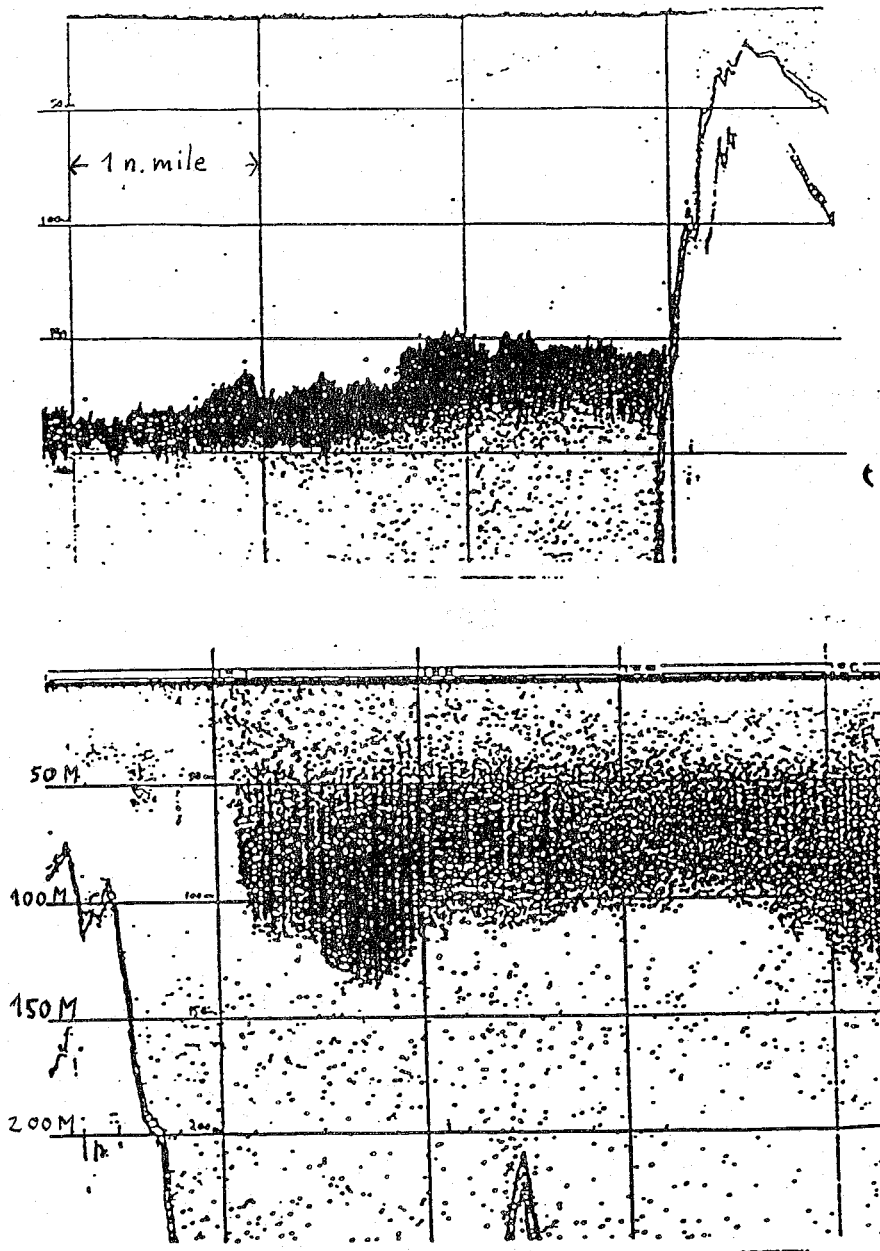
Fig. 28. Norwegian spring spawning herring
          Echo recordings during daytime (upper) and nighttime
          (lower) of the 1983 year class from approximately the same
          location in the Ofotfjord in November 1987.

The 1983 year class of Norwegian spawning herring as......

Scenario at the end of 1987

A minor part of the 1983 year class matured and spawned on the
traditional spawning sites in 1987. After spawning the herring did not
resume the feeding migration routes from the time prior to the stock
collapse, i.e. to the Jan Mayen- North Iceland area. The feeding areas
in 1987 were from the coastal areas of northern Norway between 64°N
and 70°N and extending approximately 200 nautical miles in the
Norwegian Sea. In August the herring concentrated west of the Lofoten
Islands, and in September they migrated into the Vestfjord, and in
October further east into the tributary fjords of the Vestfjord. The
wintering areas in 1987/88 (Fig 17) were thus slightly different from
1986/87, the latter wintering area was in the outer part of the
Vestfjord (Fig 20).

YEAR 1988

February 1988

According to data from the fisheries, the main part of the 1983 year
class appeared on the spawning sites off Møre in mid-February. Fig 29
gives the area where spawning herring were recorded in the period
22.2-19.3 1988. The main spawning grounds were from Statt (62°N) to
Kristiansund, and some spawning was also recorded north to Vikna.
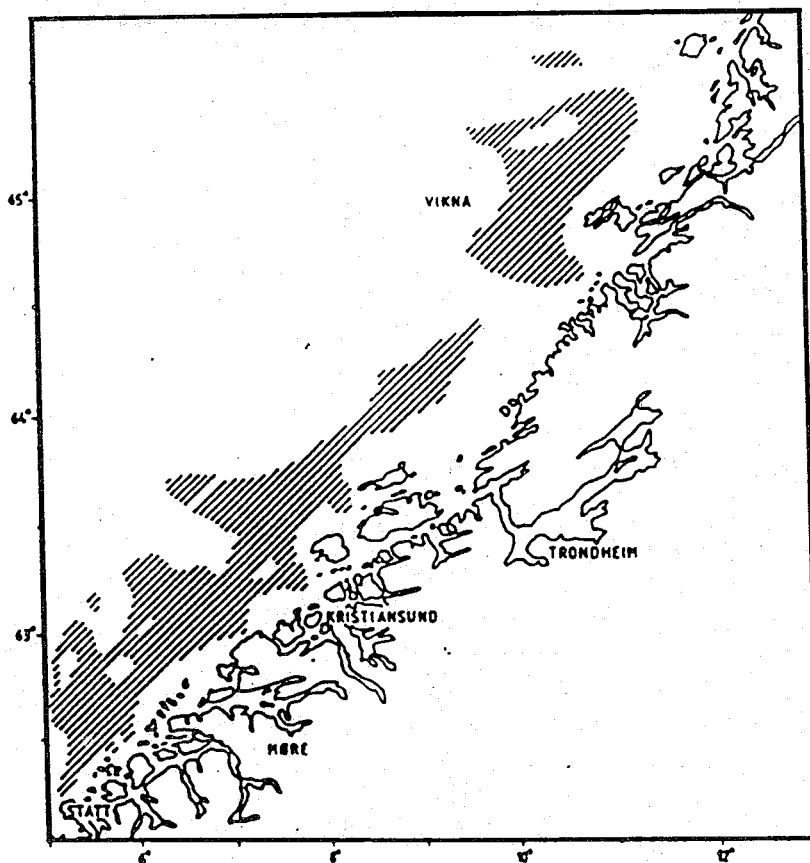
Fig. 29. Norwegian spring spawning herring.
          Distribution of the 1983 year class on the spawning sites
          off Møre in February/March 1988.

There were very few records of spawning herring in the Lofoten-
Vesterålen area. The spawning grounds were essentially the same as in
the period 1974-1987. In 1988, approximately 95% of the spawning stock
consisted of 1983 year class herring. During day time the herring on
the spawning grounds were distributed "hard" down to the bottom and
were very difficult to observe on the echo recorder. Only in a few
restricted areas could schools be seen near the bottom. However,
during night time the herring rose and dispersed in the upper 100
meters of the water masses. Fig 30 shows a typical night recording on
the spawning fields in February 1988. The main spawning commenced by
the end of February in the southernmost part of the distribution area.
Spawning on spawning grounds south of Statt was not resumed to any
extent in 1988.
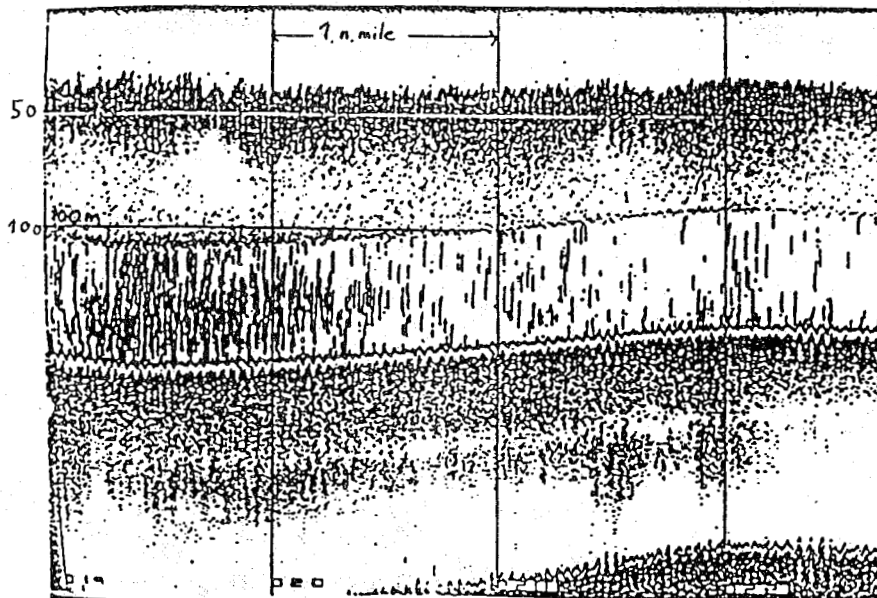
Fig. 30. Norwegian spring spawning herring.
          Nighttime echo recording of spawning herring.
          Møre, February 1988.

April 1988

The feeding migration in 1988 seems to have followed the same pattern
as in 1987. The spent herring have moved in a northern direction from
the spawning grounds and the geographical distribution at the end of
April 1988 is outlined in Fig 31. The distribution area is located off
the Norwegian coast mainly between $64^\circ N$ and $68^\circ N$ and extending
approximately 150 nautical miles westwards.

May 1988

The geographical distribution in May 1988 is shown in Fig 32. Compared
to the end of April 1988 the herring have migrated further north and
are dispersed over a wider area.

Fig. 31. Norwegian spring spawning herring.
        Distribution of the 1983 year class in April 1988.

Fig. 32. Norwegian spring spawning herring.
        Distribution of the 1983 year class in May 1988.

August 1988

The herring migrated eastwards during summer, and were located in the
outer part of the Vestfjord in August(Fig 33). However, some herring
were distributed west of the Lofoten Islands were the main
concentrations were located in August 1987 (Fig 25). The herring were
recorded as a more or less continuous layer at the bottom
(approximately depth 200-250 m) and to about 30-40m above bottom. But
from midnight to approximately 4 a.m., the herring rose and formed a
scattering layer in the upper 50 meters of the water masses.
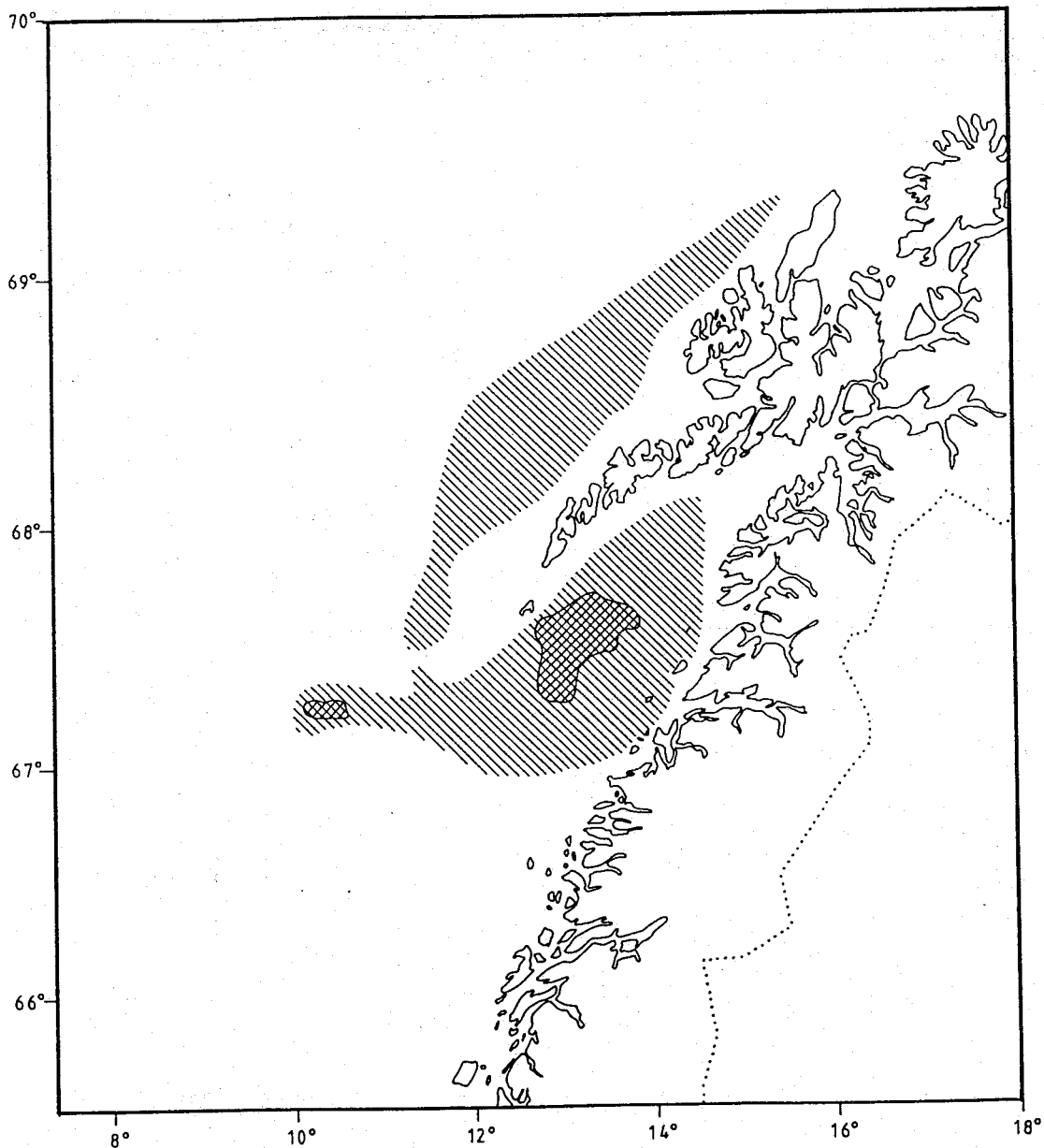
Fig. 33. Norwegian spring spawning herring.
          Distribution of the 1983 year class in August 1988.

November 1988

By November 1988, as was the case in November 1987, the herring had
migrated further into the Vestfjord and were now located in the
tributary fjords. In 1988 the main concentrations were found in
Ofotfjord, Tysfjord and Lavangen. The behaviour was similar to that of
November 1987.

Scenario at the end of 1988

In 1988 the major part of the 1988 year class matured and spawned. The
spawning and feeding migrations in 1988 were similar to 1987, thus the
1983 year class seemed to have established the spawning and wintering
areas and the migration cyclus. This cyclus was different from that of
the time prior to the stock collapse, as the 1983 year class did not
resume the feeding migration to the Jan Mayen/North Iceland area.

YEAR 1989

February-March 1989

Fig 34 gives the distribution of herring on the spawning fields in
February-March 1989. The main spawning fields are similar to 1988.
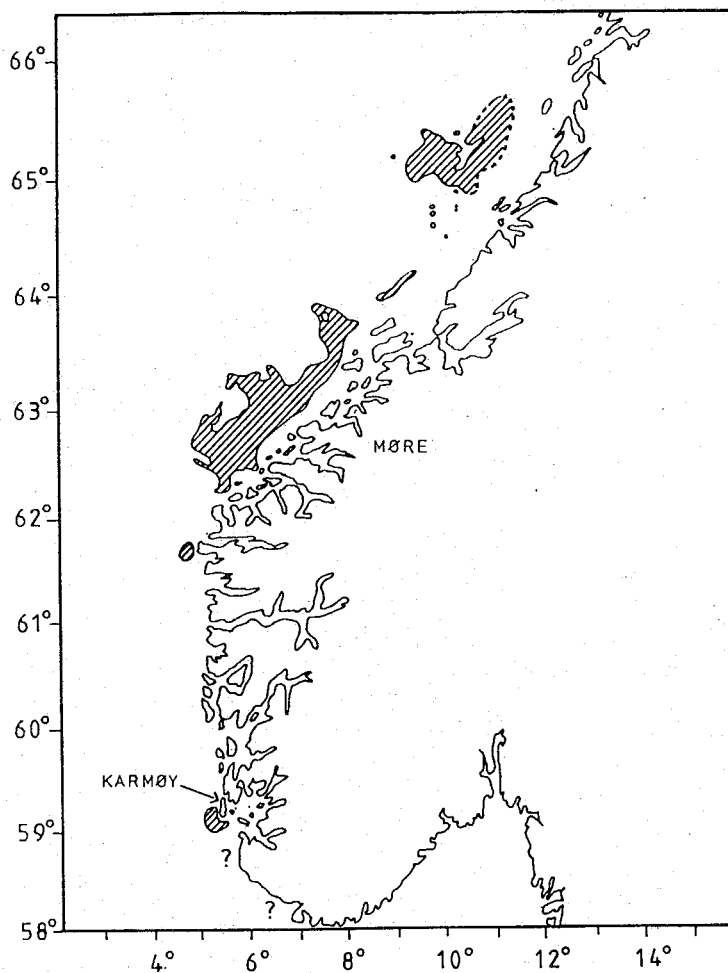
Fig. 34. Norwegian spring spawning herring.
         Distribution of the 1983 year class on the spawning
         sites in February/March 1989.

However, spawning herring were recorded off Karmøy (approximately 59°N) and there were also reports of spawning herring from areas further south, perhaps to Siragrunnen (approximately 58°N) Prior to 1955, these were important spawning grounds for the Norwegian spring spawning herring. Fig 35 gives the length and age distribution of the herring from the spawning area at Karmøy. This was practically the same length and age distribution as the herring on the spawning sites off Møre. At present it is not known if this herring had their nursery area in the Barents Sea, or if they are of coastal origin.
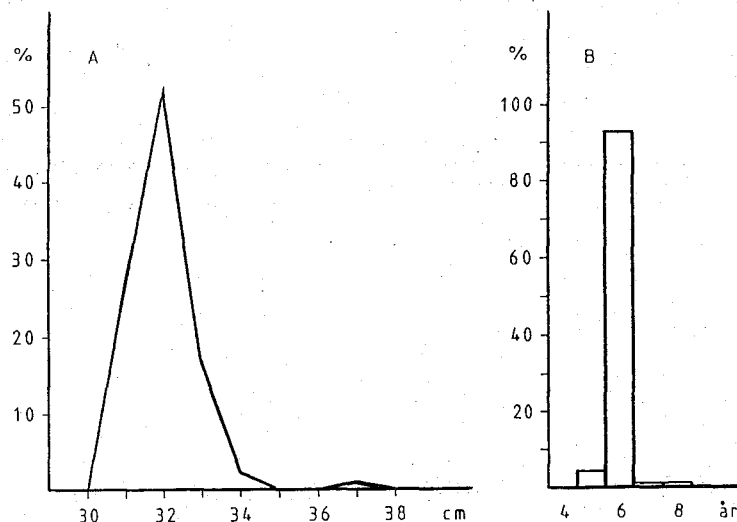
Fig. 35. Norwegian spring spawning herring.
Length and age distribution of spawning herring at Karmøy, March 1989.

Acoustic abundance estimates

Absolute abundance estimates of the 1983 year class have been made by the use of acoustic techniques. The procedures, development history, theoretical basis and the application of this technique to pelagic fish in northern waters are described in a paper to the Soviet-Norwegian symposium on Barents Sea capelin in August 1984 (Dommasnes and Røttingen 1985).

A central key in the acoustic abundance estimation is the target strength - fish length relation which is used to convert the acoustic data to number of fish. The 0-group herring in Norwegian waters have been measured acoustically since 1975 (Røttingen 1987a). The following target strength - length relation has been utilized to convert the acoustic data to number of fish during these surveys:

$$TS = 19.1 \log L - 74.0$$

This is the same target strength - length relation as is utilized for absolute abundance estimates of Barents Sea capelin, and its origin is a combination of:

1) Counting capelin traces on the echogram paper and relating this to the actual integrator value obtained from the recording.

2) The length dependant dimension (19.1 logL where L is the length of the fish) originates from experimental measurements of several clupeoid fish (Dalen et al. 1976).

The target strength - length relation is not based on 0-group herring data exclusively, and abundance estimates of 0-group and young herring based on this conversion factor should be used with care when applied in an absolute sense. However, this was the only target strength - length relation "available" when the systematic 0-group herring investigations started in 1975.

The Working group on Atlanto-Scandian herring has thus not applied these estimates as absolute, they have applied the estimates as abundance "indices", and a non-biological "conversion factor" has been used to convert the 0-group number for a certain year class to number of recruit spawners 4 years later. Other difficulties have been encountered during the acoustic survey work on the 1983 year class in the Barents Sea. The survey in November 1983 was severely hampered by bad weather and the total distribution area was therefore probably not covered. In 1984 and especially in 1985 the herring recordings were mixed with capelin, making an exact estimation of the herring abundance difficult. In January 1986 the herring were recorded close to the bottom. Table 1 gives the abundance estimates of the 1983 year class using the target strength - length relation described above.

Table 1.   Acoustic abundance estimates of immature 1983 year class
           (TS = 19.1 logL - 74.0)

YEAR	PERIOD	ABUNDANCE $(N \times 10^{-6})$	COMMENTS	
1983	Nov	13730	Coastal areas	
	Nov	35700	Barents Sea	(Fig 4)
1984	June	42700	Barents Sea	(Fig 6)
	Nov	3600	Coastal areas	
1985	May	39800	Barents Sea	(Fig 10)
	Sep	23300	Barents Sea	(Fig 12)
1986	Jan	16100	Barents Sea	(Fig 14)
	May	5900	Barents Sea	(Fig 15)
	Nov	7353	Outer Vestfjord	(Fig 19)

There has been considerable discussion of the "real" target strength value for herring (Anon. 1987b). There has now been presented strong evidence for accepting a general "20 logL" dependance in the target strength - length regression equation for herring. However, the target strength is not a fixed value. It is strongly related to the swimbladder area and volume and will change due to physiological changes of the swimbladder with depth and fish condition. Thus the intercept value in the target strength -length regression equation wil vary according to season, depth etc.

From the chronological review given in the present paper, it can be seen that herring have been recorded with varying behaviour according to season, geographical distribution etc., some examples are given below:

1) recordings of I-group in small schools in deeper water, summer season (Fig 7).

2) Vertical migration, adult herring in wintering areas. The "correct" target strength value will probably change dramatically from night to day situation (Fig 28).

3) Night scattering layer, spawning areas (Fig 30).

By using only one TS - value one should of course be careful to compare estimates made during different times of year and/or day. The most reliable results will be obtained by comparing estimates made under the same conditions, i.e. the same time of the year.

From 1987 the abundance estimates of the 1983 year class of herring have been used as absolute estimates in the assessment work of the Working Group. Taken into account the information available in October 1987, the Working Group on Atlanto-Scandian herring recommended the following target strength - length equation for use in acoustic abundance estimations of adult Norwegian spring spawning herring:

$$TS = 20.0 \, logL - 71.9 \quad (Foote \; 1987, \; Anon. \; 1988)$$

This value is based on "in-situ" target strength measurements of adult herring and may not be the correct target strength - length relation for 0-group and young herring.

Table 2 gives the acoustic absolute estimates of the 1983 year class obtained since August 1987 by the use of the recommended target strength-length equation. The estimates of the adult herring obtained in 1987 are lower than the estimates in 1988 and 1989. Reasons for this may be dense schooling in Vestfjord/Ofotfjord (Fig 28) with a possible acoustic shadowing. Further, the herring of coastal origin may not have recruited to the main stock in 1987.

Table 2. Acoustic abundance estimates of adult 1983 year class
        $(TS = 20.0 \, logL - 71.9)$

YEAR	PERIOD	ABUNDANCE $(N \times 10^{-6})$	COMMENTS	
1987	Aug	4100	Off Lofoten	(Fig 25)
	Sept	2000	Vestfjord	(Fig 26)
	Nov	2800	Vestfj/Ofotfjord	(Fig 27)
1988	Feb	6805	Spawning area	(Fig 29)
1989	Feb	5118	Spawning area	(Fig 34)

Migration

In autumn 1983 the 0-group herring were distributed in two geographically different nursery grounds:

1) The main part of the 0-group population was distributed in the offshore regions of the Barents Sea

2) A minor part of the population was distributed in the fjord areas of northwestern and northern Norway

It has been possible to map the general migration routes of the part of the population distributed in the Barents Sea. This population has probably been augmented by herring which spent their first (or first and second) winter in the fjords of northern Troms and Finnmark and then emigrated to the offshore areas of the Barents Sea. (The term "component" should therefore be used with care to discriminate the herring in the fjords and offshore areas respectively, as "component" indicates a static situation with minimum interchange). The migrations of the herring distributed in the fjord areas have been more difficult to follow.

1) This herring stayed in the Barents Sea until May-June 1986, i.e. a time period of 3 years. Fig 36 gives a schematic presentation of the migrations which the herring in the offshore regions of the Barents Sea carried out in the period it stayed in the Barents Sea. The wintering areas were in general located further to the east than the feeding areas.
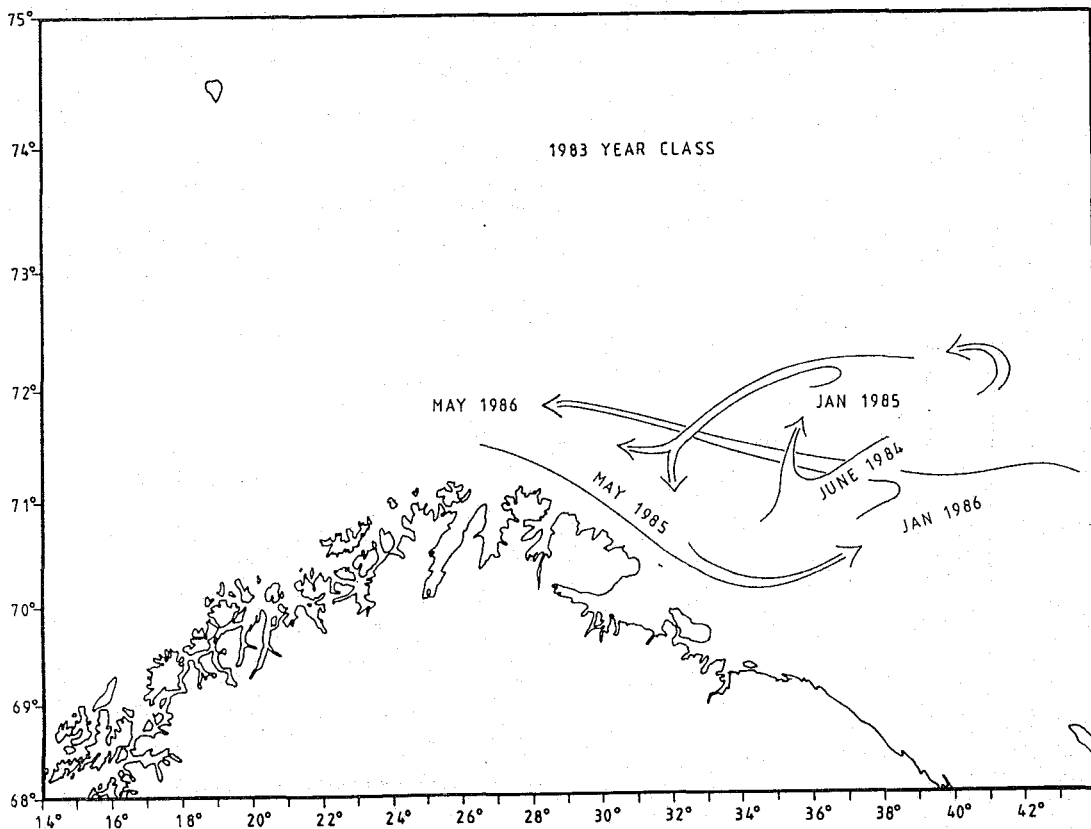
Fig. 36. Norwegian spring spawning herring.
         Migration routes (schematic) for the 1983 year class in
         the Barents Sea.

2) Fig 37 gives a schematic presentation of possible migrations which
the fjord distributed 0-group herring later undertook. In spring and
summer 1984 it is possible that I-group herring emigrated from the
fjords of northern Troms and from Finnmark and joined the herring in
the offshore regions of the Barents Sea. If this was not the case, the
disappearance of herring from the fjord areas must be due to natural
mortality. Dragesund (1970) states that the herring of the rich 1959
year class which wintered in 1959/1960 in the fjords of Northern
Norway migrated from the fjords to offshore areas in the Barents Sea
in spring 1960 and thus increasing the offshore population of young
herring in the Barents Sea. Contrary to 1960, when schools of I-group
herring originating from the fjords of Troms (Dragesund 1970) were
observed in the area between Lofoten and Sørøya, no I-group herring
were observed in this area in 1984. Samples of young and adolescent
herring with faster growth rates than the herring in the Barents Sea
were observed off Helgeland in spring 1985 and 1986, in the wintering
grounds at Møre in 1985-1987, and on the spawning sites off Møre in
1986 and 1987. It is thought that this herring had a coastal origin.
From the spawning seasons 1987/1988   this herring has probably
followed the migrations of the main population, i.e. the herring from
the Barents Sea. However, the nature of this mixing is not known.
There may still be groups of herring of coastal origin within the main
population, a total mixing needs not to have taken place.
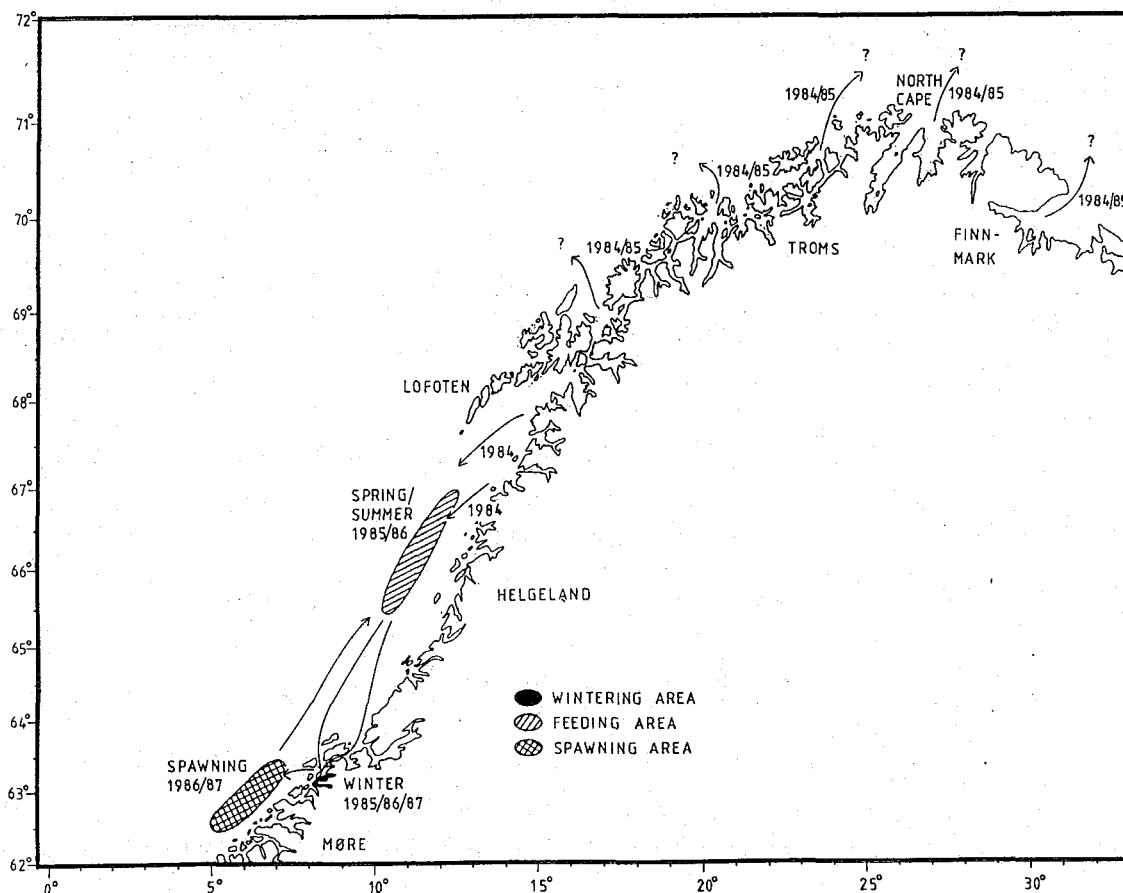
Fig. 37. Norwegian spring spawning herring.
         Possible migration routes for the 1983 year class of coastal
         origin.

The 1983 year class migrated from the Barents Sea and into the eastern
part of the Norwegian Sea as 3 year old immature herring in May-June
1986. The following movements of that component for the period August
1986 to February/March 1989 can be outlined as follows. In the
beginning of August the herring accumulates in an area west of the
Lofoten Islands and in the outer part of the Vestfjord. Medio August
to primo September the migration into the Vestfjord starts. The
wintering areas were however somewhat different in 1986/87 compared to
1987/88 and 1988/89. In 1986/87 the herring wintered in the middle and
outer part of Vestfjord, but in the latter winter the herring wintered
closer to the shore and in tributary fjords of the Vestfjord. The
spawning migration started at the end of January. The 1983 year class
spawned on the traditional spawning grounds off Møre. After spawning
the herring undertakes a northward feeding migration. During summer
the herring are dispersed in small scattered schools, and feed in an
area from approximately 64°N to 69°N and extending to 200 miles from
the Norwegian coast, an area of approximately 40 thousand square
nautical miles. These seasonal changes and migrations are summarized
in Fig 38D.

DISCUSSION

The biology and migrations of the early stages of Norwegian spring
spawning herring have been a topic of discussion for many years. 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 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. Others (Marty and Fedorov 1963) argued that most of them were
distributed in the Norwegian coastal waters. Dragesund (1970) studied
the year classes 1959-1965 and his conclusion was that strong year
classes (e.g. 1959,1960) had an oceanic distribution, and only a minor
part of the 0-group population entered the fjords of northern Norway.
For weak year classes (e.g. 1961,1962) the distribution was more
restricted to the coastal areas, and a greater proportion of the total
0-group population was present in the coastal areas.

In the 1950's and 1960's the distribution of the young herring and the
recruitment to the spawning stock was a central point in the
discussion of the population dynamics and assessment of the Norwegian
spring spawning herring. If most of the young herring were distributed
in the coastal waters, then the industrial fishery on the 0- and
I-group herring, which up to the mid 1960's only took place in the
inshore waters, would have great effect on the recruitment to the
spawning stock. Contrary, if most of the 0-group herring had an
offshore distribution then the coastal industrial fishery would be of
less importance to the population dynamics of the stock.

The situation after the stock collapse supports the theory that young
herring of weak year classes have a mainly coastal distribution, and
the young herring of strong year classes have an offshore
distribution. The year classes which have occurred since the stock
collapse up until 1982 were all weak, and were as young herring
mainly distributed in coastal waters. The strong 1983 year class had a
typically oceanic distribution as 0-group, only a minor part of the
year class had their nursery area in the coastal waters. The general

distribution picture for young herring is thus in principle the same
for the 1983 year class as for other strong year classes in the time
prior to the stock collapse. But are the migrations similar?

According to Dragesund (1970) herring of the strong 1959 year class
were observed in the regions of Bear Island and Hope Island as I-
group. Later the herring migrated south to the central and southern
parts of the Barents Sea. The seasonal migrations of the 1983 year
class in the Barents Sea are shown schematically in Fig 36. The 1983
year class had a more eastern distribution than the 1959 yearclass in
the Barents Sea. For the 1983 year class the wintering areas are
generally distributed further to the east than the feeding areas in
summer, the migrations have therefore, in some contrast to the 1959
year class, taken place in an east-west direction

In May-June 1986 the offshore distributed herring of the 1983 year
class emigrated from the Barents Sea and into the eastern part of the
Norwegian Sea. Have the later migrations been comparable to the
migration routes of the adult herring before the stock collapse?

Figs 13A-C (Dragesund et al. 1980) show the migration routes for
adult Norwegian spring spawning herring from 1950 to the stock
collapse at the end of the 1960's. From the begining of the 1970's to
1986 the adult herring stock was distributed in the Norwegian coastal
areas. The situation for the period August 1986 to August 1988 is
shown in Fig 13D.

Some herring of the 1959 year class migrated westwards to the feeding
areas in the Jan Mayen-North Iceland area in summer/autumn of 1962,
but the main part of this year class spent the summer and autumn
seasons off Troms, where they also wintered.They appeared as recruit
spawners and spawned off Lofoten in winter 1963 (Devold 1968,
Dragesund 1970).

After the emigration from the Barents Sea in May-June 1986, the 1983
year class was distributed off Lofoten (Figs 17 and 38D), that is
further south than the 1959 year class was distributed as 3 years old.
The 1983 year class wintered in 1986/87 in outer Vestfjord (Fig 20).
Contrary to the herring of the 1959 year class, the 1983 year class
did not spawn in the Lofoten area, but migrated south to the
traditional spawning areas off Møre (Fig 38D). The main part of the
northern population of the 1959 year class became recruit spawners in
1963, i.e. 4 year old fish (Devold 1968). The majority of the 1983
year class, however, were recruit spawners in 1988, one year older
than the 1959 year class.

Fig 38 shows that the 1983 year class, until now, has not migrated out
to the "old" feeding grounds in the North Iceland-Jan Mayen area. The
feeding areas of the 1983 year class has been from the coastal areas
and extending approx. 200 nautical miles out in the Norwegian Sea.

At present it cannot, of course, be said with any certainty if the
1983 year class in the future will keep to the same migration routes
as it has done since summer 1986. It should be kept in mind that the
northern "component" of the 1959 year class made an abrupt change in
the migration pattern in autumn 1966 as 7 year old fish. (Devold
1968). Is the fact that the herring in spring 1989 appeared on the
spawning grounds off Karmøy (Fig 34) for the first time in 30 years an
indication that the migration pattern of the 1983 year class is
changing?
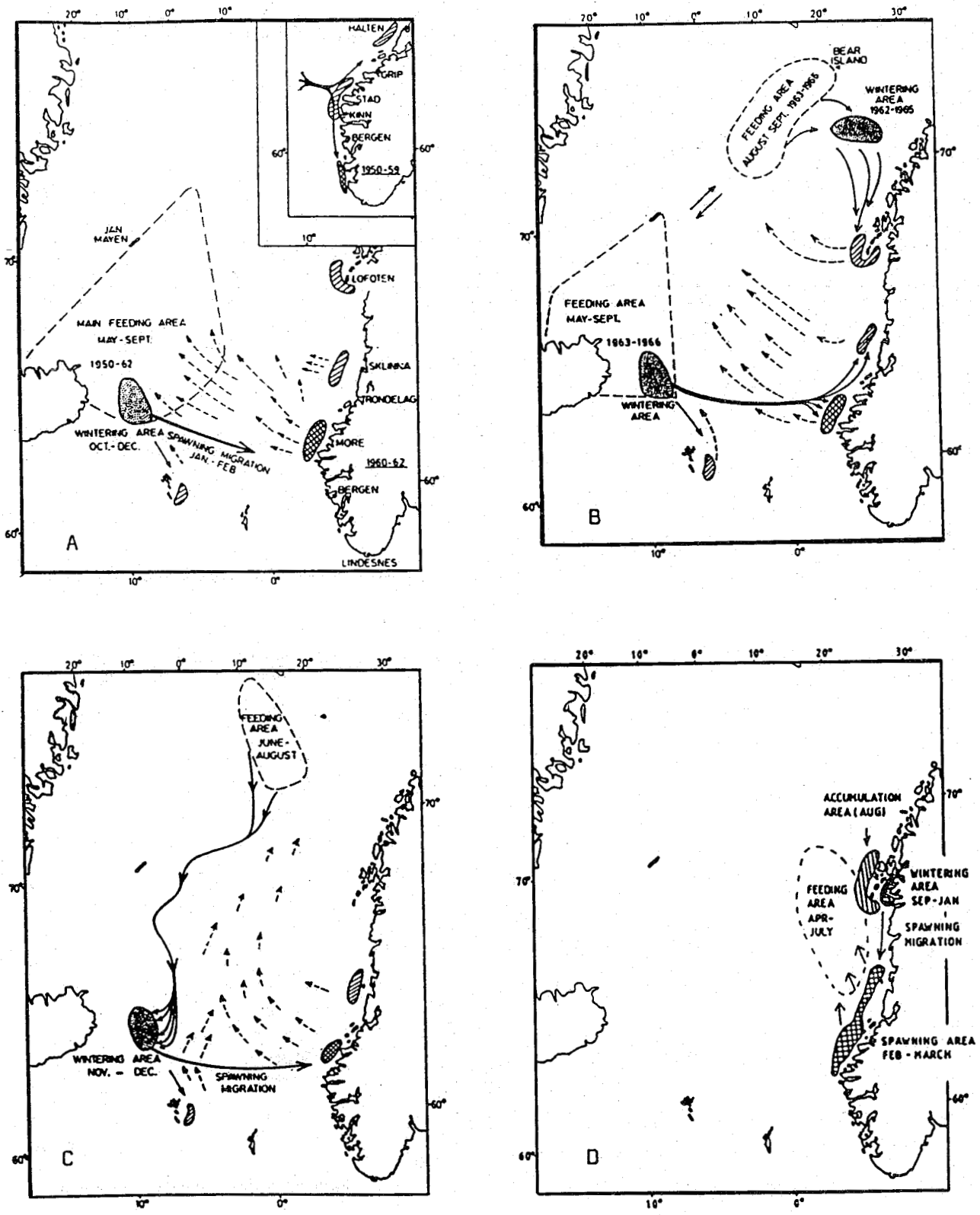
Fig. 38. Migration routes of Norwegian spring spawning herring.
        A. 1950-1962
        B. 1963-1966
        C. 1967-1968
        D. August 1986 to present.
        (A,B and C from Dragesund et al. 1980).

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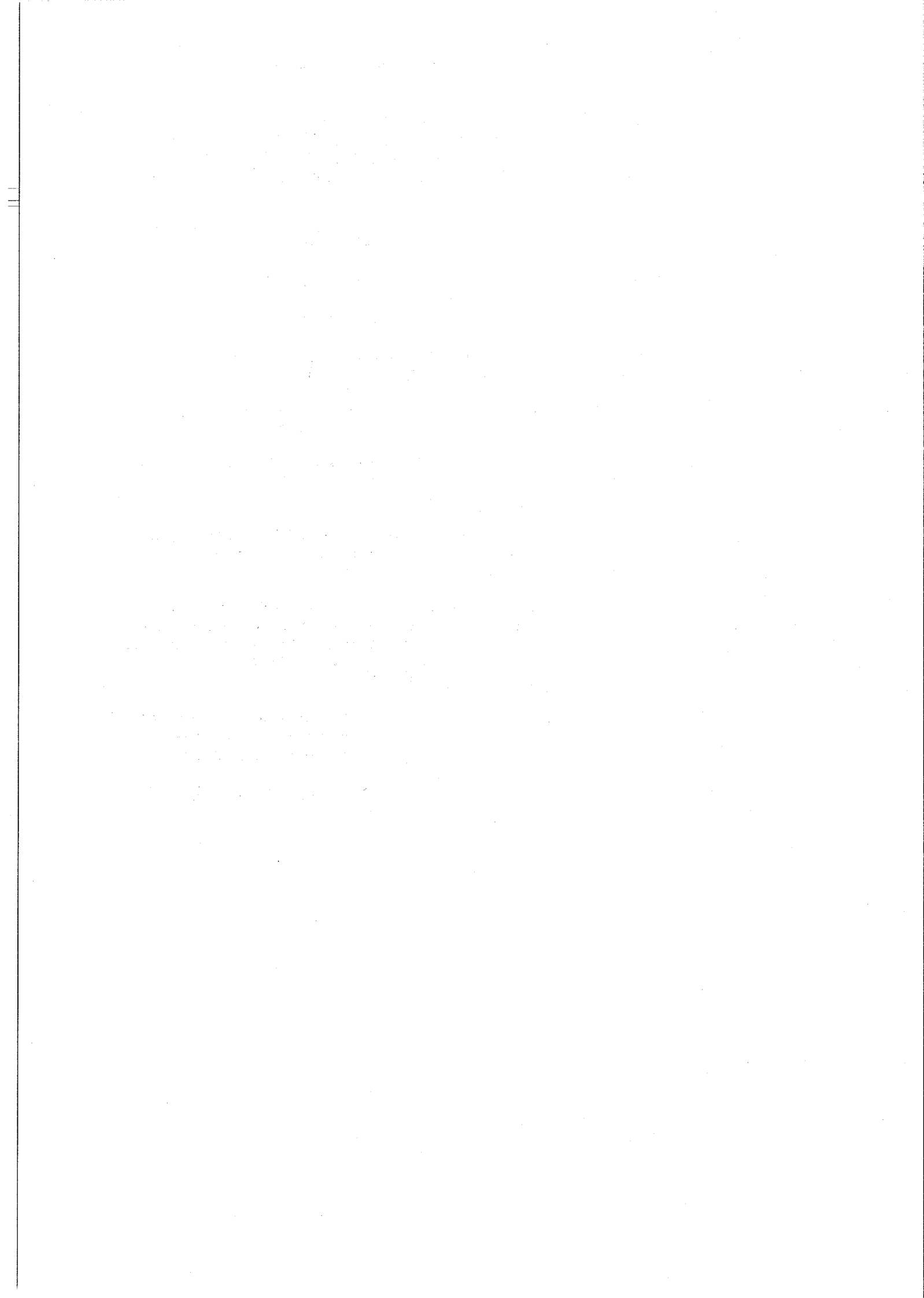
Blue whiting

Section IV: Life history

DYNAMICS OF BLUE WHITING ABUNDANCE IN THE NORWEGIAN SEA

by

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ABSTRACT

There is a lot of paradigms available to illustrate how the modern oceanic fisheries armed with effective techniques for fishing and searching, can deplete the stocks. Pelagic fish and those bottom fish species, which in certain times of their life history aggregate in dense concentrations easily accessible for fishing are most often susceptible to overfishing. The analysis shows that this is due to overfishing of the young or because of discrepancies between catch level and stock status. The impact of the fisheries is most significant in the period of depressive stock status, caused by natural reasons. In view of this, one of the key tasks in studies of fish stock population dynamics is to provide objective evaluation of changes in the commercial stock, to isolate major factors responsible for fluctuations in its numbers and to determine their effects on stock status in order to implement regulation measures in due time.

At present the state of the Hebrido-Norwegian blue whiting stock - one of the commercially important species in the Northeast Atlantic - is of great concern. During the period of intensive fishing from 1978 to 1988 considerable changes occurred in the yearly and daily catches, the commercial value of some areas as well as in the size-age structure of the stock.

The purpose of this paper is to analyse on the basis of historic data the blue whiting fishery in the Norwegian Sea and to make an attempt at gaining insight into mechanisms of the stock abundance dynamics.

METHODS

Statistical fisheries indices are analysed by areas, isolated based on 200-miles economic zones.

Catch per effort data were standardized according to Beverton and Holt (Beverton and Holt, 1957) by three factors: type of ship, area and time of fishing. Catch per day fishing by large frig trawlers (BMRT) - most representative ships in all years of fishing - was taken as standard unit effort. Strength of individual year classes was evaluated by their total catch fitted to the yearly effort (Borisov and Blinov, 1984), the numbers of partially harvested year classes were estimated with account for the mean survival rate calculated from catch per effort for previous year classes at identical age

Size-age structure of the blue whiting stock is studied on the basis of material collected by Soviet research and scouting ships.

RESULTS

The blue whiting fishery in the Northeast Atlantic is supported largely by the most plentiful Hebrido-Norwegian stock, its distribution ranges from 48^0 to 72^0N along the European coast (Zilanov 1984).

Until the second half of the 1970's the intensity of blue whiting was low and the total catch hardly exceeded 80 thousand tonnes. Since 1976 the total catch had increased sharply and by 1979-1980 it reached the peak value of 1100 thousand tonnes. However, from 1981 onwards the yearly catch declined drastically owing chiefly to a reduction of catch in the Norwegian Sea - a foraging ground for the majority of mature fish. The catch of blue whiting on the spawning grounds west of Great Britain and Ireland during all those years remained fairly steady at 330-510 thousand tonnes.

Fig.1 shows the dynamics of USSR yearly catch in the Norwegian Sea. With the introduction of the 200-miles economic zone, the Faroese government allocated a catch quota of 60 thousand tonnes for the USSR fleet in 1978, that was successfully taken by a small group of ships in the period from April to September. The same year, the blue whiting fishery was initiated in the offshore areas of the Norwegian Sea and near Jan Mayen. In 1979 the USSR commenced fishing for blue whiting in the Norwegian economic zone (continental), where the allocated quota was 20 thousand tonnes. The following years, catch quotas for the USSR fleet both in the Norwegian and Faroese zones were much larger.

USSR catches in the offshore areas of the Norwegian Sea, where it was not limited, attained a peak level of 560 thousand tonnes in 1979. In 1980 however, it decreased by nearly 100 thousand tonnes and it was only 190 thousand tonnes in 1981. The following years no steady aggregations of commercial importance were found there. The fisheries have been observed to improve since 1984. This was due to development of fishing for immature fish from the two rich 1982 and 1983 year classes. In recent years, because of intensive exploitation of these year classes and poor recruitment to the commercial stock from the following year classes a decline in the total catch was once again noted. In 1988 no stable fishing occurred in fact in the Norwegian economic zone, and the yearly catch was the lowest on record - about 10 thousand tonnes.
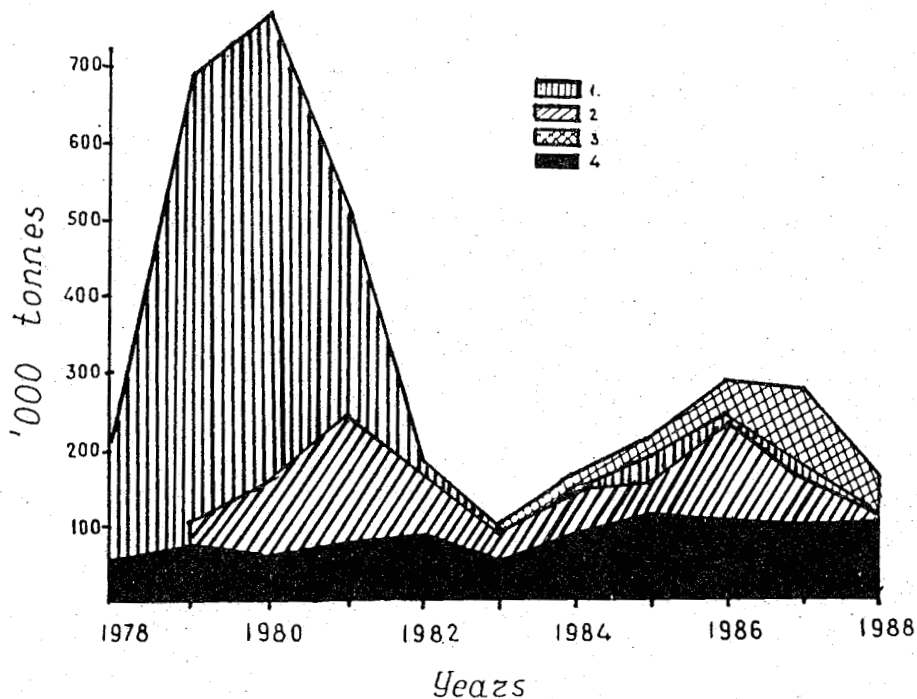
Fig. 1. Dynamics of USSR catches in the Norwegian Sea
        1 - offshore areas of the Norwegian Sea and Jan Mayen;
        2 - Norwegian economic zone;
        3 - area outside 200 miles zones of
            Great Britain and Ireland;
        4 - Faroese zone.

Of all mentioned areas, the blue whiting catch in the Faroes zone was
found to exhibit the smallest variations. This was due, first of all,
to a small catch quota for this area (about 100 thousand tonnes) as
well as to the behaviour of fish migrating after spawning (April to
June) through this area and aggregating in dense concentrations.

Besides, with a decline in the number of fish in foraging areas in
recent years, the season of productive fishing was reduced, thus
handicapping the withdrawal of a quota.

Seasonality on commercial fishing associated with a decrease of stock
size was most evident in the outermost parts of the species range. For
example, during early years the fishery for blue whiting in the
offshore areas of the Norwegian Sea was prosecuted on a yearly basis.
Later, however the fishing season was reduced to 2-3 months (Fig.2).
This was due to a decrease in number of older fish not participating
in the spawning (Ushakov and Mazhirina, 1978), which arrived in
foraging areas much earlier in spring and left them later in autumn,
aggregating under favourable hydrological conditions in very dense
concentrations of commercial value.

Catch per effort data provide evidence of changes in the density of
aggregations and, hence, stock numbers. For example, mean yearly
efficiency estimates shown in Fig. 3 are in good conformity with the
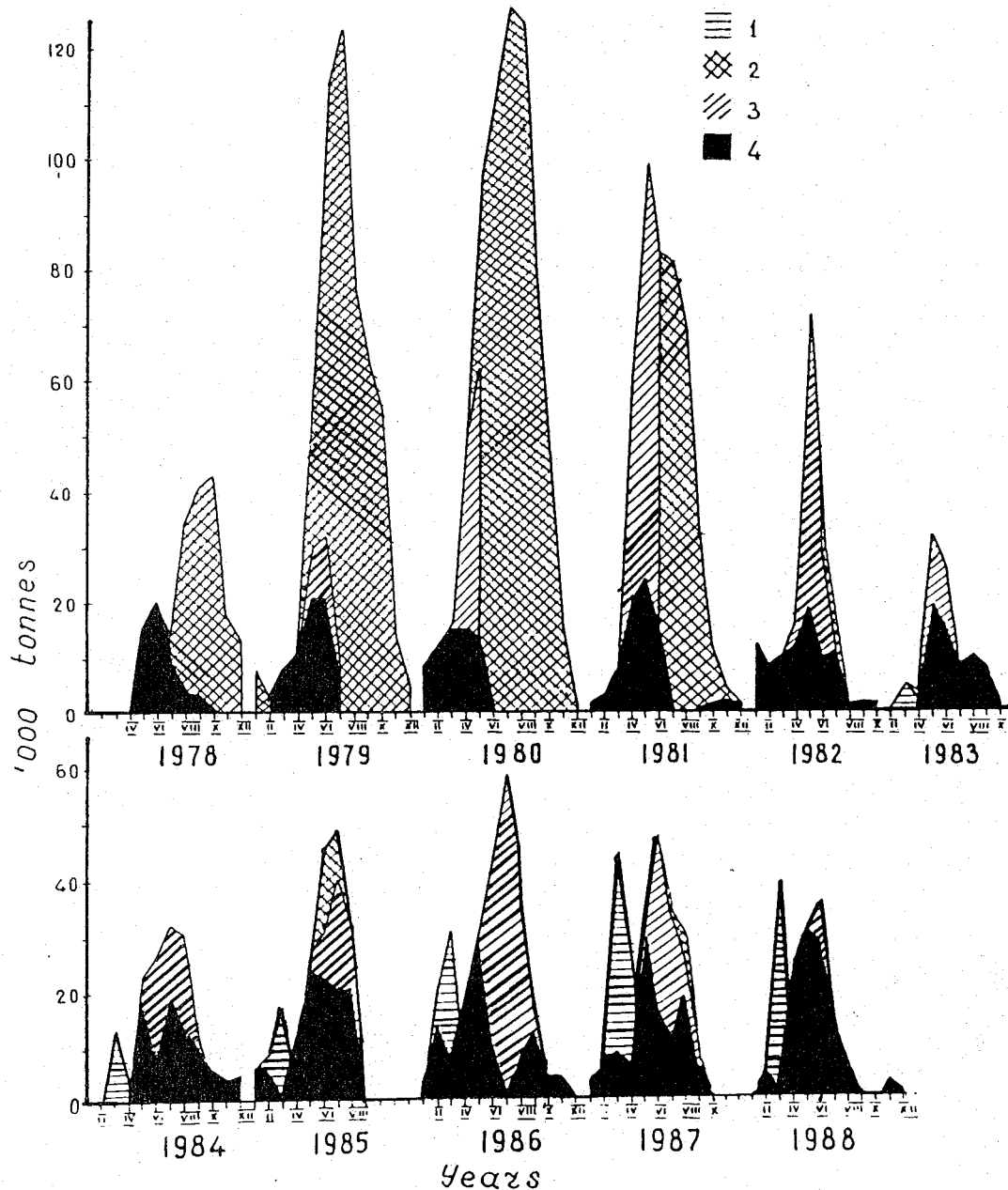
Fig. 2. Blue whiting catch by month for 1978-1988
        1 - offshore area west of Great Britain and Ireland
        2 - offshore areas of the Norwegian Sea;
        3 - Norwegian zone (continental);
        4 - Faroese zone.
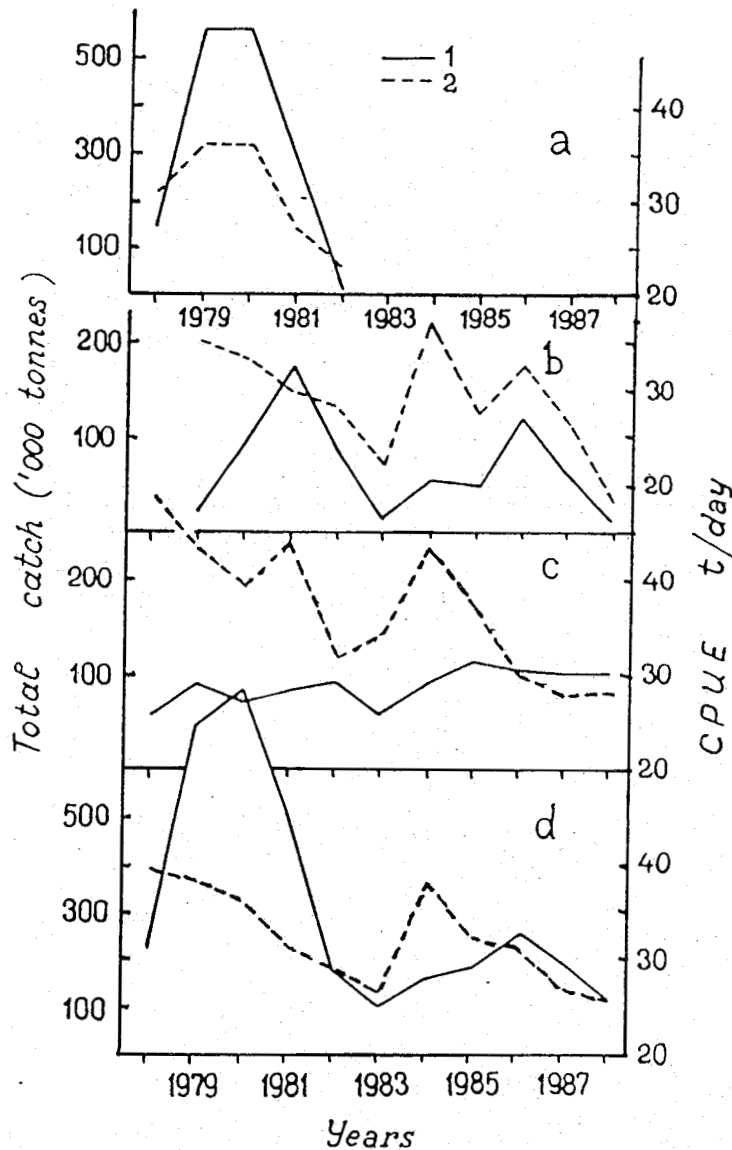
Fig. 3. Yearly catch (1) and mean yearly efficiency (2) of
        the USSR fleet in the blue whiting fishery in the
        Norwegian Sea
        a - offshore part of the Norwegian Sea;
        b - Norwegian zone;
        c - Faroese zone;
        d - total for all areas.

dynamics of the total yearly catch. Catch per effort was at the
highest level during early years of intensive fishing, with high catch
level and long fishing season, and this was indicative of a good stock
status. Later, however, the mean daily efficiency decreased steadily
in all fishing areas until 1983. A sharp increase in catch per effort
in the Norwegian and Faroese zones in 1984 was due to, as aforesaid,
recruitment from rich 1982 and 1983 year classes. However, since 1985
the average efficiency was found to decrease gradually, reaching a
record low by 1988.

Data on the size-age structure illustrate variations in the abundance
of blue whiting (Figs. 4-7) In early years of intensive fishing
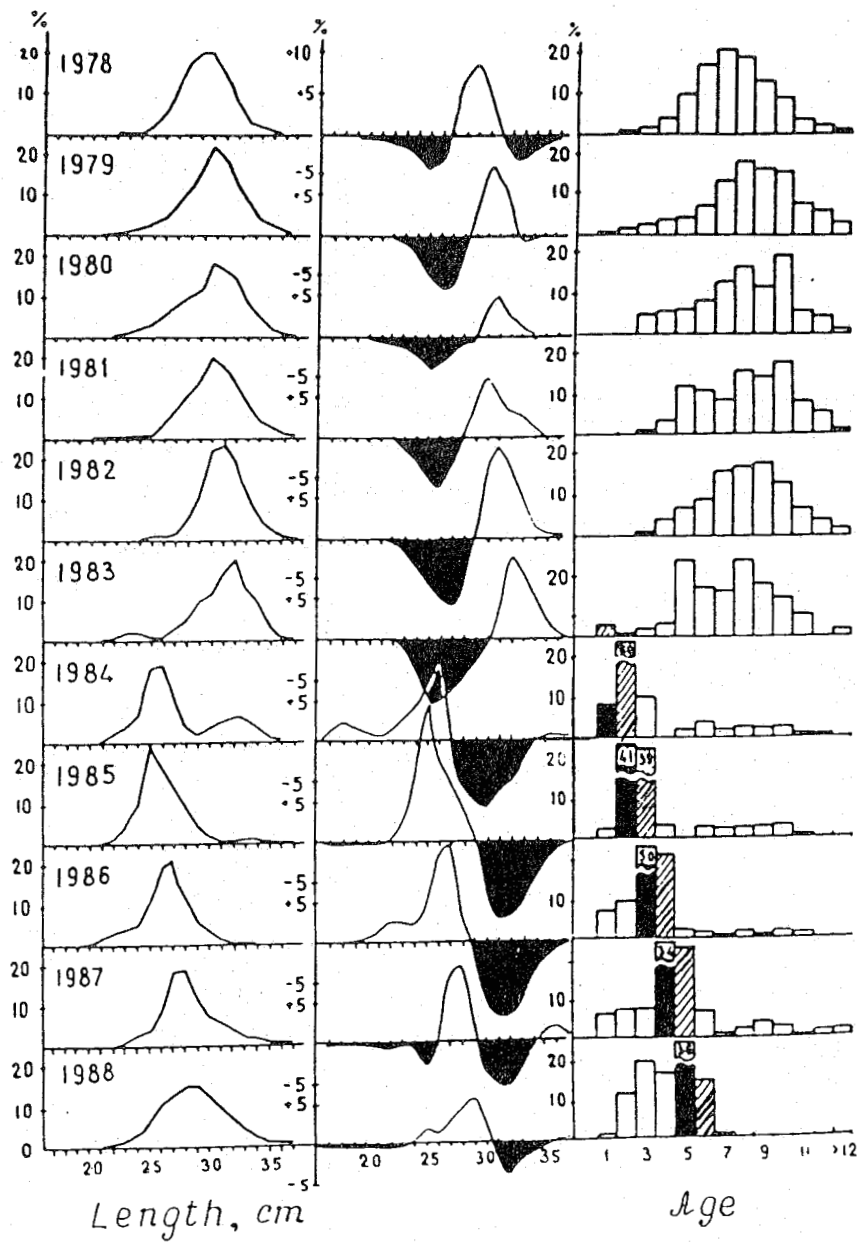
Fig. 4. Size-age composition of blue whiting in the offshore part of the Norwegian Sea.

catches from all areas were composed predominantly of large fish, 27-
33 cm long, aged 5-12 years. The first few years , the intensive
fishing did not cause any significant reduction in the average age of
the population, on the contrary, (as indicated by curves of deviations
of size frequency distributions from the long term mean) until 1984
the proportion of larger fish gradually increased and smaller fish
grew more and more scarce (Figs. 4-7). This could happen only due to
growing fishing pressure on younger ages or because of weak
recruitment, caused by natural reasons.

Data on catch rate presented in Table 1 show that fishing pressure on
younger ages (0-5 years) decreased until 1982, with the mean age of
fish in the harvested part of the population gradually increasing from
4.7 to 7.4 years (Table 1). The proportion of smaller fish in a catch
had increased only since 1982, and since 1984 in the USSR catch, due
to recruitment from strong 1982 and 1983 year classes. Larger portion
of small fish in catches (to 87% in 1987) was indicative of both
emergence of rich year classes and considerable reduction in numbers
of older fish by that time. Strength of year classes may be judged by
their mean catch per effort by age, and by total amount in the actual
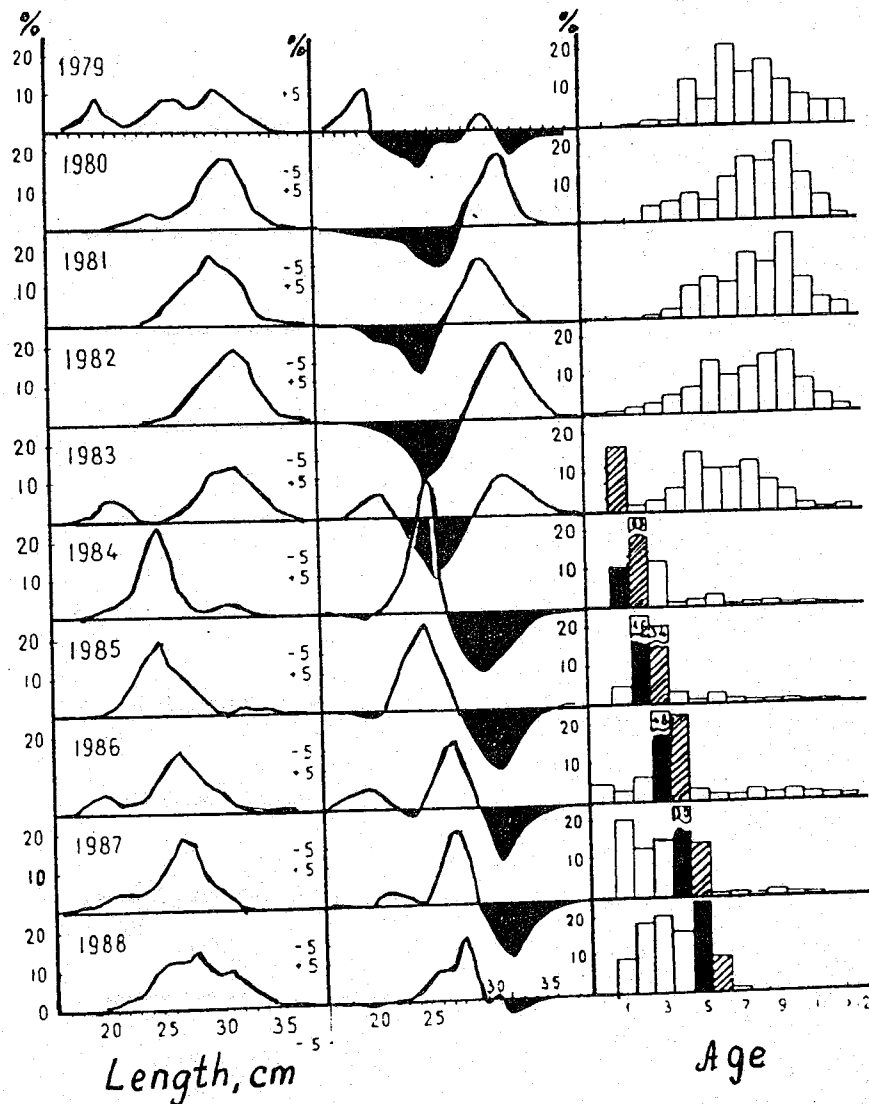
Fig. 5. Size-age structure of blue whiting in
        the Norwegian economic zone.
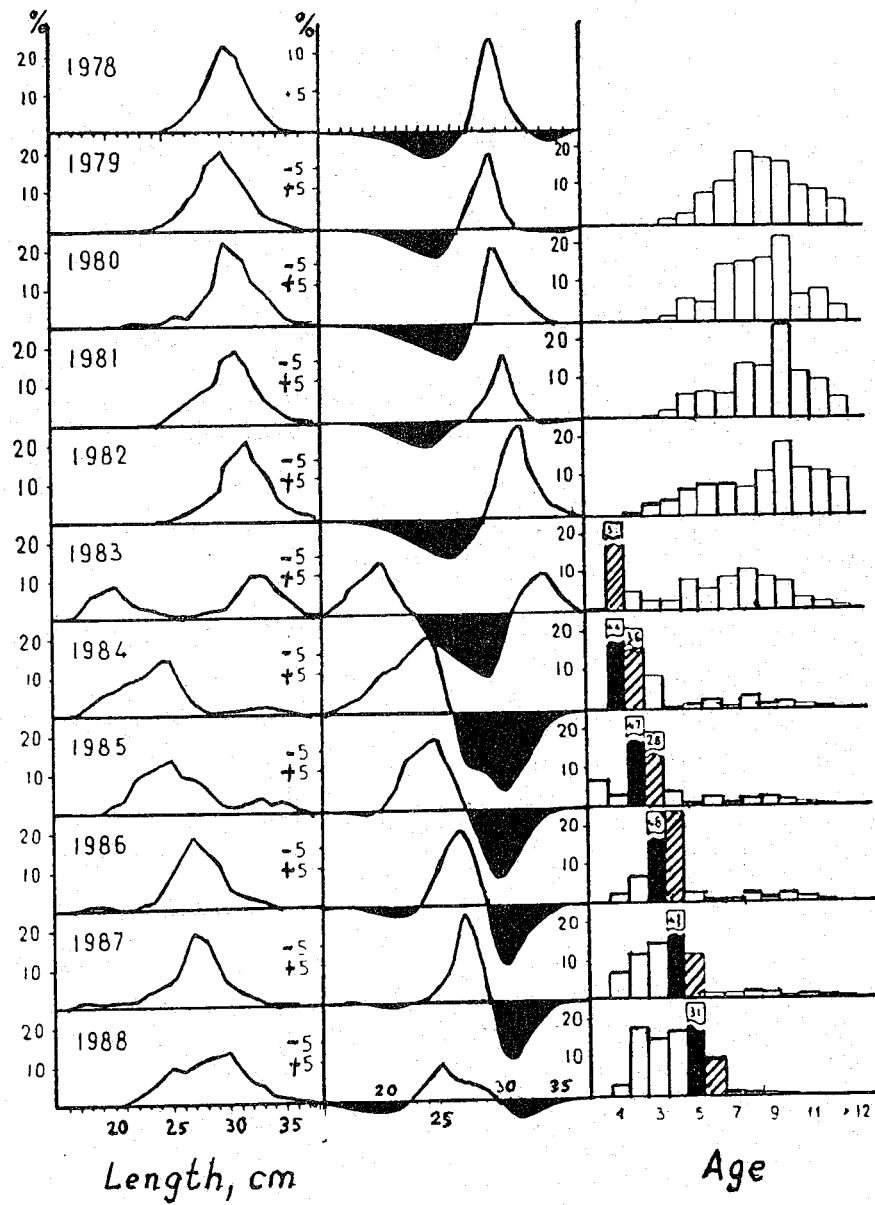
Fig. 6. Size-age structure of blue whiting
        in the Faroese fishing zone.

Length, cm   Age
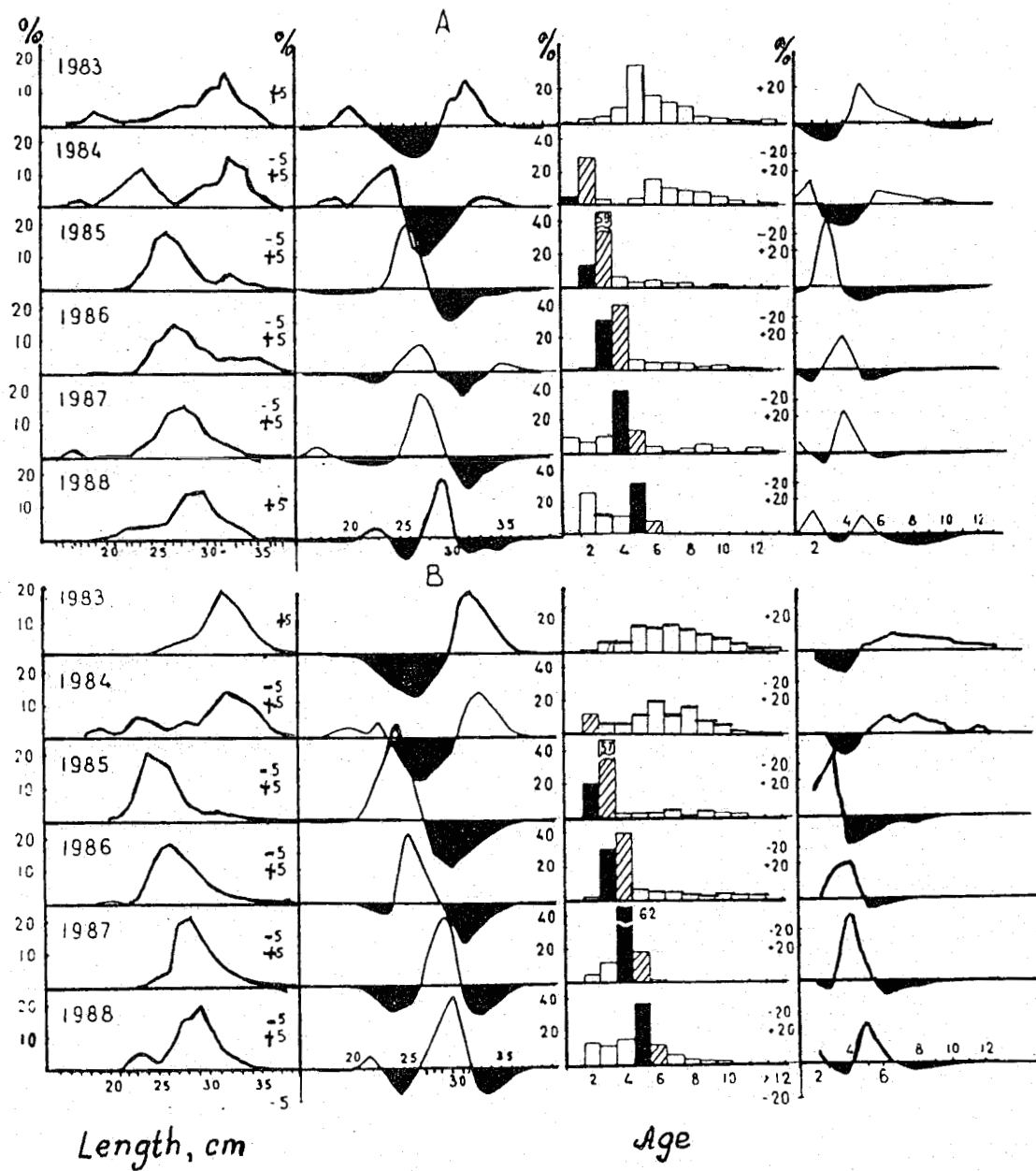
Fig. 7. Size-age composition of blue whiting west of Ireland
        and Great Britain
        A - within the 200 miles zones;
        B - outside the 200 miles zones.

Table 1.   Catch of blue whiting (%) by age

Year	AGE GROUPS						Total*		Mean age
	0 - 5		6 - 10		11+		10^6 fish	1000 ton- nes	
	USSR	Other	USSR	Other	USSR	Other			
1978	2.5	53.7	15.0	22.5	1.3	5.0	5759	575	4.7
1979	5.3	35.9	32.6	13.4	7.8	5.0	8475	1092	6.2
1980	8.2	25.3	36.0	17.2	6.6	6.7	7068	1093	7.0
1981	6.2	22.9	31.3	25.5	8.6	5.5	5206	871	7.4
1982	2.1	69.8	7.7	13.9	3.3	3.2	6283	590	3.2
1983	5.5	66.8	5.0	19.2	0.7	2.8	5132	539	3.6
1984	23.7	56.9	2.5	14.8	0.2	1.9	6676	611	3.1
1985	19.4	65.1	2.0	11.1	0.2	2.2	7052	653	2.9
1986	25.5	55.6	2.7	12.6	0.9	2.7	6078	794	4.2
1987	24.4	62.6	2.2	7.9	0.6	2.3	5063	632	4.0

* ICES data

and predicted catch. Since the fishing effort by the USSR fleet exhibited considerable variations in the period of fishery, a cumulative catch of these year classes would better indicate their strength, with yearly catches being brought in accord with yearly effort. Table 2 presents results of calculations. As seen in Table 2, catch indices for the 1974-1976 year classes, estimated as average, are very close. They were followed by a series of year classes (1977 1981) with gradually decreasing strength. 1982 and 1983 appeared to be the strongest year classes, and the harvest from these year classes as 5-6 year olds was 2-3 times greater than from any earlier fished year class. This caused a 3-6 times decline in the efficiency against the initial level.

Subsequent 1984-1987 year classes were 3-4 times less numerous than the 1982 and 1983 year classes, and bearing in mind that like in rich year classes their survival rate was much reduced because of their being harvested at an earlier age (Fig. 8), their contribution to the commercial stock could hardly make up for existing fishing mortality, which eventually results in a further catch decline.

Total catch level, catch per effort or year class strength being very important criteria in evaluation of the relative stock abundance, stock size assessments by instrumental or mathematical methods can provide insight into variations of absolute abundance and biomass.

An analysis of blue whiting stock size estimates obtained by USSR and Norwegian acoustic surveys shows inconsistencies (Table 3). This particularly pertains to surveys on spawning grounds with the results, obtained by the two countries or even by only one country (USSR), but within the same season, exhibiting a difference twice as big or more. In our opinion, this was due to difficulties in identification of blue whiting aggregations , especially in the period of northerly migrations (late March-April), when an outburst of zooplankton (euphausiids) occurred. Besides, the survey conducted northwardly, following migrating fish, provided overestimates, not taking into account the velocity of migration. This, with only one vessel operating (over 20-25 days), resulted in a significant bias in the final estimates.

Table 2. Total catch and catch per effort (thousand fish per day fishing) by year class.

Year class	Age, catch per effort										Catch, 10^6 fish		
											USSR		Total
	1	2	3	4	5	6	7	8	9	10	Actual	Revised	
1974				8	9	15	14	14	17	8	856	748	3529
1975			3	8	13	17	13	21	8	4	814	752	4284
1976			5	11	17	15	17	14	5	5	788	759	3501
1977		3	9	5	10	14	3	5	4	2	455	451	3616
1978		+	2	7	21	11	5	6	4	1	289	476	5973
1979		+	5	6	6	7	4	4	1		165	279	1812
1980		1	5	4	4	3	3	2			106	191	1068
1981		8	45	11	7	4	3				352	670	1450
1982	49	206	85	60	30	18					2162	3928	11690
1983	160	114	97	75	55						2771	4939	7677
1984	21	21	30	30							620	1284	2793
1985	13	26	28								400	1018	2080
1986	28	33									330	1338	507
1987	6										29	447	236
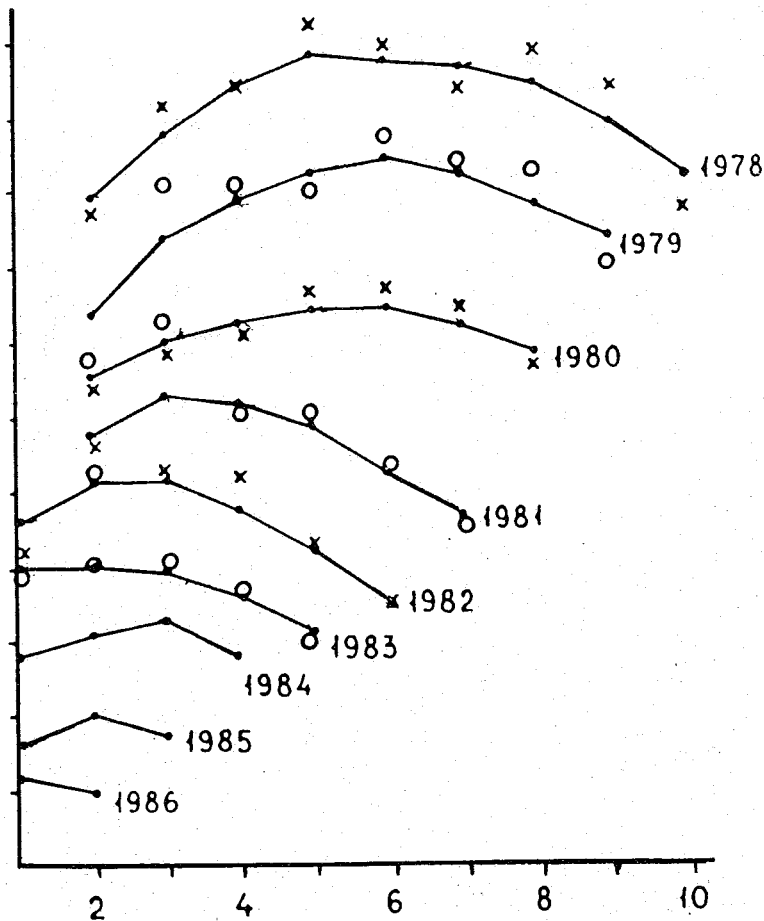
Fig. 8. Catch curves illustrating variations in survival rate of blue whiting from various year-classes.
X-axis = age, Y-axis = logarithm of the number of fish (10) of given age.

Table 3.   Blue whiting stock size estimates for Northeast
           Atlantic (ICES data), mill. tonnes

YEAR	Acoustic estimates				VPA
	Spawning ground			Foraging area	
	USSR	NORWAY	Other countr.		
1979		5.0	10.6		6.2(5.2)
1980			3.8		5.2(4.4)
1981		4.0	4.2 6.1(5.4)		4.4(3.6)
1982			2.5	4.6	4.1(3.2)
1983	3.6(3.6)	4.7(4.4)		2.8	4.8(2.7)
1984	2.7(2.4) 3.4(2.7)	2.8(2.1)	2.4(2.2)	3.8	5.3(2.6)
1985	2.6(2.0)		6.4(5.6)	4.9	6.0(3.4)
1986	6.4(5.6)	2.6(2.0)		3.0	6.4(4.7)
1987	5.4(5.1) 7.4(6.9)	4.8(4.5)		1.7 1.4	
				1.2	5.5(4.3)
1988	2.0(1.8) 3.9(3.1)	7.1(6.8)		0.6 2.4	5.8(4.3)

In brackets - spawning stock estimates

The most reliable acoustic estimates are obtained during pre-spawning and spawning periods, when the fish aggregate in a small area and do not perform extensive horizontal migrations. This survey, covering a post-spawning period too, produces usually underestimates (Tables 2).

Acoustic surveys in foraging areas in the Norwegian Sea (July-August) demonstrate certain shortcomings too: and namely, when during a survey period the fish are distributed over a vast area, this prevents a complete coverage of the stock. However, in recent years results from these surveys provide evidence of a continuous stock decline and are in a better agreement with the dynamics of catch and fishing efficiency in this area.

Indicating a general trend in the stock size variation, the VPA technique used by the ICES working Group for abundance and biomass estimation shows,nevertheless, a noticeable shortcoming too - it does not allow for fishing intensity dynamics. Therefore, stock size estimates by VPA, employing the total catch by all countries as a basis, show the catch fluctuations better than actual stock size variations.

Using the USSR catch of blue whiting by age and yearly standard effort we have made an attempt at a rough quantitative estimation of the part of the commercial stock, arriving in the Norwegian Sea for foraging. Actual yearly catches by USSR were revised in accord with the long-term mean fishing effort (Borisov and Blinov,1984). Table 4 shows estimates for abundance and biomass of the commercial stock. During the period investigated (1978-1988) two maximum and two minimum levels of stock size were observed. In early years of intensive fishing the stock was at a maximum level, older fish predominated. One more peak level was recorded in years, when the strong 1982 and 1983 year classes contributed to the stock. However, in both instances intensive fishing and, to a certain degree, weak year classes caused a reduction of the commercial stock. By 1988 the commercial stock was found to be the lowest on record.

Table 4. Indices for blue whiting commercial stock in the
Norwegian Sea, calculated by biostatistical method

YEAR	Fishing effort in thousand of standard boat/day	Catch, mill.fish		Commercial stock	Intensity, % of abundance
		Actual	Revised	Mill. fish	
1978	4.6	1080	1925	9808	11.0
1979	17.4	3874	1826	8162	47.5
1980	17.1	3591	1722	6527	55.0
1981	14.1	2398	1395	5475	43.8
1982	5.6	816	1195	8262	9.9
1983	3.1	570	1508	11693	4.9
1984	3.8	1760	3798	9179	19.2
1985	5.8	1525	2156	8041	19.0
1986	7.8	1767	1858	7223	24.5
1987	6.6	1379	1713	5812	23.7
1988	4.5	803	1463	5459	14.7
Mean	8.2				

DISCUSSION

A statistical analysis shows that the growth of intensity of the USSR
blue whiting fishery in the Norwegian Sea, coincident with increased
fishing effort by many European countries entailed a sharp rise of
annual yield first, and thereafter its dramatic drop. This was
aggravated by production of a series of weak year classes (1977-1982).

A drastic decline of the blue whiting yearly catch occurred in
conjunction with a reduction in catch per effort and fishing area as
well as a shortening of the productive fishing season.

A rise in catch per effort and total catch recorded since 1984 in the
southern Norwegian Sea was associated with production of two strong
year classes of 1982 and 1983, which accounted for more than 60% in
catch. In recent years these year classes have been heavily harvested
and followed by weak year classes that cannot support the fishing
efficiency at a high level, and thus the stock decline and
deterioration of fisheries will continue.

In view of that the blue whiting stock status in the Norwegian Sea
reflects the status of the whole Hebrido-Norwegian stock, which is
confirmed by similarity of size-age structures (Figs. 4-7), it is
necessary to develop and implement effective regulatory measures.
These measures should be first focused on both limitation of the young
fish catch and a reduction of mature fish catch on the spawning
grounds.

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USSR BLUE WHITING RESEARCH
IN THE NORTHEAST ATLANTIC IN 1982-1988

by

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ABSTRACT

The paper presents results from USSR blue whiting research on the spawning grounds west of Ireland and Great Britain and south of the Faroes during spring 1982-1988. This research provided basis for evaluation of the spawning stock dynamics, distribution of fish and for description of the spawning process. In February-March the largest aggregations of spawning blue whiting were recorded in a narrow zone along the eastern slope of the Faroe-Shetland Channel west of Ireland and Great Britain above isobaths 250-600 m, and especially, at points of inflexion of isobaths 300-500 m. The biomass varied from 2.4 to 6.2 mill.t and abundance from 14.5 to 53.1 x 10^9 fish.

INTRODUCTION

Blue whiting research has been carried out by PINRO for more than 15 years. In the 1980's the employment of more developed echo sounders and echo integrators enhanced the quality and reliability of survey results. Blue whiting research on the spawning grounds has been carried out since 1982 on a yearly basis (Ermolchev et al., 1983, 1984, 1985; Belikov et al., 1987; Belikov et al. 1989; Isaev et al., 1988).

Results from the research are used by the ICES Blue Whiting Assessment Working Group for long-term forecasting.

MATERIAL AND METHODS

Echo sounders EK-S-38, EK-400 (Norway) and echo integrators SIORS and EI-2 (USSR) are used for surveying the blue whiting. Five-channel digital echo integrator SIORS has a dynamic range of $\geq$ 50 db, while the EI-2 integrator has a narrower range ($\leq$ 30 db). However, it comprises the echo integrating and echo counting systems operating simultaneously and affording estimation of the mean target strength of fish in scattered aggregations (Ermolchev, 1988). The survey track allows for the time allocated, weather conditions (wind and wave direction) and distribution of fish (The densest aggregations occur in a narrow zone along the eastern slope of the Faroe-Shetland Channel above 250-600 m isobaths). Therefore, the vessel recurrently covers the eastern slope of the Faroe-Shetland Channel at an angle of approximately 45^0 to isobaths.

In the shelf zone where one finds the largest aggregations and sudden changes in fish density, the echo integrator readings M and depth are taken every 1 mile of the distance covered. Such a direction of tracks in contrast to a perpendicular one and frequent readings of M (every 1 mile) ensure acceptable accuracy of estimates in areas of blue whiting aggregation of varying density in a narrow zone along the slope. In other areas with relatively homogeneous density, M readings are taken every 5 miles of the distance covered. Readings of M, depth, log indications and positions are noted in a special book.

To verify integrator and echo sounder readings check tows are made. M readings are corrected by excluding noise and SSL and plotted in a survey chart. We are convinced that it is reasonable to use a special chart for plotting the isobaths 200, 500 and 1000 m and where the whole area is divided into rectangles of $1^0 00'$ longitudinally and $00^0 30'$ latitudinally, the area of each rectangle is noted in the chart for each latitude. The chart is handled by dividing the totality of M readings and size composition by areas with relatively similar M values and size of fish L. Density of fish within each area for each size group (or age) is calculated from:

$$\varrho_{Ni} = \frac{PiC_IM}{\sum\limits_{i=1}^{m} Pi\sigma i} \quad ; \quad \varrho_{wi} = \varrho_{Ni}\bar{W}_i 10^{-6} \qquad (1)$$

$$C_I = \frac{\sigma_1 \quad 3.43 \cdot 10^6}{M_1 R_1^2 \Psi} \quad ; \quad \sigma_1 = 4\pi \cdot 10^{0.1TS_1} \qquad (2)$$

$$\bar{\sigma}_i = a \bar{L}_i^b = 4\pi \cdot 10^{0.1TS_i} \quad ; \quad \overline{TS}_i = A + Blg\bar{L}_i \qquad (3)$$

where

ϱ_{Ni} - density of fish from size group i, in number, $1/mile^2$;

ϱ_{Wi} - density of fish from size group i, by biomass, $t/mile^2$;

C_I - instrument constant of echo sounder and integrator, $m/^2/mile^2$;

i - index of size group (or age group) (i=1,2..., m);

M - echo integrator readings during the survey;

P_i - proportion of fish of size group i in the aggregation, estimated from check tows;

$\bar{\sigma}_i$ - mean acoustic back scattering section for fish of size group i, m^2;

$\bar{w}_i$ - mean weight of fish from size group i, g;

R_1 - distance from a transducer to standard target, m;

Ψ - equivalent beam angle, steradian;

σ_1 - acoustic back scattering section for standard target, m^2;

TS_1 - target strength of standard target, db;

$\overline{TS}_i$ - mean target strength of fish from size group i, db;

$\bar{L}_i$ - mean length of fish (total length) in size group i, cm;

a,b,A,B - coefficients in relations between target strength and fish length (3).

Standard target, a copper sphere of 60 mm in the diameter and target strength of TS_I= -33.6 db, was used for estimation of the instrument constant C_I.

From our measurements the target strength of single fish was close to the estimate earlier accepted for young cod

$$\bar{\sigma} = 6.75 \cdot 10^{-7} \cdot L^{2.18} m^2$$

Estimates of fish density in each area derived in accord with (1) were summed for the whole area, total abundance and biomass were determined for each size group (age) and for all groups together.

RESULTS AND DISCUSSION

Tables 1, 2 and 3 present survey results.

In 1982 the survey covered areas north of 58°N only, therefore, the results showed underestimation. Since 1983 annual acoustic surveys have covered the whole distribution area of spawning blue whiting.

During 1983-1985 the research was commonly carried out after the spawning season, and therefore, the assessment was based on results from surveys in areas of postspawning migrations west and north of Great Britain. In the period from 1986 to 1988 the surveys were carried out earlier in the year, therefore, the data obtained were in our opinion more reliable.

During one cruise the blue whiting were surveyed acoustically from one to three times at various time periods and areas, with the biological condition of fish being different. It should be noted, that there is a discrepancy between final blue whiting biomass estimate presented in this paper and previously published estimates (Ermolchev et al., 1983, 1984, 1985; Belikov et al., 1987, 1989, Isaev et al., 1988). This discrepancy is caused, first of all, by some differences between mean weight of one fish in the size-weight key and mean weight used in stock size calculations by acoustic surveys. Most pronounced discrepancies arise when target strength (TS) estimate for mean length, calculated from measurements in the whole survey area or its part, is used instead of TS for each size group. However, even then they do not exceed 5%.

Comparison of acoustic results with estimates by the VPA (Anon., 1989) showed that in general the trend in the stock size variation in both assessments was the same (Table 4). However, the VPA seemed to produce overestimates, because averaged data on the mean weight and age were used in calculations.

Changes in the population age structure caused variation of abundance and biomass of blue whiting (Tables 1, 2 and 3). In 1982-1984 the spawning stock was composed of old fish mostly (5-10 years). Besides the recruitment was poor in that period. Biomass estimates derived by the VPA (Anon., 1989) indicated that precisely in those years the blue whiting stock, both total and spawning, was the lowest on record. By 1985-1986 due to recruitment from rich 1982-1983 yearclasses the stock biomass increased to 6.4 mill.t.

With reduction in the average age of the population an increase was observed in maturation rate and population fecundity (Belikov et al., 1989). In recent years the blue whiting fishery has been supported largely by rich yearclasses, whose numerical strength and biomass decreased by 1988 to 15×10^9 fish and 1.9 mill.t, respectively. It should be noted, that since 1984 only weak yearclasses have been produced, except the 1986 yearclass estimated as average.

In the absence of rich yearclasses of blue whiting the approach to provision of advice for future fishery should be very cautious. In our opinion, the rational management of this stock implies that the spawning stock biomass should not be below 3.5 mill.t, affording natural fluctuations of abundance (Belikov et al., 1989).

Table 1. Results from USSR acoustic surveys for blue whiting in spring of 1982-1988

Year	Period	Area	N x 10^9	Biomass, 10^6 t
1982	22.04-26.05	58°-64°	14.54	2.37
1983	04.04-10.05	50 -62	28.48	3.78
1984	17.03-31.03	51 -56	23.3	3.4
1985	21.04-29.04	51 -56	23.18	2.64
1986	13.03-06.04	56 -62	53.14	6.25
1987	19.02-13.03	50 -62	40.89	5.48
1988	28.03-22.04		31.2	3.7

Table 2. Numbers of blue whiting by age (fish x 10^9) as estimated by USSR acoustic surveys in 1982-1988.

Age	Year						
	1982	1983	1984	1985	1986	1987	1988
1		3.26	0.41	0.05	0.75	2.92	0.15
2	0.27	1.51	3.8	3.59	2.91	3.15	2.95
3	0.54	2.33	1.3	13.22	18.75	4.48	4.46
4	2.75	2.93	1.08	0.93	23.18	19.17	5.34
5	1.34	9.39	1.49	0.58	2.54	5.86	10.14
6	1.38	3.88	5.7	1.78	0.61	1.07	4.93
7	1.57	1.97	3.0	0.86	0.62	0.50	1.51
8	2.35	1.37	1.63	0.61	0.75	0.81	0.56
9	1.73	0.78	2.3	0.58	0.64	0.86	0.27
10	1.29	0.66	1.63	0.54	0.71	0.67	0.3
11	0.65	0.10	0.68	0.11	0.72	0.56	0.4
12	0.38	0.07	0.41	0.22	0.50	0.53	0.13
13	0.11	0.09		0.06	0.33	0.24	0.02
14	0.11	0		0.05	0.11	0.03	0.08
15	0.07	0.11		0	0	0.04	0
16	0	0.03		0	0.02	0	0
Total	14.54	28.48	23.3	23.18	53.14	40.89	31.24

Table 3. Biomass (10^6 t) of blue whiting by age as estimated by USSR acoustic surveys in 1982-1988.

Age	Year						
	1982	1983	1984	1985	1986	1987	1988
1		0.14	0.03	0.01	0.03	0.08	0.01
2	0.03	0.12	0.24	0.27	0.23	0.25	0.23
3	0.07	0.25	0.16	1.24	1.76	0.52	0.45
4	0.37	0.40	0.15	0.11	2.69	2.45	0.63
5	0.20	1.34	0.24	0.10	0.38	0.91	1.24
6	0.23	0.62	0.92	0.32	0.11	0.19	0.64
7	0.27	0.33	0.48	0.15	0.13	0.11	0.2
8	0.41	0.24	0.26	0.26	0.12	0.17	0.09
9	0.31	0.15	0.4	0.12	0.16	0.22	0.05
10	0.24	0.11	0.3	0.10	0.17	0.17	0.06
11	0.12	0.02	0.13	0.02	0.17	0.15	0.07
12	0.07	0.01	0.09	0.05	0.13	0.14	0.03
13	0.02	0.02	0	0.02	0.09	0.07	0
14	0.02	0	0	0.01	0.02	0.01	0.01
15	0.01	0.02	0	0	0	0.01	0
16	0	0.01	0	0	0.01	0	0
Total	2.37	3.78	3.4	2.64	6.25	5.48	3.71

Table 4. Blue whiting biomass estimates (10^6 t) obtained by acoustic surveys and calculated by the VPA (Anon., 1989).

Year	Acoustic surveys	VPA	
		Total stock	Spawning stock
1982	2.4	4.1	3.0
1983	3.8	4.8	2.6
1984	3.4	5.4	2.6
1985	2.6	5.8	3.5
1986	6.2	6.4	4.4
1987	5.5	6.2	4.2
1988	3.7	5.8	4.3

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DISTRIBUTION AND GROWTH OF BLUE WHITING IN THE NORTH-EAST ATLANTIC 1980 - 1988

by

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ABSTRACT

The distribution pattern of the blue whiting spawning stock have gradually changed in recent years, and concentrations are recorded more offshore and more to the south than before. The activity of the fleet with its shifting of fishing localities, gives knowledge of the blue whiting's migration route during the spawning season.

Also during the summer season the distribution pattern has changed. The recordings of the highest concentrations have shifted from north and northwest of the warmer side of the Norwegian Sea to more southern parts. The acoustic estimates, which are considered as indices only, have decreased noticeably since the beginning of the 1980's. In some years they have been lower than the spawning stock assessments, and thus demonstrated that the total stock has not been properly covered during the feeding season.

For the last 5-6 years the structure of the blue whiting stock has been dominated by the strong of 1982- and 1983-yearclasses.

The growth of blue whiting, based on observed lengths as well as back-calculated lengths, is described for various years and yearclasses as occuring in various areas. Especially the 1982 and 1983 yearclasses when, as juveniles, being basis for the mixed industrial fishery in the North Sea.

The growth pattern varied significantly among the various yearclasses, and the rate increased with increasing years up to the 1978-yearclass. Thereafter this effect was reversed up to the 1983-yearclass.

After the age of 5 years the blue whiting growth pattern may diverse significantly between some areas, and off the Norwegian Coast blue whiting grow to a larger size than more offshore in the Norwegian Sea and west of the British Isles. However, while the growth in the Hebrides area was quite similiar to that in the Norwegian Sea, it differed slightly from the growth in the Porcupine bank area. This indicates influence of blue whiting from other areas which don't take part in the migration back to the Norwegian Sea. Analysis of annual zone measurements also indicates differences in the stock.

INTRODUCTION

Blue whiting (<u>Micromesistius poutassou</u>) in the northeast Atlantic
system probably consists of several stocks, which most likely overlap
each other. From the feeding area in the Norwegian Sea, the majority
of blue whiting each spring undertakes a spawning migration to the
main spawning ground in the area west of the British Isles. The ICES'
Blue Whiting Assessment Working Group in 1980 decided to treat the
entire area as a single assessment unit with southern boundary at the
Porcupine bank, i.e. along latitude 52^0 $30'$ N (Anon. 1980).

The Porcupine bank area is considered an area where blue whiting from
the south, from the north and from local populations mix. Some years,
however, catches taken on the southern slope of the bank have been
thought belonging to the northern stock and consequently confined to
the northern area. The Working Group therefore found it natural also
to have the boundary between the southern and the northern stocks to
be further south, and in 1988, for practical reason decided to have it
located at latitude 48^0 N (Anon. 1989).

In the 1970's the interest in commercial exploitation of blue whiting
had a rapid increase. International fishery took place in the feeding
area as well as in the spawning area, and in addition blue whiting was
caught as by-catch in the mixed industrial fishery in the North Sea. A
number of approximately 13 nations have used to exploit the blue
whiting stock.

Since the 1960's the blue whiting stock has been surveyed in the
feeding area during summer or autumn by research vessels from various
countries, for exempel USSR (Ushakov and Mazhirina 1978, Shevchenko
and Isaev 1983), Norway (Blindheim et.al. 1971, Blindheim and
Jakupsstovu 1976, Monstad and Blindheim 1978, 1986) and Germany
(Sarhage and Sshøne 1980). In the period 1982 - 86 the summer surveys
have been coordinated by ICES and research vessels from The Faroes,
Iceland, GDR, Norway, USSR and Denmark have participated (Anon. 1982,
1983b- 1986b).

The assessments from these surveys, considered as relative indices
because of, most probably incomplete coverage of the total northern
stock, indicate a steady decrease of the stock from 1980 onwards
(Monstad and Blindheim 1986). In the Working Group's VPA-results an
increase of the stock size due to the strong 1982 and 1983 yearclasses
is reflected. From 1986 a slight decrease set in again (Anon. 1989).

Every year since the beginning of the 1970's the spawning stock of the
northern blue whiting has been monitored acoustically in the spring
season by vessels from one or more countries. However, due to
incongruence of time and area covered, the resulting estimates show a
great discrepancy (Anon. 1983a, 1984a, 1986 a, 1989).

The assessments of the stock size in the spawning area in general have
been, however, higher than the assessments in the feeding area. This
indicates a bias in methodology, and in 1985 an ICES Workshop dealing
with this matter was set up. It concluded that to obtain proper
recordings of the stock in the Norwegian Sea the size of it has to be
above a certain level or distributed in a smaller area in larger
concentrations than was the case some of the years, especially in 1983
and 1984 (Anon 1985 a).

The change of the blue whiting distribution pattern in the Norwegian Sea in the 1980's may not only be due to a stock decrease. It can also have been caused by changes in the enviromental conditions described by Shevchenko and Isaev (1983, 1985), (Monstad and Blindheim 1986).

The growth of blue whiting has been discussed by Bailey (1982). He compares parameters obtained by several authors and show a great variety in the growth. This may indicate the existence of separate stocks. The growth rate is highest in the female which also grow to a larger size than the male. Within its first year of life the blue whiting may reach a size of 20-25 cm (Gjøsæter, Beck and Monstad 1979).

MATERIAL AND METHODS

Blue whiting was recorded during surveys by use of echo sounders. For measurements of fish density the echo sounder was connected to an echo integrator. Some of the survey results like the cruise track with stations, the distribution, structure and estimate of the stock have previously been published in survey reports and others.

The density symbols of the distribution pattern are based on relative values adjusted to the abundance estimate for comparison of the various years in the array. The patterns during the spring season are all based on Norwegian surveys (Monstad and Midttun 1980,1981; Dahl 1982; Midttun 1983; Monstad 1984, 1986, 1987a, 1988a), except for 1985 when Norway did not survey the spawning area. For that year the result from a Faroese survey is used (Jakupsstovu and Thomsen 1985).

The patterns during the summer season are based on Norwegian surveys alone for the years 1980, 1981 and 1988 (Hamre et al. 1980; Blindheim and Monstad 1981; Monstad 1988b). For the years 1982-1986 the distribution patterns are based on the ICES-coodinated surveys (Anon. 1982, 1983b-1986b) and for 1987 on combined results of Norwegian and GDR surveys (Danke 1987; Monstad 1987b).

During the joint surveys, data like echo integrator readings, trawl catch informations, blue whiting length measurements and temperature observations were exchanged between the vessels from participating countries. For all the years concerned, however, the age compositions for both the spring and the summer situations, are based on otolith readings of Norwegian samples only.

For the Norwegian Sea age-length keys were used on either separate or combined length measurements, weighted by the echo abundance obtained within the various areas surveyed. For the spawning area the length measurements were all from Norwegian research vessels, except in 1985 when samples from commercial catches were used. The description of the total age compositions is based on the results from the Working Group's VPA-run, and hence includes the total catch of blue whiting presented as number of fish per age group (Anon. 1989).

The description of the fishery progress during spring season is based on catch statistics from the Directorate of Fisheries.

The biological samples used in the length-growth analysis were in general collected with research vessels, supported by complementing samples from commercial catches. The otoliths were kept whole and soaked in water while being aged and measured under microscope. The annual zones were measured along the largest diameter using the inner

edge of the hyaline area.

Von Bertalanffy's equation was used in the analysis, and the values
fitted to length-growth curves as descibed by Ricker (1975). The cal-
culations were run by a computer programme. A plot of fish length
against otolith size was used for "back-calculation", and mean values
of the zones were entered the graph to get the corresponding fish
lengths (Tesch 1968).

Illustration of the growth of juvenile blue whiting in the North Sea,
was made possible by use of age-length keys on the material of length
measurements obtained from commercial catches at the fish plants by
the Directorate of Fisheries.

For description of the temperature trends at different depthts during
the spring and the summer season were used observations made with CTD-
sonde from Norwegian research vessels only. The 2^0-isoline at 200m
depth during summer is obtained from the Norwegian sea surveys
mentioned above.

RESULTS AND DISCUSSION

Distribution;

1) In the spawning area.
Distribution and density of blue whiting in the spawning season, i.e.
March-May, of 1980-1988 are shown in Fig. 1a-c. Outlines of the actual
areas surveyed are also marked on the figure. Due to more or less
constant movement of the stock while migrating to and from the
spawning grounds, the picture of distribution, as well as the acoustic
abundance estimates, varies from year to year depending on the time
period and the actual area surveyed.

The text table below shows the biomass (in mill. tonnes) of the blue
whiting spawning stock estimated from the Norwegian acoustic surveys,
and the corresponding VPA-results obtained by the Working Group (Anon.
1989).

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Survey:	5.4	6.0	-	4.4	2.1	-	2.1	4.1	6.8
VPA :	4.4	3.5	3.0	2.6	2.6	3.5	4.5	4.2	4.3

The stock size was found to vary through this period and the lowest
values was observed in 1984 and 1986. During the next two years a
larger stock was measured and in 1988 it had reached the level of the
stock size observed in the beginning of 1980'ies. The VPA-results,
however, reflect a more even picture, but with the highest value in
1986 when the acoustic one was lowest.

In general the highest densities of blue whiting were found near the
continental slope, but some years also more westerly over deep water.
During the array of years concerned it is, however, possible to dist-
inguish a slight change from a mainly northern to a more southern
pattern.

In the years 1980-1984 the best recordings were made, and hence the
greater part of the spawning stock observed mainly in the areas off
the Hebrides. Blue whiting was, however, found all the way from the

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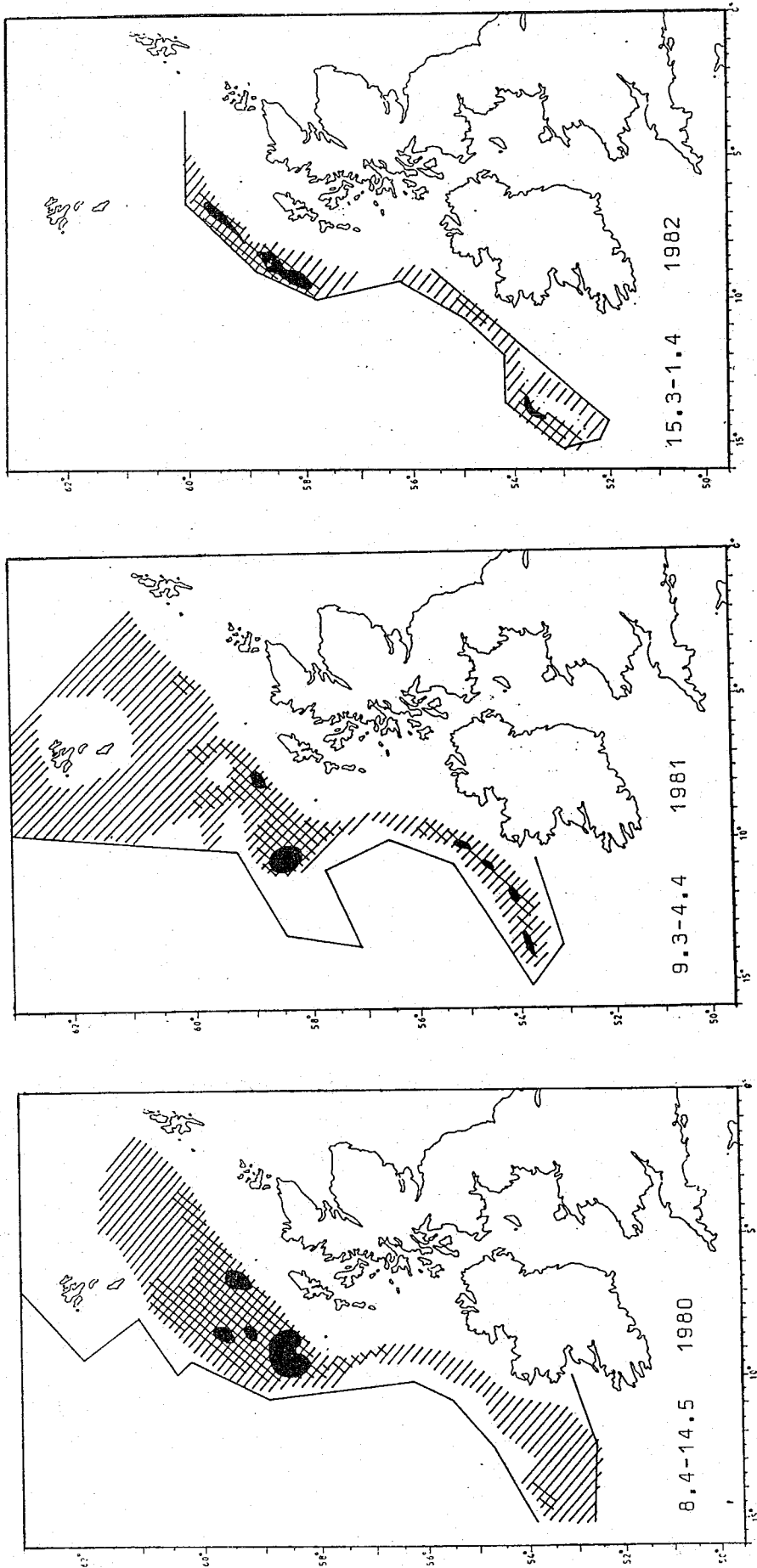
Fig. 1A. Distribution and densities of blue whiting during spring
1980-1982. Single hatch: area with scattered recordings,
double hatch: dense recordings, black: very dense
recordings. Full line indicates the area surveyed.
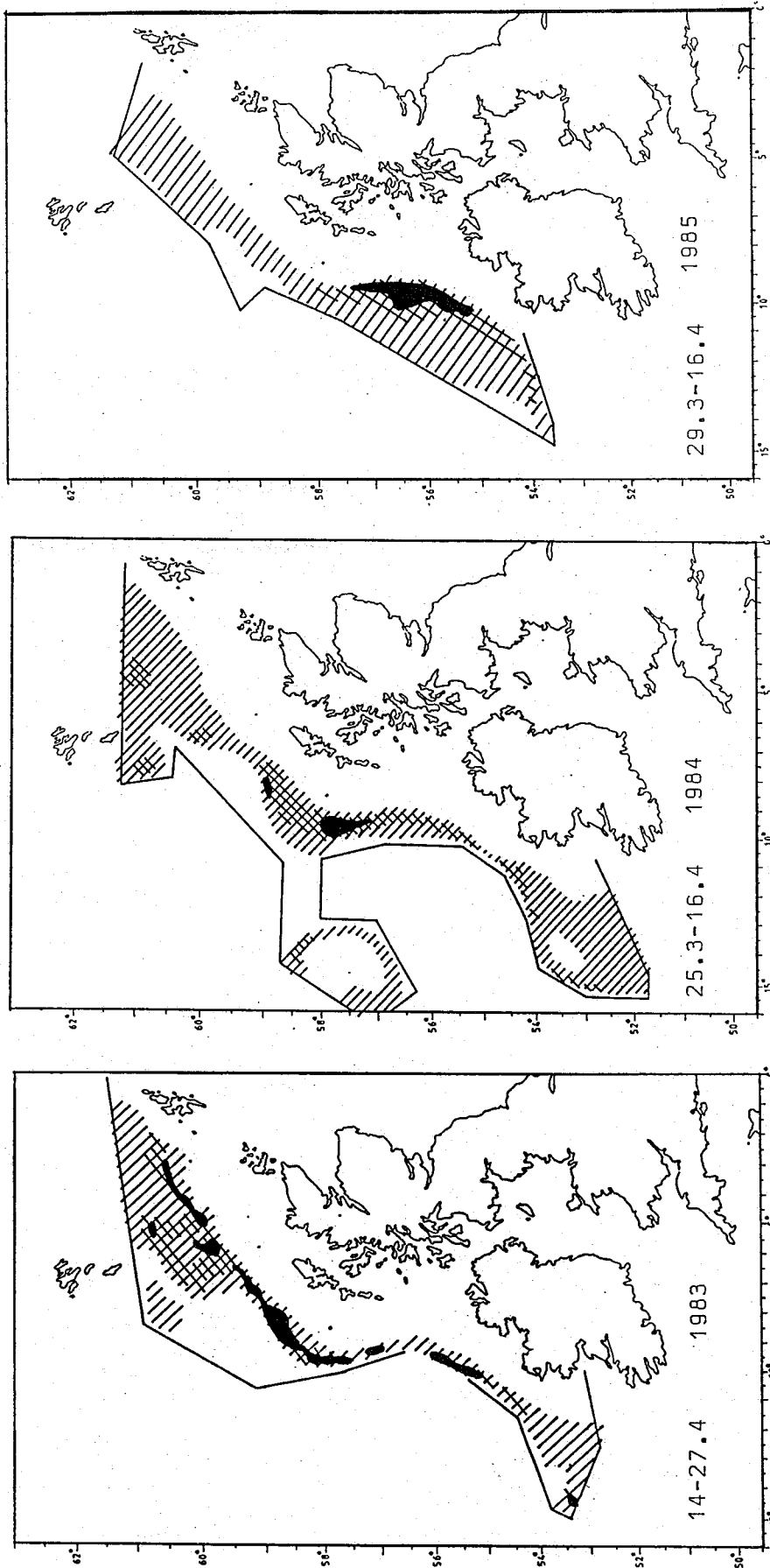
Fig. 1B. Distribution and densities of blue whiting during spring
           1983-1985. Symbols as in Fig. 1A.
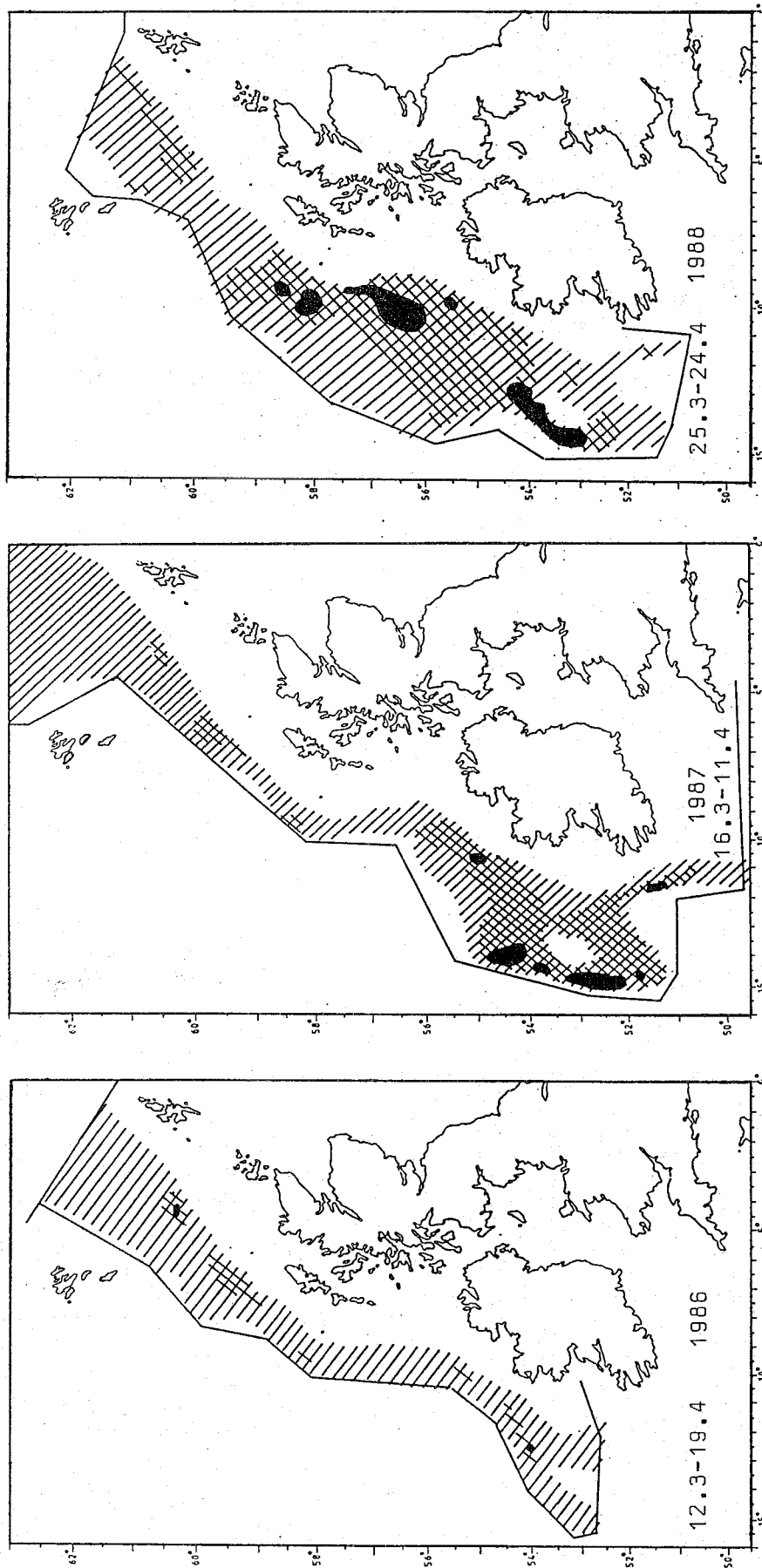
Fig. 1C. Distribution and densities of blue whiting during spring 1986-1988. Symbols as in Fig. 1A.

Porcupine bank to The Faroes-Shetland area, except for 1982 when only
a smaller area was surveyed. In 1981 blue whiting was observed around
The Faroes and in 1984 on either side of the Rockall bank.

In 1985 the best recordings of blue whiting were made in an area more
to the south than in the previous years, i.e. on the shelf between the
Hebrides and Ireland.

In the spring of 1986 blue whiting was found scattered distributed
over an area from the Porcupine bank to north of The Faroes. An
extended survey demonstrated the continuation of the distribution
further northwards along the shelf edge west of Norway up to the
Lofoton Isles (Monstad 1986). However, mostly weak recordings were
obtained, and hence probably only a portion of the spawning stock was
recorded that year.
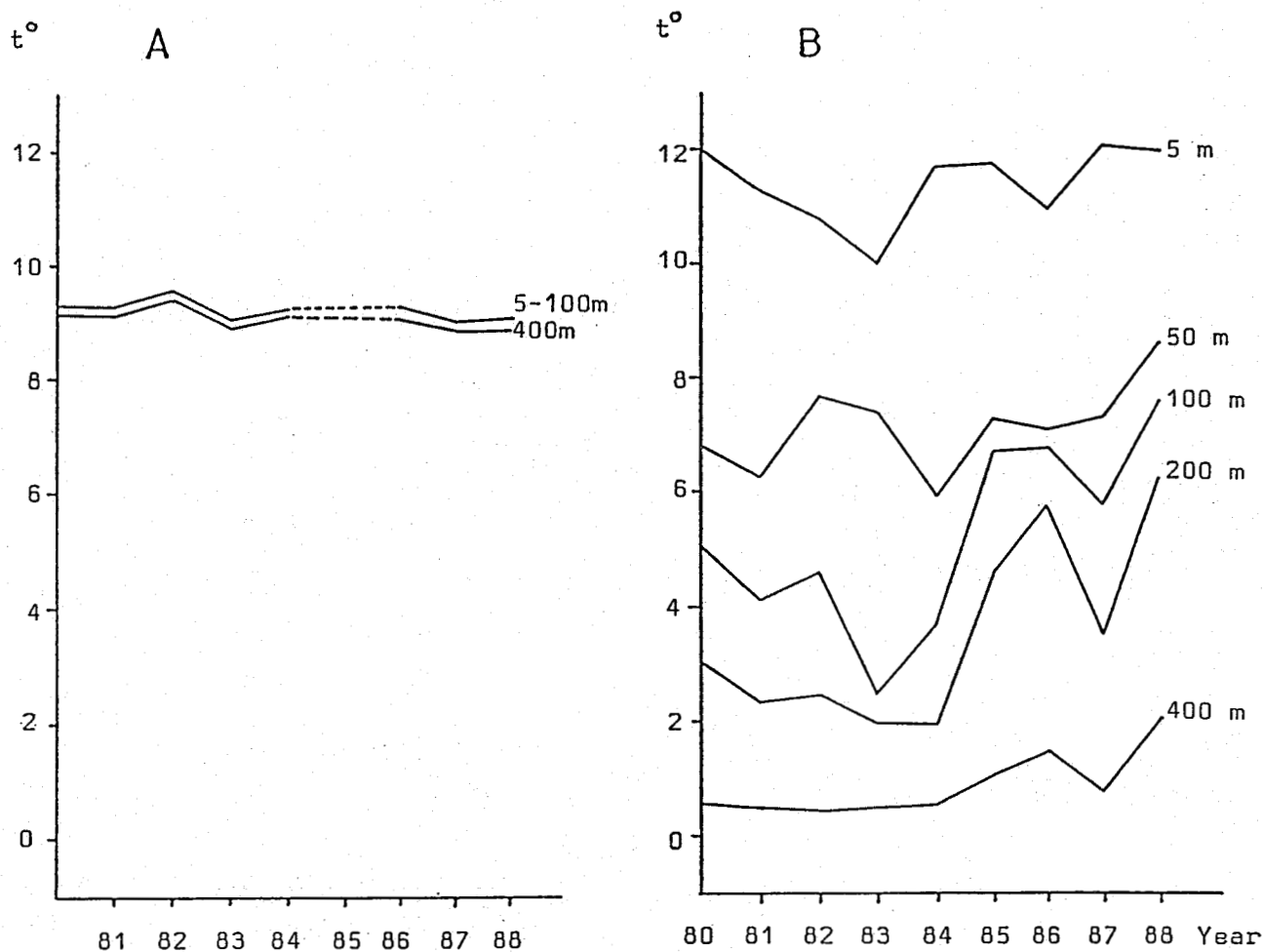
Fig. 2.   Temperature trends at 5, 50, 100, 200, and 400 m depth for
          the period 1980-1988. A) In the spawning area west of the
          Hebrides in March/April near position: 58°N, 10°W.
          B) In the Norwegian Sea in August at the outer station of
          the Svinøy-NW section, position: 64°40'N, 00°00'E/W.

In 1987 the density was found to be significantly better than in 1986.
Recordings of blue whiting were made from south of Ireland to over the
Porcupine bank and north of it, and further along the shelf edge to
the area north of Shetland and The Faroes. The highest concen-
trations and the majority of the stock were found to be located more
to the south than previously, i.e. the western part of the Porcupine
bank and over deep water north of it.

In spring 1988 an even larger part of the spawning stock was recorded
than in 1987, distributed from south of Ireland to the Faroes-Shetland
area. Very high concentrations of blue whiting were found both to the
south and to the north, i.e. near the slope west and north of the
Porcupine bank and west and southwest of the Hebrides. In addition
blue whiting appeared in notable concentrations farther off the
continental shelf and over deeper water than usually observed.

The observed gradual change in the distribution pattern could indicate
that during the last 2-3 years the Porcupine bank area has become more
important as the main spawning ground than the area off the Hebrides.

The temperature conditions on the spawning ground were found to be
very homogeneous in the water coloumn, with only minor year to year
changes, varying slightly around 9^0 C (Fig.2a).
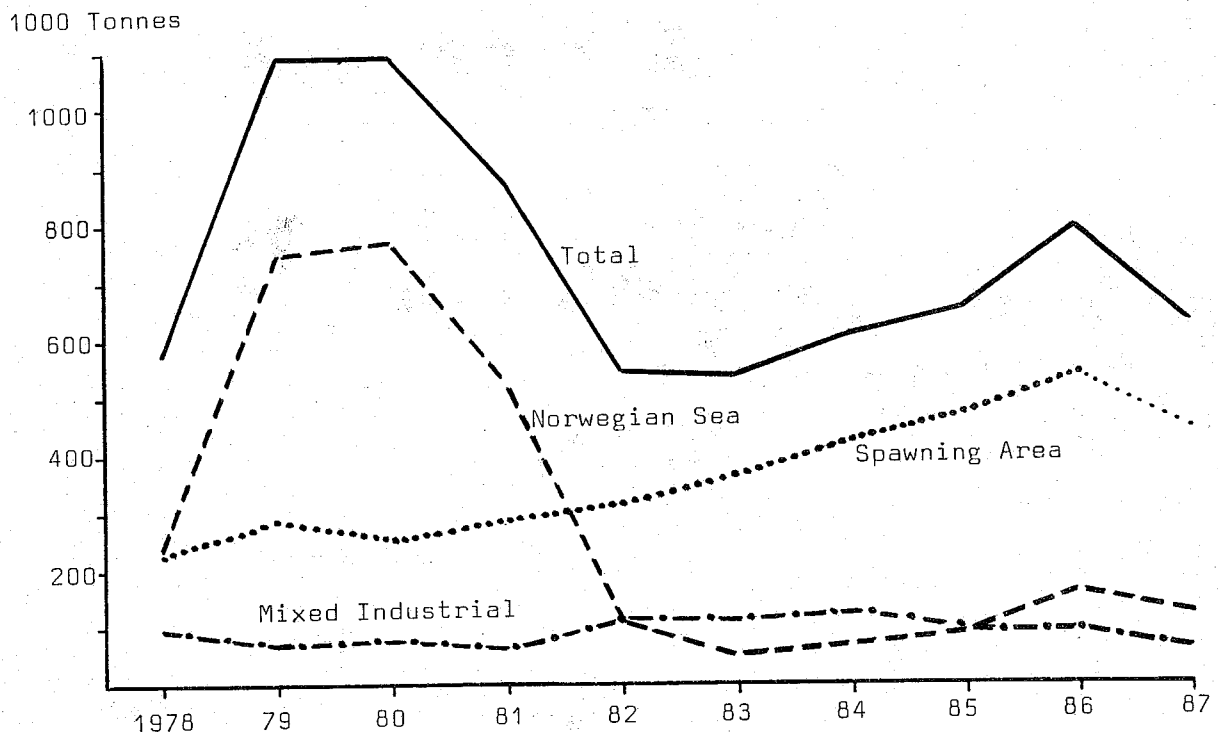
Fig. 3. Annual landings of blue whiting, from the main fisheries and
total, of the northern stock, 1978-1987. Source: Working
Group Report of 1988.

2) During the spawning fishery season.

From a modest fishery in the first half of the 1970's, the commercial exploitation of the northern blue whiting stock increased to maxima in 1979 and 1980 with annual catches of more than 1 mill. tonnes (Fig.3). A few years later the catch rate was cut down to approximately the half, and then again increased to a new maximum in 1986.

In the years 1978 - 1981 the bulk of the catches was taken in the Norwegian Sea with the USSR as leading nation (Fig.4). Since 1982, however, the largest quantities of blue whiting have been taken in the spawning area west of the British Isles. In this fishery Norway use to take significantly more than the other nations and is responsible for approximately half of the landings.

In the mixed industrial fishery in the North Sea, where blue whiting is taken as by-catch, Denmark and Norway are the main actors. The
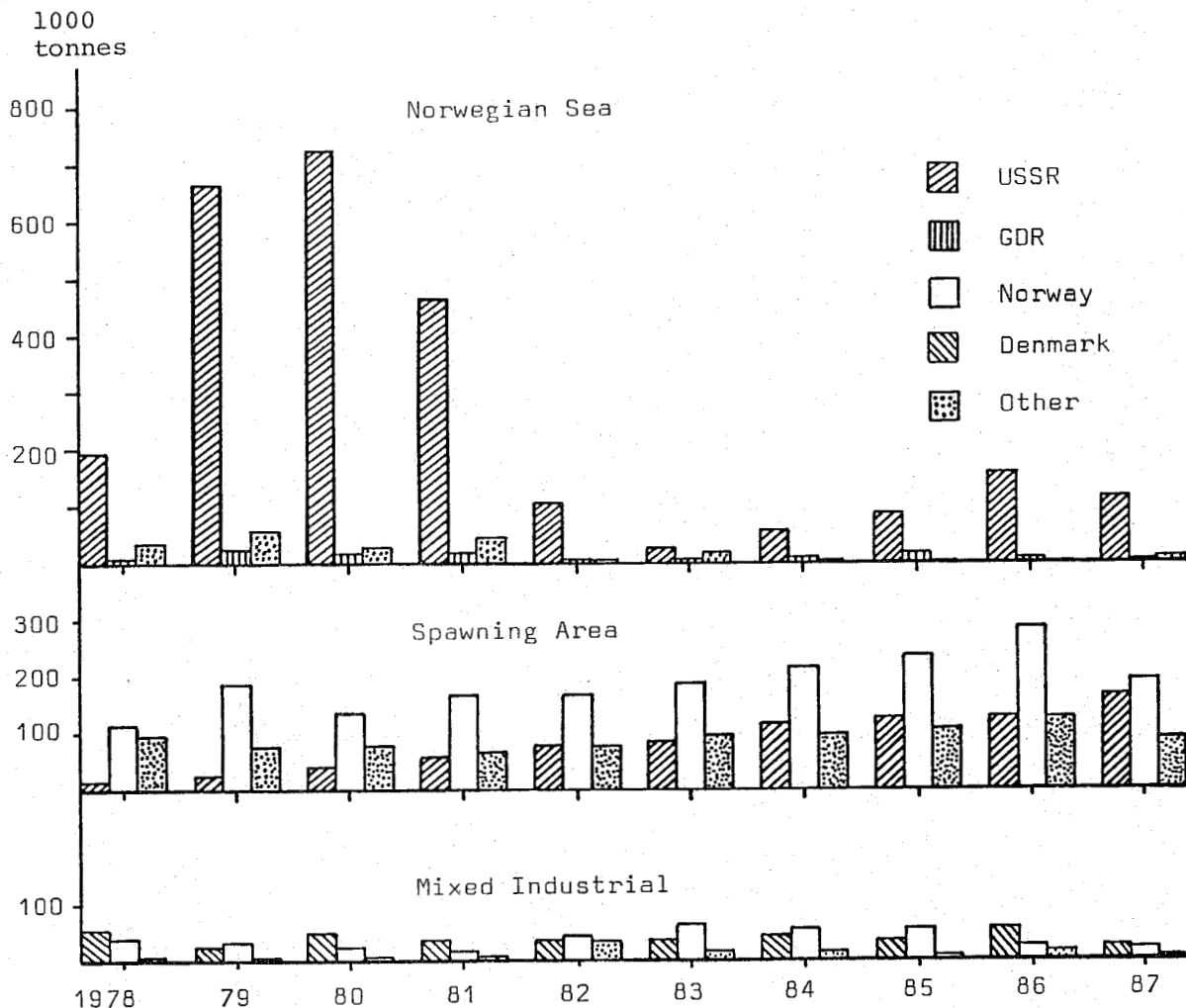
Fig. 4. Annual landings of blue whiting by nations from the main fisheries of the northern stock, 1978-1987. Source: Working Group Report of 1988.

annual landings, however, exceeded 100 000 tonnes only in the years
1982 - 1984 (Fig.3).

During spring the migration of blue whiting concentrations within and
from the spawning area, can be illustrated by the activity of the
fishing fleet. Preferably, the fleet will always operate on the
densest concentrations, and thus its transfer route through the
season, to a great extentcan be a parallel to the migration route.
Fig. 5a-c, which is purely based on Norwegian catch statistics
allocated on statistical rectangles, shows the fishery progress in the
spring season of 1980 - 1988.

In general the fishery starts at the Porcupine bank in March or late
February, continues in the area off the Hebrides in April and
terminates in Faroes-Shetland waters by the end of May or beginning of
June. The bulk of the catches is usually landed in April from the area
between the Hebrides and Faroe Islands.

There has been a tendency for the fishery to start gradually earlier
each year. While it began in the middle of March in 1980 and 1981, it
was initiated in late February in 1982 and -83, off Ireland and the
Hebrides respectively. Since then the fishery has taken place in
February every year in the area off the Hebrides.

From 1985 onwards it already started in early January in Faroes waters
and continued southwards to the area west of the Hebrides in February.
After that the fishery fell back to its traditional pattern, with
activity on the Porcupine bank area in March, off the Hebrides again
in April and in Faroes and Shetland waters in May and early June.

Some years the fishery could take place over extensive areas with
catching both at the edge of the Porcupine bank and off the Hebrides,
or off the Hebrides and in the Faroes-Shetland area at same time.

In 1985 and 1986 the catching of blue whiting in the Faroes area in
early January, was a continuation of catching which actually had
started up on those fishing grounds in December the previous year.

In 1987 and 1988 the Norwegian fishery for blue whiting in the area
west of Ireland, in addition to an extreme western location took place
more to the south than ever before.

In general the bulk of the catches is taken near to the continental
slope, i.e. the pelagic trawl is used very close to, and some times
actually at the bottom. In 1988, however, the fleet had to work more
off the slope area and over deeper water than before to get the best
concentrations of blue whiting. The catches taken nearer to bottom at
ther slope contained a significant part of greater silver smelt
(Argentina silus) as by-catch. This was especially the case in the off
the Hebrides in May.

Viewing the fishing fleets operation localities through the period
1980 - 1988 as shown on Fig. 5, it is obvious that greater parts of
the blue whiting stock have annual oscillation between the Norwegian
Sea and the slope area west of the British Isles. However, to what
extent also parts of the spawning stock migrate to other areas is
still a valid question.

Due to a fishery ban in the area south of 56°30'N and east of 12°W,
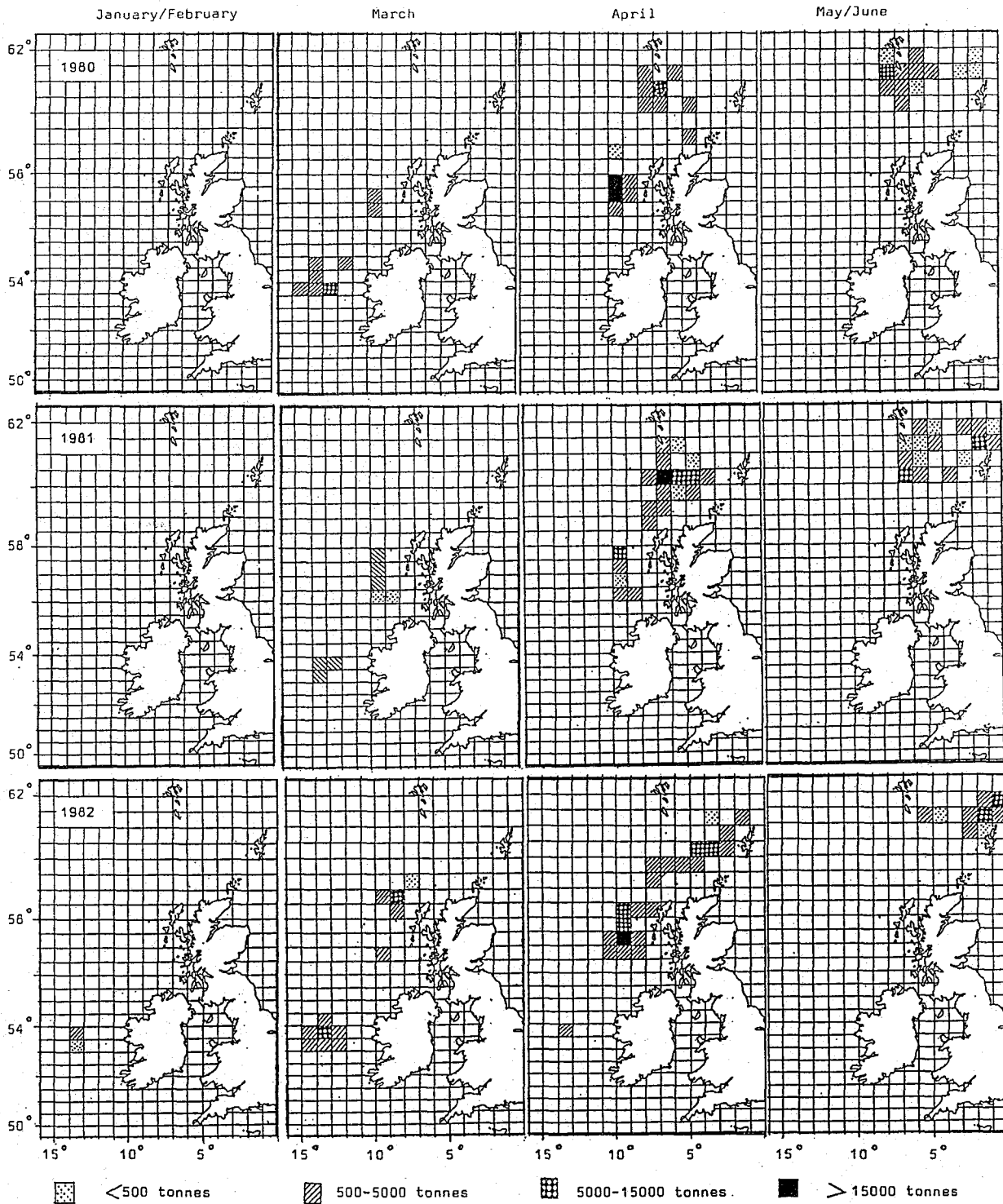there is a gap in the fishery activity between the Porcupine Bank area

Fig. 5A. Progress of the Norwegian blue whiting fishery in the
         spawning area, 1980-1982.

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Fig. 5B. Progress of the Norwegian blue whiting fishery in the spawning area, 1983-1985.
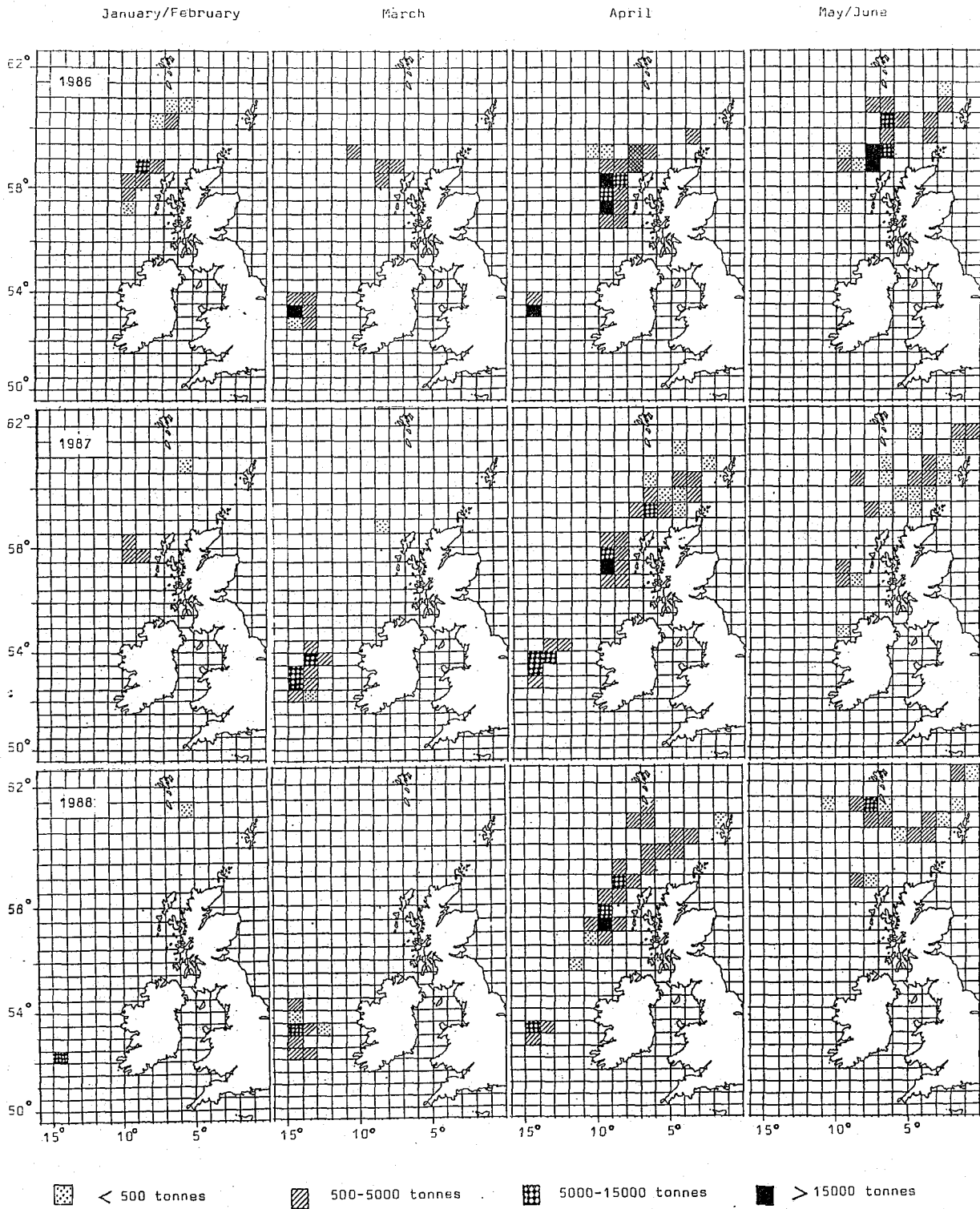
Fig. 5C. Progress of the Norwegian blue whiting fishery in the spawning area, 1986-1988.

and off the Hebrides. Part of the stock at the Porcupine Bank may not
migrate northwards, but rather southwards to Biscaya and the Azores
area, or even westward and north-westward to East-Greenland and south
of Iceland.

3) In the feeding area.

The distribution and density of blue whiting in the Norwegian Sea
during the summer season of 1980 - 1988 are shown in Fig. 6a-c. The
area surveyed is also marked in the figure together with the termoline
of 2^0 C at 200 m depth. The fish were recorded from the surface down
to mainly 300 m depth, but frequently even deeper, i.e. to 500 m. The
overall majority of the recordings, however, was obtained at 200 m
depth, and hence the termoline in that depth is chosen.

In the text table below is given the total estimates (in mill. tonnes)
of the blue whiting biomass from the Norwegian Sea surveys in 1980-88
of which the results in 1982-86 are from the international surveys,
and the corresponding VPA-results of the total stock obtained by the
Working Group.

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Survey:	9.1*	4.9*	4.6	2.8	3.8	4.9	3.0	2.5**	2.6*
VPA :	5.1	4.3	4.1	4.8	5.4	5.8	6.4	6.2	5.8

* Norwegian surveys only,
** Combined result of Norwegian and GDR surveys

The highest acoustic estimate in the Norwegian sea was made in 1980 as
also the spawning stock was observed at a comparative high level west
of The British Isles. In 1981 there was a significant drop in the
"total" stock estimate, as was the case also from 1982 to 1983.
Thereafter the stock had an increase due to the numerous 1982- and
1983-yearclasses. However, the new deacrease observed in 1986 and the
low estimates obtained in 1987 and 1988 are in no correspondance with
the abundance estimates in the spawning area over the same period of
time.

Though the area surveyed did not cover the entire stock in the
Norwegian Sea, it was most probable a main and important part. As
mentioned earlier, the recordings of blue whiting during the summer
season in the Norwegian sea when the stock is dispersed over vaste
areas and at great depths, do not reflect the true picture. The esti-
mates have to be treated as indices only, with the observations to a
certain degree describing the distribution pattern.

The VPA-results, like the acoustic estimates show a drop from 1980 to
1981 and -82, but thereafter an steady increase in the stock size up
to 1986-87.

For all the years concerned the blue whiting was observed scattered
over the greater part of the area surveyed, i.e. on the eastern and
warmer side of the Norwegian Sea. Most years, however, denser concen-
trations of blue whiting were most of the years found in minor and
limited areas only.

The highest abundance was measured in 1980, with the best concen-
trations to a great extent confined to the north in an area between
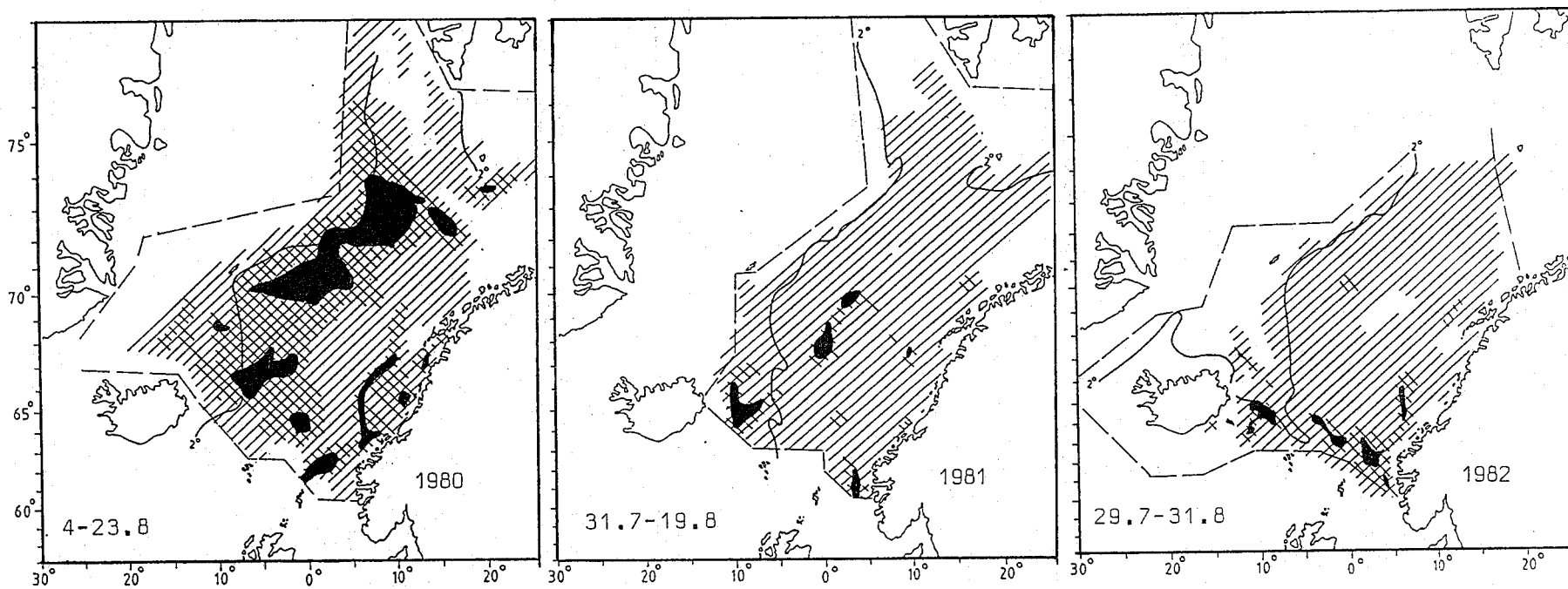Jan Mayen and Bear Island (Fig.6a). In the succeeding years the

Fig. 6A. Distribution and densities of blue whiting with 2°C
isoline at 200 m depth, during summer 1980-1982. Single
hatch: area with scattered recordings, double hatch: dense
recordings, black: very dense recordings. Stippled line
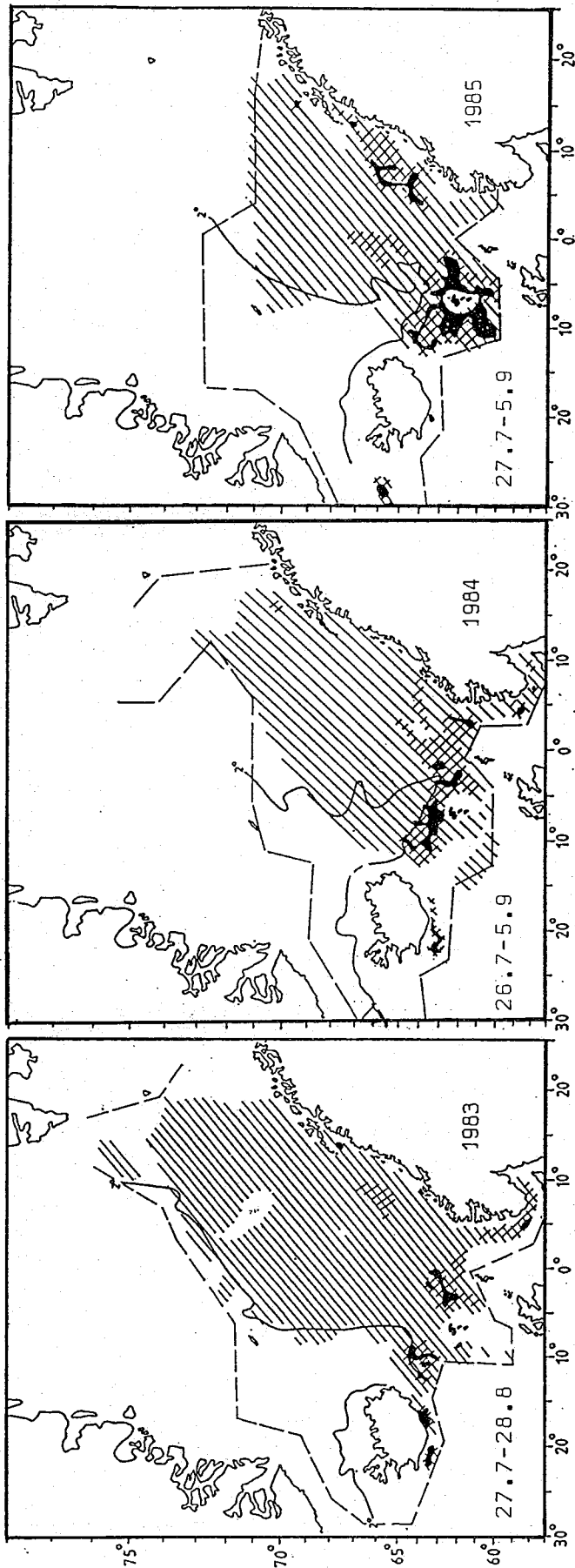indicates the area surveyed.

Fig. 6B. Distribution and densities of blue whiting with 2°C
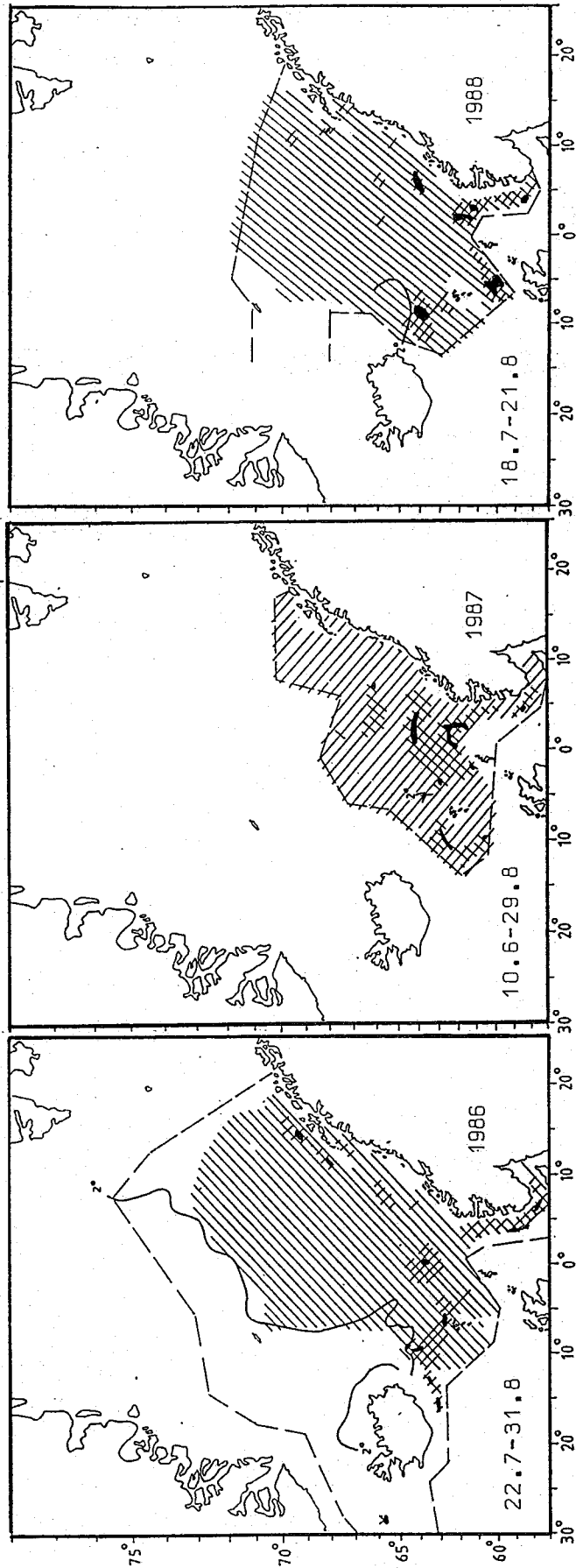isoline at 200 m depth, during summer 1983-1985. Symbols
as in Fig. 6A.

Fig. 6C. Distribution and densities of blue whiting with 2°C isoline at 200 m depth, during summer 1984-1988. Symbols as in Fig. 6A.

abundance decreased, and the best concentrations were found more to
the south in a "belt" from Iceland to western Norway.

In the years 1982-1985 the densest concentrations were solely recorded
in the south. During this period the contributions of the successful
1982- and 1983-yearclasses were significant, and the total stock
abundance increased. The juvenile part of the stock, however, still
appeared mostly in the southern part of the Norwegian Sea. In 1985
high densities were observed on the shelf around the Faroe Islands
(Fig.6b).

From 1986 to 1988 the abundance of blue whiting decreased once more
and mostly very scattered recordings were made in the feeding area.
Dense concentrations these years were only obtained within separate
minor areas in the south and in the north (Fig.6c).

The western limit of the distribution could in some years be related
to the 2^0 -isoline at 200 m depth, especially in the northwestern part
in 1981 - 1986. In 1987 and 1988 water of temperature around 2^0 C at
200 m was only observed within a narrow ara north of the Faroe
Islands.

The temperature conditions in the Norwegian Sea differ significantly
from the conditions observed further south on the spawning grounds. In
Fig 2b are shown the observations made at the outer station of the
standard hydrographic section Svinøy-NW, i.e at position $64^040'$ N
$00^000'$ E/W, in August 1980-1988. This station may represent the south-
eastern area of the Norwegian Sea, where colder water from north
penetrates in the deep and thus mixes in the water coloumn with warmer
water from south.

The August temperature in the surface layer varied between 10^0 and 12^0
during the period, while at 400 m it varied from 0.5^0 in 1980 to 2^0 C
in 1988. The greatest variation was observed in the medium depth layer
of 100 - 200 m where a greater part of the blue whiting stock usually
is recorded.

At 200 m depth the August temperature increased from 1.9^0 in 1983 to
5.8^0 in 1986, dropped to 3.5^0 the next year and then increased radi-
cally to 6.2^0 C in 1988 when the influx of colder water from the north
was reduced once more. The same pattern of variation could also be
observed at 100 m depth, only at a 0.5^0 - 2^0 higher temperature level.

The distribution pattern in the feeding area to a great extent is
influenced by the avaiability of food, but also by the hydrographic
conditions both directly and indirectly.   Plekhanova and Soboleva
(1982) found that in years with high plankton production the blue
whiting stock is widely dispersed, and in years with low production
the concentrations is mainly found in the areas where the production
is best.

Due to increased extent of Artic water with temperature below 3^0 C the
Artic front at 200 m depth shifted from 1980 to 1984 about 300 km
eastward. This may have acted as a barrier which has forced the stock
to chose a more eastern migrating route than earlier (Monstad and
Blindheim 1986).

The migration route to the Norwegian Sea thus followed the southern
slope of the Faroe-Shetland Channel as described by Shevchenko and
Isaev (1983, 1985). This is also evident from the illustrations of the
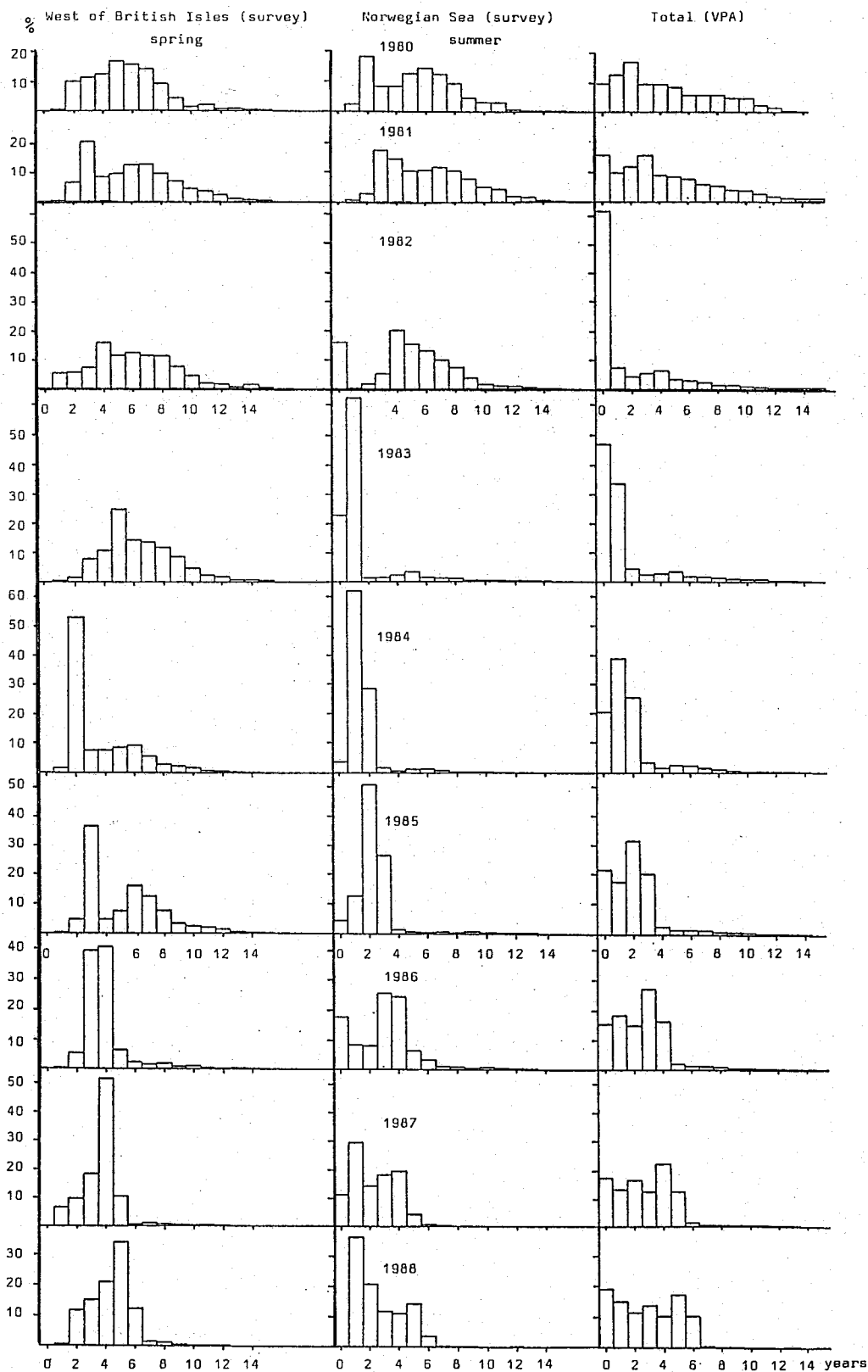
Fig. 7. Age composition (N%) of blue whiting in the period 1980-1988
        in the spawning stock west of the British Isles during
        spring, in the stock recorded in the Norwegian Sea during
        summer and in the total stock as calculated by VPA.

operation positions of the Norwegian fishing fleet (Fig. 5 a-c). While
the fishing season was terminated at the western side of the Faroes in
1980 it was at the eastern side from 1981 to 1987.

This alone does not give the explanation to the reduction of congrea-
gations in the feeding areas more north. The shift of route, however,
may somehow have led the stock into areas where it could disperse into
deeper water and thus been more difficult to record.

Age composition.

Age compositions of blue whiting in the years 1980 - 1988 are shown in
Fig. 7 for the spawning stock, the stock observed in the Norwegian Sea
during summer and for the total stock as obtained from VPA-results. In
the three sets of illustrations the strong 1982- and 1983-yearclasses
dominate the picture.

In 1980 fish of 5 -7 years of age were the most numerous ones in the
spawning stock. Then, in 1981 the 1978-yearclass was the most abundant
with more than 20% of the stock, and up to 1983 became the dominating
yearclass.

In the Norwegian Sea the 1978-yearclass was also found to be the most
significant one in this period, and is reflected in the VPA- results
as a rather abundant yearclass. In 1985 it contributed with 13% to the
spawning stock, but thereafter only traces of it were found.

Already as 0-group the 1982-yearclass was observed to be a numerous
yearclass (Anon.1982). A minor part of it appeared in the spawning
stock already in 1983. In 1984 a greater part of it had become mature
and dominated in the spawning stock with a contribution of 53% .

Likewise the 1983-yearclass was observed to be a rich yearclass as
0-group (Anon. 1983b). Minor parts of it appeared for the first time
in the spawning stock as one and two year old, and in 1986, as three
year old, it contributed to the spawning stock in the same degree as
the 1982-yearclass, i.e. with approximately 40%.

In 1987 and 1988 the 1982-yearclass was found only in modest measure
in the samples, and the contribution to the spawning stock in the two
years hence was observed to have dropped to just above 10% . The
1983-yearclass, however, made up more than half of the spawning stock
in 1987 and 34% of it in 1988.

In the Norwegian Sea the 1982- and 1983-yearclasses were found at
equal contribution level as one year olds, namely more than 60% in
1983 and 1984 respectively. The sudden drop in 1987 of the 1982-
yearclass abundance was recorded also in the Norwegian Sea. The
abundance of the 1983-yearclass also decreased from 1987 onwards, but
not as significantly as the 1982-yearclass. The VPA-results reflect a
more modest reduction of the two yearclasses' dominance (Fig.7)

Growth;

1) By observed lengths
The growth of blue whiting in the north-east Atlantic is described for
6 various areas indicated in Fig. 8 and appropriately named as:

Vestfjord,	Norwegian Coast,	North Sea,
Norwegian Sea,	Hebrides,	Porcupine.

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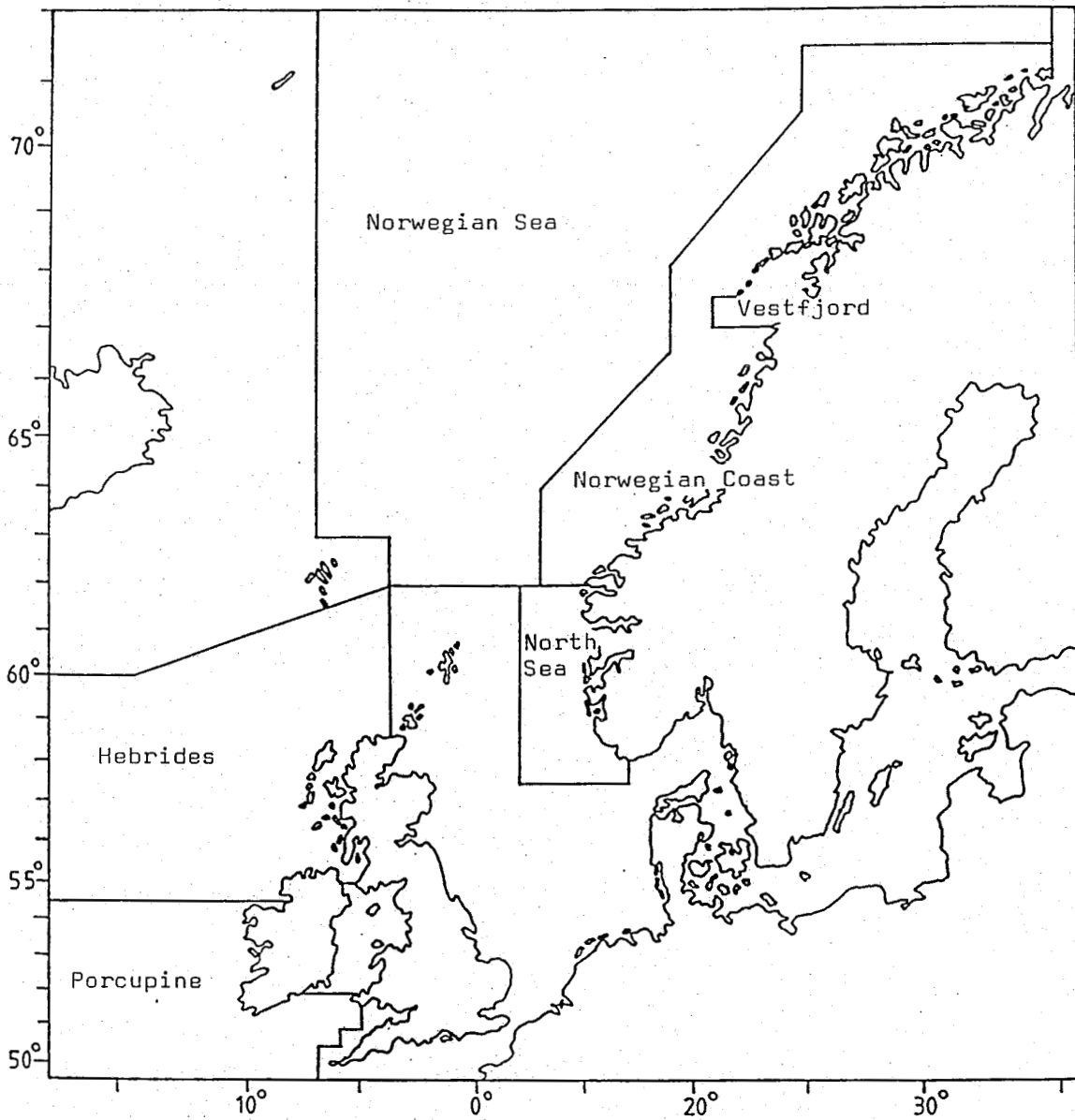Distribution and growth of blue whiting......

Fig. 8. Borders of the six different areas mentioned in the text.

The samples used were collected in the spring season, i.e. February-
April for the Hebrides and Porcupine areas, and in the summer season,
i.e. May-September with the bulk in August for the other areas.

Using von Bertalanffy's equation

$$l_t = L_{inf}(1 - e^{-K(t - t_0)})$$

the values for L_{inf}, the "rate" K and the hypothetical age when
the fish would have been zero length, t_0 (Ricker 1975) were obtained
for the six different areas in the period 1980 - 1988, for males,
females and both sexes combined. These are shown in Table 1.

The data were fitted to von Bertalanffy's growth curves and are shown
for the sexes combined in Fig. 9 for all the areas, scaled to
respective season for each year.

Except for Vestfjorden the growth up to the age of 5 years was found
tobe very similar in the various areas. After 5 years the growth
diversed significantly. However, the pattern in the Hebrides area was
all the way up to 14 years of age, very much like the pattern in the
Norwegian Sea area, indicating the same kind of fish. This may verify
the migration from the spawning area off the Britishy Isles to the
feeding area in the Norwegian Sea. The slight difference of the growth
pattern in the Porcupine and the Hebrides areas, indicates the
influence of "other" blue whiting in that "mixing area", i.e. it
could be individuals from the south or from local stocks.

Table 1. Growth parameters of von Bertalanffy's equation for both
sexes and combined of blue whiting from six areas in 1980-88.

Area	sex	L_{inf}	K	t_0
Vestfjord	female	38.9	0.23	-3.34
	male	34.6	0.31	-2.28
	comb.	36.8	0.28	-2.63
Norw.Coast	female	37.2	0.25	-2.72
	male	33.9	0.29	-2.81
	comb.	35.9	0.26	-2.67
North Sea	female	38.8	0.24	-2.51
	male	35.8	0.21	-3.70
	comb.	37.9	0.21	-3.30
Norw. Sea	female	35.7	0.30	-2.62
	male	32.9	0.34	-2.50
	comb.	33.9	0.35	-2.20
Hebrides	female	35.7	0.32	-1.66
	male	32.4	0.38	-1.51
	comb.	33.8	0.36	-1.52
Porcupine	female	35.9	0.32	-1.64
	male	32.8	0.34	-1.74
	comb.	34.2	0.35	-1.48

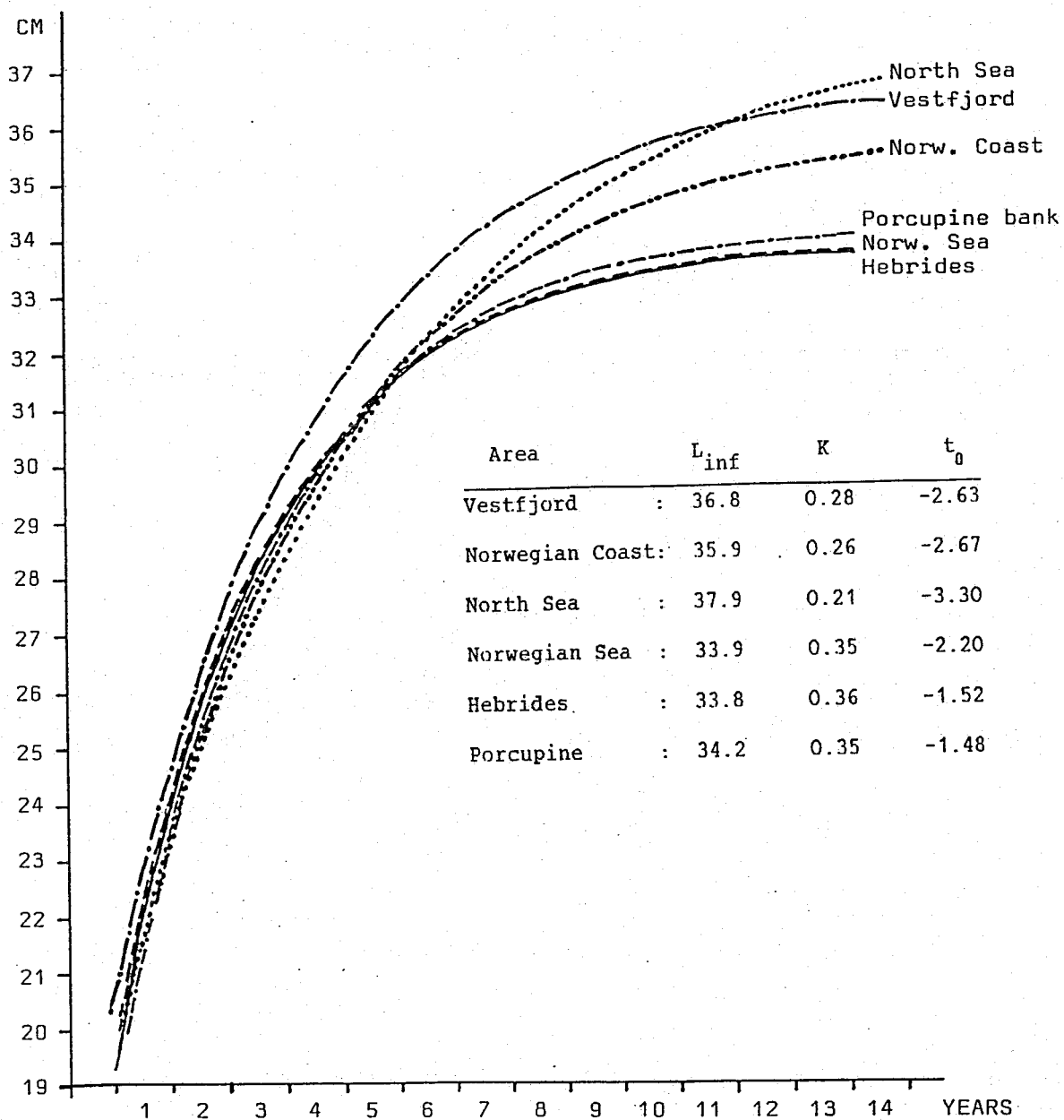| Area		L_{inf}	K	t_0
Vestfjord	:	36.8	0.28	-2.63
Norwegian Coast:		35.9	0.26	-2.67
North Sea	:	37.9	0.21	-3.30
Norwegian Sea	:	33.9	0.35	-2.20
Hebrides	:	33.8	0.36	-1.52
Porcupine	:	34.2	0.35	-1.48

Fig. 9. von Bertalanffy's growth curves and parameters of blue whiting, combined sexes, from six different areas in the North-east Atlantic.
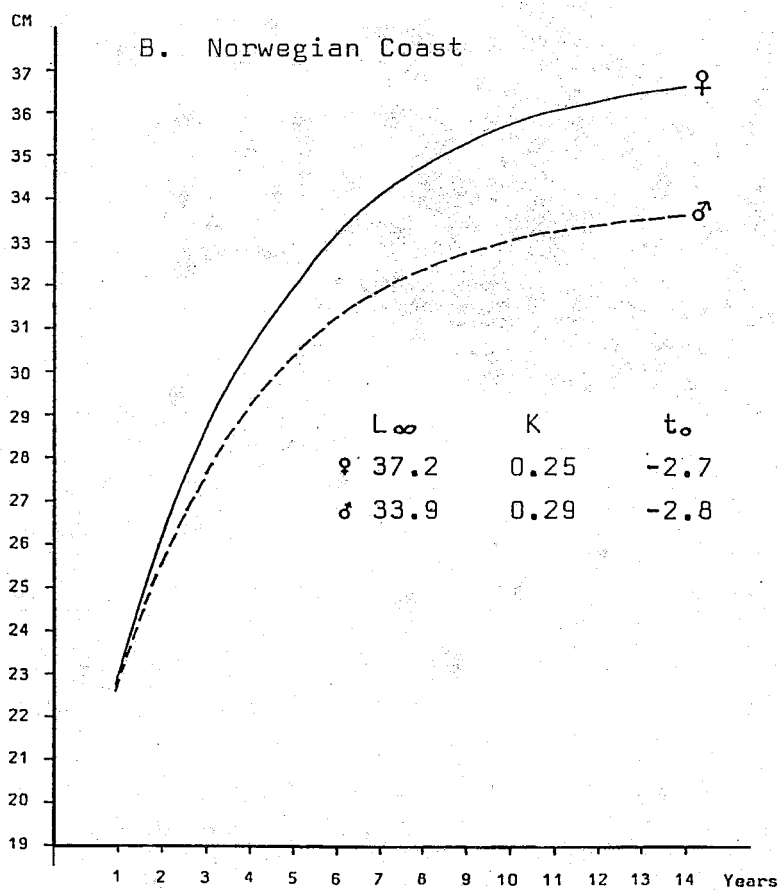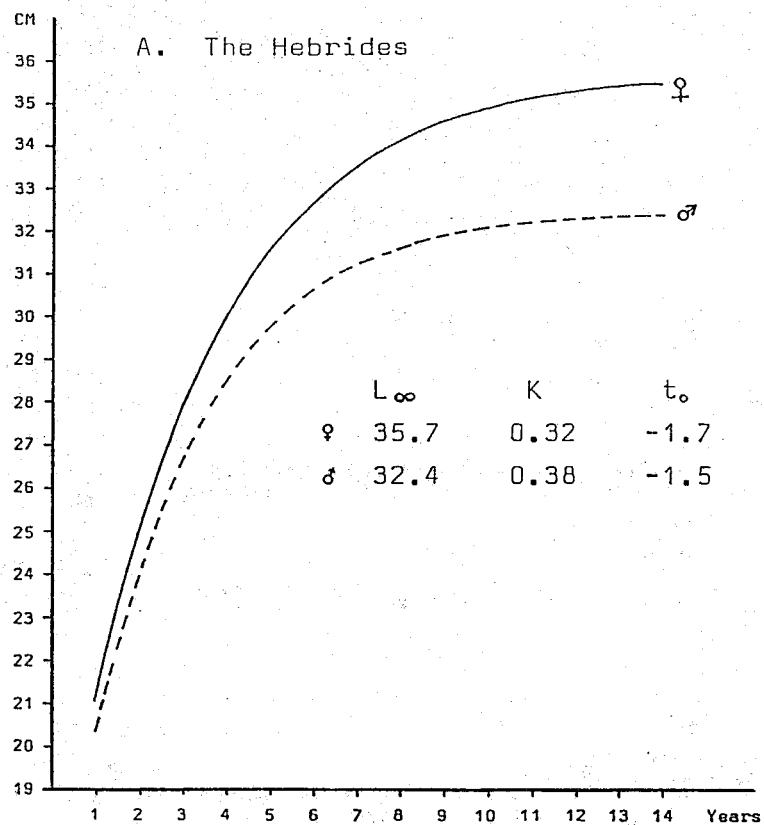
Fig. 10. von Bertalanffy's growth curves and parameters of blue
          whiting, male and female from A) the Hebrides and B)
          the Norwegian Coast.

The growth pattern for the Hebrides area differ a bit from the
observations Bailey (1982) did for the area. For both sexes he found a
smaller L_{inf}, but a higher growth rate K. In the Porcupine area
the gowth pattern also differ from what Ushakov and Mazhirina (1978)
calculated from data collected in 1970-1976, the L_{inf} for both
sexes combined being 34.2 cm and K 0.35, against theirs 37.2 cm and
0.16.

Bailey (1982), however presents a wide variety of growth parameters
fom various authors, and suggests that this variation may be the
result of real variation in growth rate, but could also be due to
biases in sampling. The differential migrations could be related to
size rather than to age.In the Hebrides area where presumedly adult
fish dominate, not all of the yearclasses may be fully recruited and
hence a different rate K could be observed here than in feeding area.

Blue whiting off the coast of Norway grow to a larger size than the
blue whiting in more offshore areas of the Norwegian Sea and west of
the British Isles. This may also suggest the appearance of local
stocks not taking part in the major spawning migration.

The difference in growth pattern of male and female is illustrated in
Fig.10a-b, by von Bertalanffy's growth curves from the Hebrides and
the Norwegian Coast. At an age of 5 years the difference is approxi-
mately 1.5 cm, and at 10 years it has increased to almost 3 cm.

Females in the Vestfjord and the North Sea areas grew to the largest
size, while males in the Porcupine area had the smallest growth, the
calculated L_{inf} being 5 cm shorter.

The different growth patterns of the various yearclasses are
demonstrated in Fig. 11a-c by the 1971 - 1983 yearclasses when they
appeared in the Hebrides area at 1 -6 years of age. For the 1971-1974
yearclasses the growth was quite similar up to the age of 4 years.
After that it diversed, with the 1974 yearclass clearly showing the
fastest growth the following two years.

The 1976 - 1978 yearclasses had a "congruence-point" between the age
of 4 and 5 years, and at a 1.5 cm higher level than the previous group
of yearclasses. For the next group, 1979 - 1983, no such common point
appeared from the analysis. Except for the 1979 yearclass, which grew
a bit slower than the 1980 yearclass, the yearclasses had parallel
growth patterns at different rates from the age of 1 year. The two
numerous year- classes of 1982 and 1983, however, had very similar
growth patterns up to the age of 5 years, being relatively low and at
the same level as the 1971 and 1972 yearclasses. The overall picture
indicates an increasing growth rate of the yearclasses with increasing
years up to 1978 yearclass, when this effect is reversed further up to
the 1983 yearclass (Fig.11a-c).

The growth patterns of the yearclasses of 1979-1983 when they appeared
in the various areas at the age from 1 up to 8 years, are illustrated
in Fig. 12 for male and female separate. For some of the yearclasses
the data basis was not sufficient to produce a reliable fittnes to the
von Bertyalanffy's curves when split on sex. The decreasing tendency
in growth by increasing years of the yearclasses was obvious for all
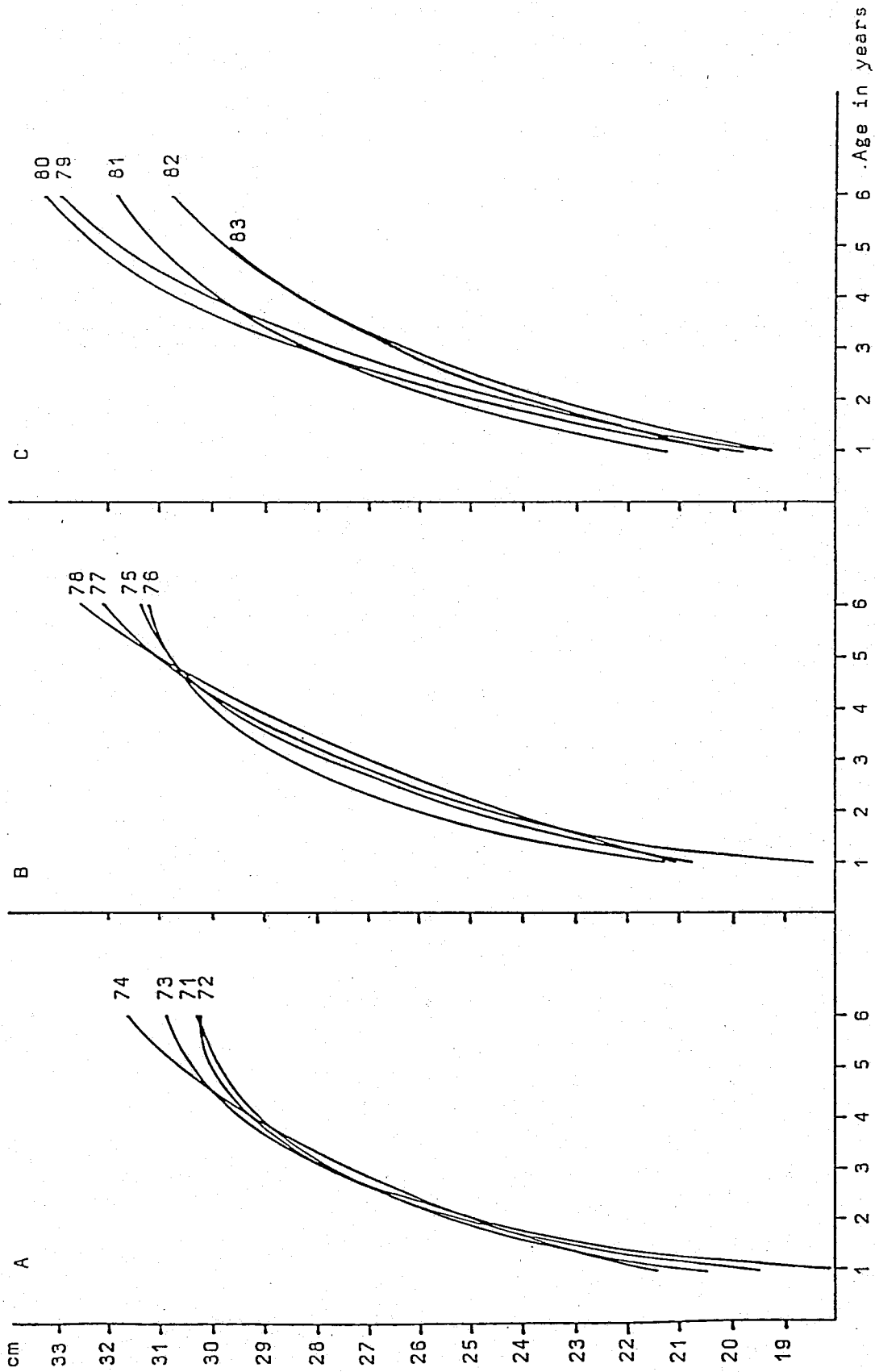the 5 areas for the arrays of 1979 - 1983.

Fig. 11. von Bertalanffy's growth curves of blue whiting, combined
          sexes, for the six first years of life as appearing in the
          Hebrides area for A) the 1971-1974, B) the 1975-1978, and
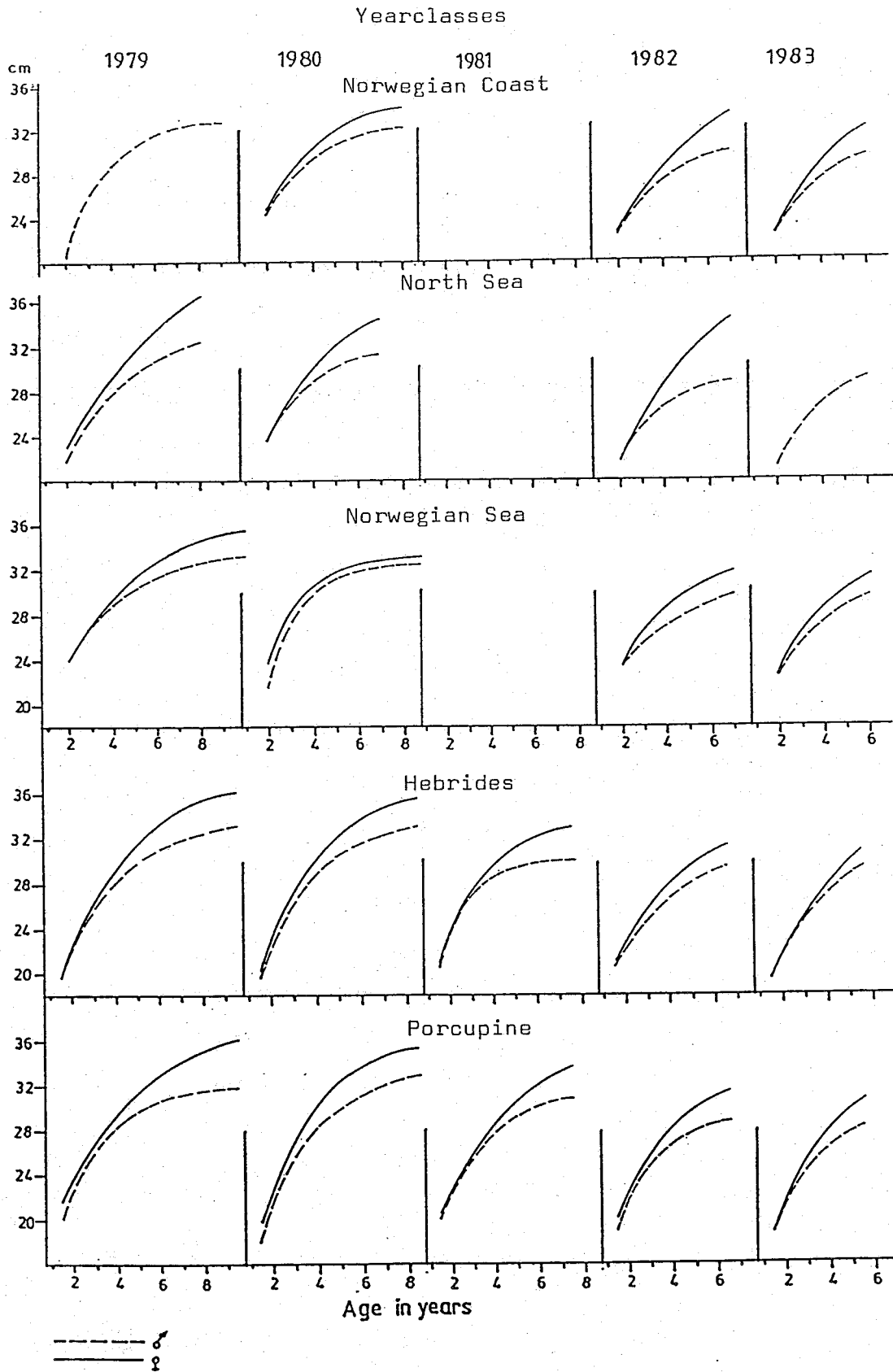   C) the 1979-1983 year classes.

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Yearclasses

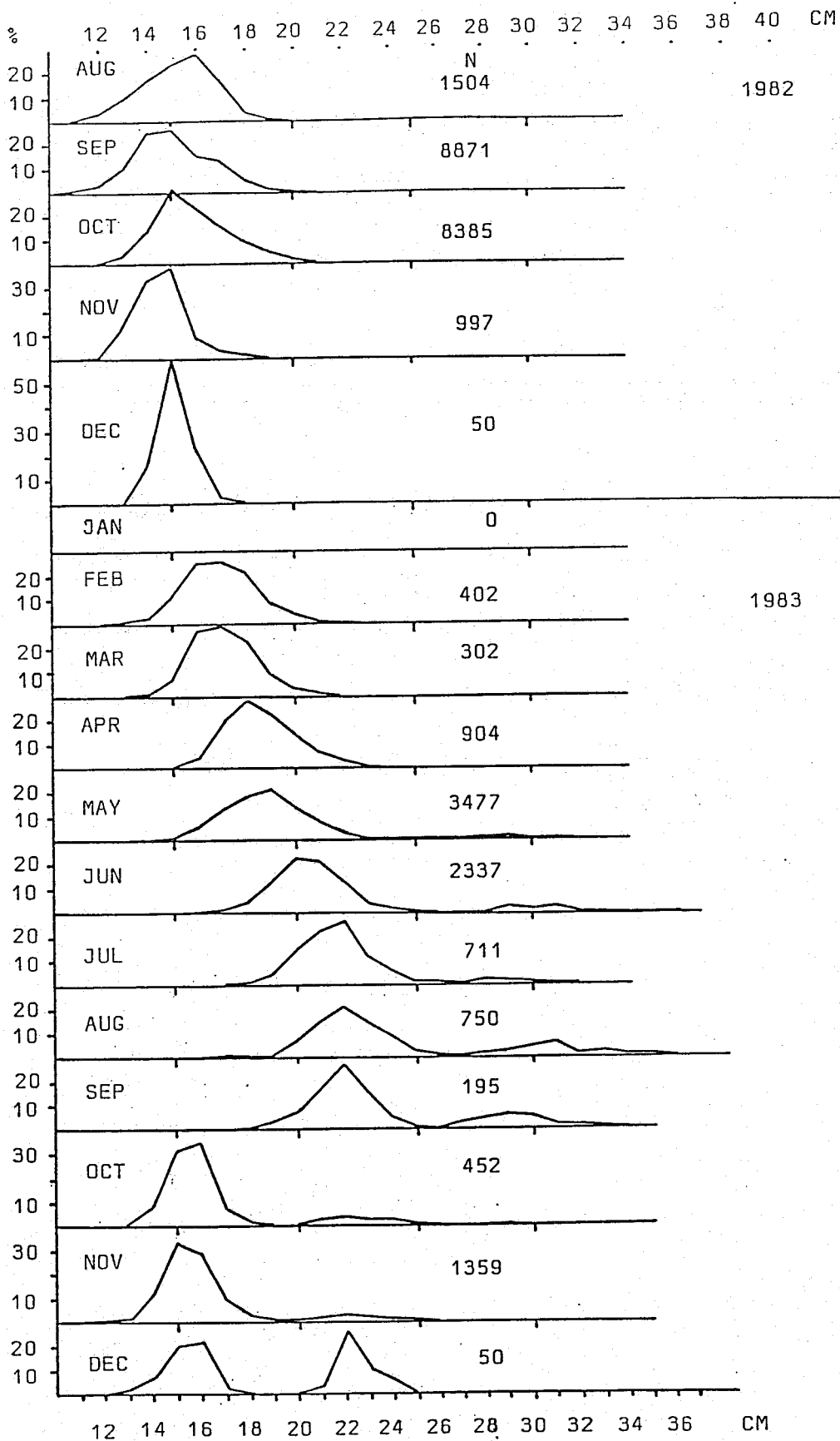Fig. 12. von Bertalanffy's growth curves of the 1979-1983 year classes of blue whiting, males and females, as appearing five different areas during the last decade.

Distribution and growth of blue whiting......

Fig. 13A. Length distribution (N%) by month of blue whiting in
samples from the mixed industrial fishery in the North Sea,
1982 and 1983.

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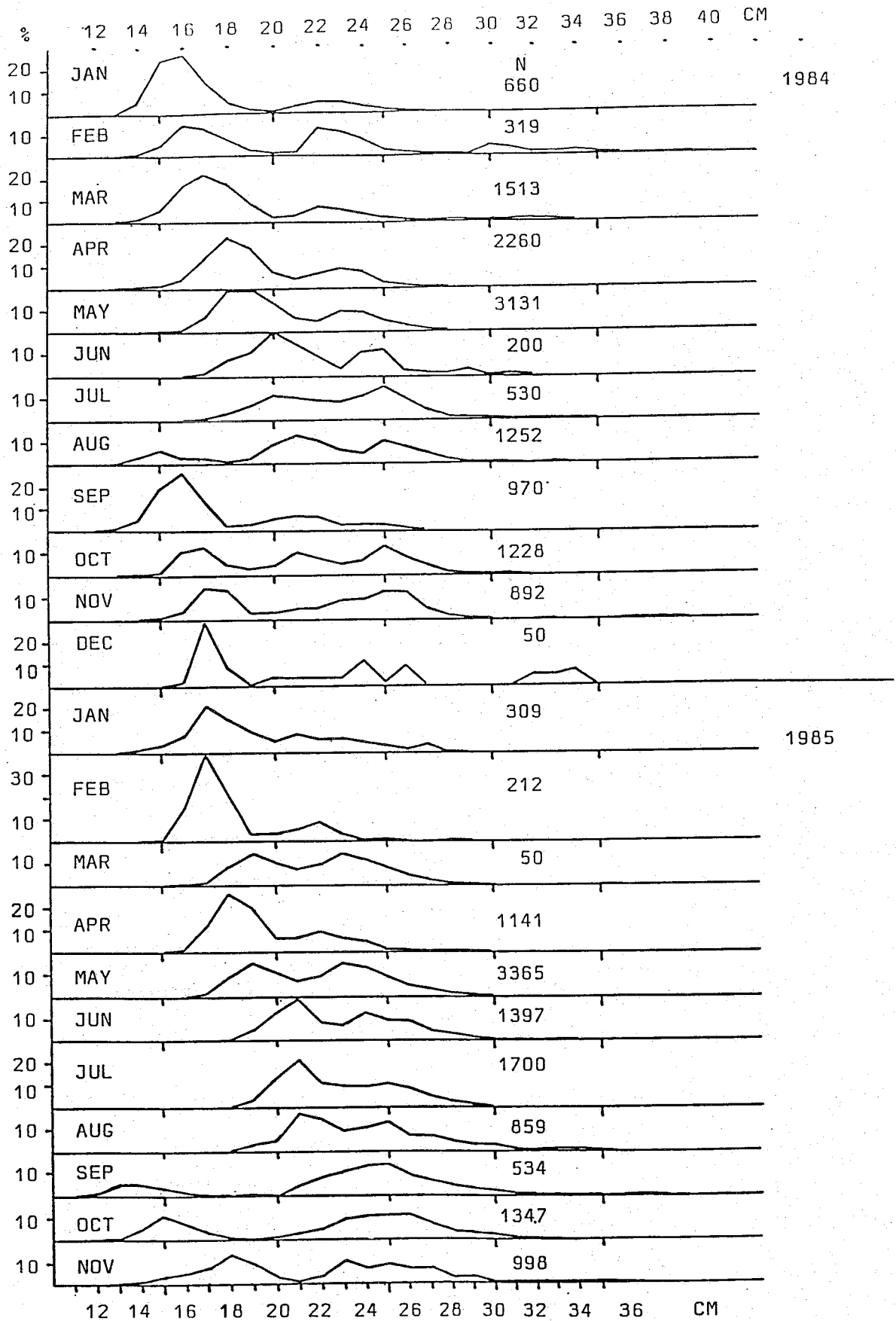
Fig. 13B. Length distribution (N%) by month of blue whiting in samples from the mixed industrial fishery in the North Sea, 1984 and 1985.

2) For juveniles in the North Sea.

Blue whiting recruits to the fishery already in its first year of life, in general as O-group to the mixed industrial fishery during the autumn. The largest quantities of blue whiting as by-catch in this fishery are taken in the North Sea by Norway and Denmark (Fig. 4).

The successful yearclasses of 1982 and 1983 first started to influence the fishery when O-groups appeared in the catches from the important nursery area of the North Sea during August 1982. The blue whiting landings from the mixed industrial fishery increased significantly in the years to come, especial the Norwegian landings.

In the text table below are shown the annual Norwegian landings of blue whiting (in thousand tonnes) from the mixed industrial fishery in the North Sea for the last decade.

1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
31	22	19	48	63	58	54	27	25	20*

* Preliminary

The figures, published in the Working Group Report (Anon. 1989), are based on official statistics from which the blue whiting portion has been separated by use of species-composition tables obtained by Lahn-Johannessen (Pers. com.).

The annual catch was more than doubled from 1981 to 1982 and still increased significantly in 1983 when that new yearclass recruited to the stock. The catch dropped to half of the volume from 1985 to 1986 when a great portion of the two yearclasses had matured and joined the adult stock in the Norwegian Sea.

Length measurement of the samples from a great number of commercial catches were grouped by month and are presented in Fig. 13a-b. The youngest age groups are clearly separated by the difference in the

Table 2. The growth parameters of von Bertalanffy's equation based on backcalculated lengths from three areas in 1978-1988.

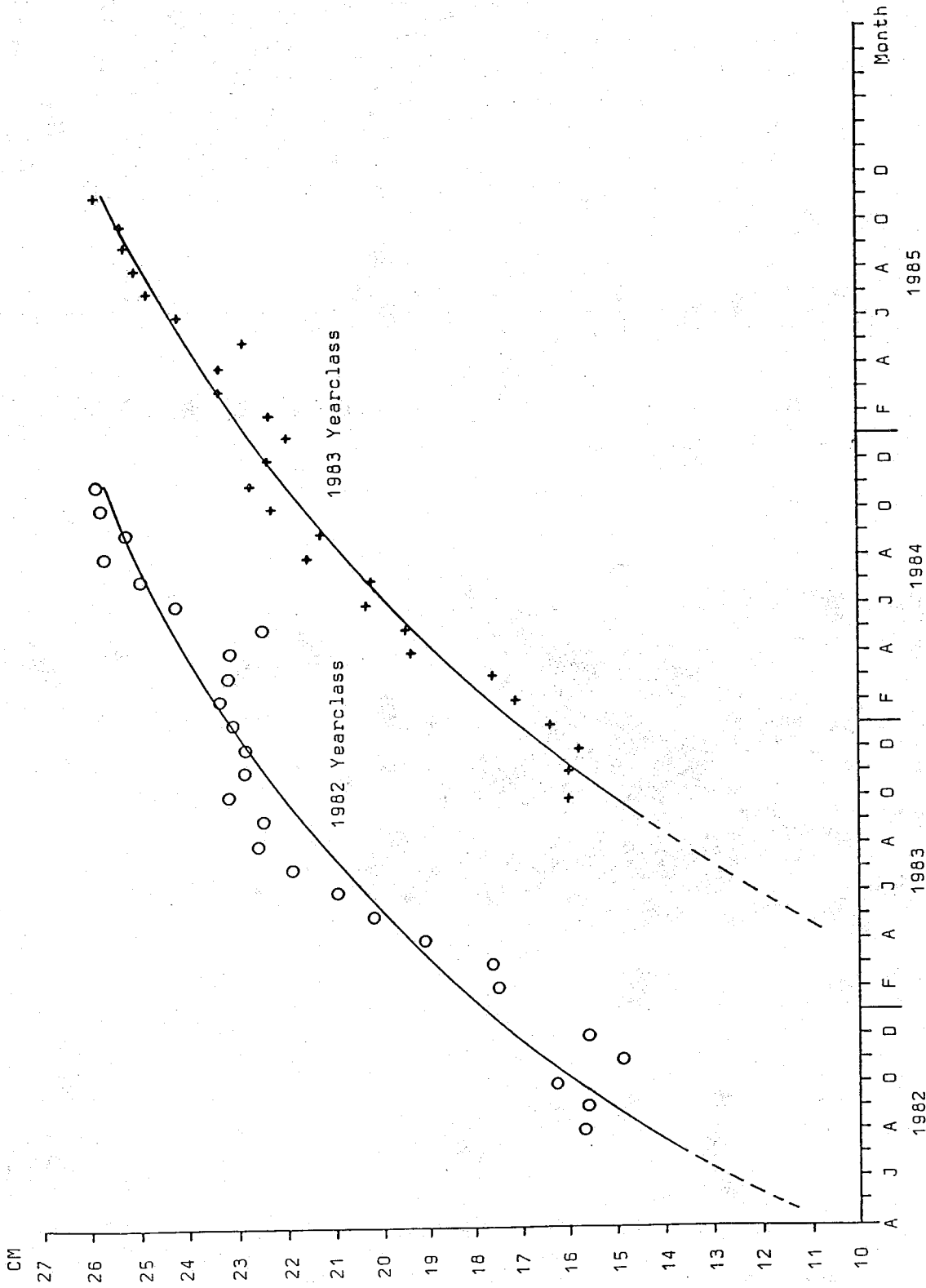|	1987				1988			
	L_{inf}	K	t_0	n	L_{inf}	K	t_0	n
Porcupine								
female	34.3	0.39	-1.11	141	33.0	0.29	-1.57	211
male	30.5	0.51	-0.95	137	29.6	0.36	-1.38	246
combined	34.1	0.37	-1.26		32.3	0.29	-1.67	
Hebrides:								
female	57.4	0.10	-3.16	230	29.7	0.41	-1.07	185
male	32.0	0.47	-0.88	258	27.2	0.50	-0.93	286
combined	36.3	0.30	-1.54		29.2	0.40	-1.15	
Norw.Sea:								
female	44.6	0.18	-2.11	26	30.7	0.46	-0.95	199
male	32.8	0.36	-1.31	22	30.2	0.44	-1.04	270
combined	34.8	0.33	-1.39		30.5	0.45	-0.98	

Fig. 14.   von Bertalanffy's growth curves for the first three years
           of life of the 1982 and 1983 year classes, based on samples
           from the mixed industrial fishery in the North Sea.
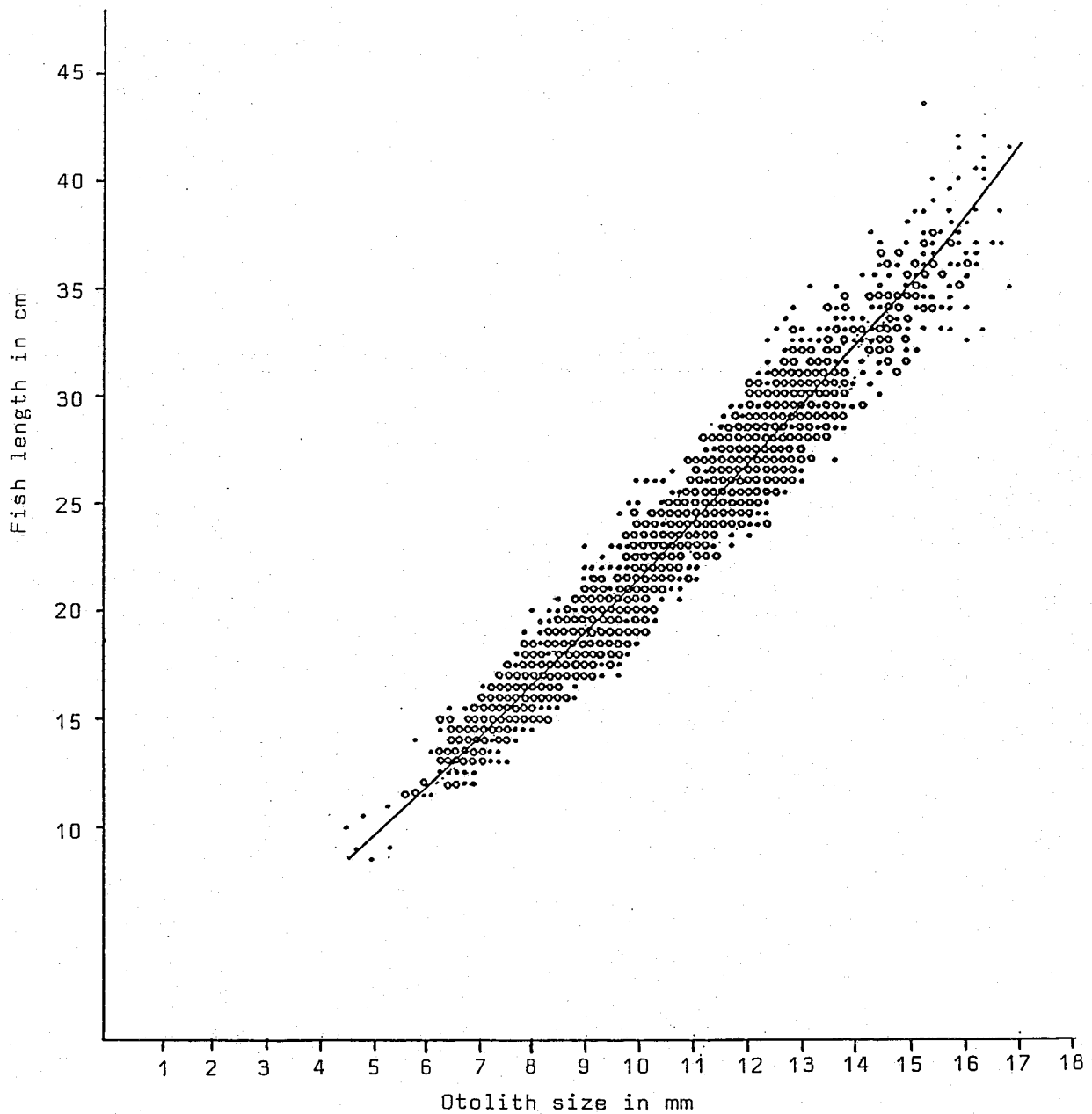
Fig. 15. Fish length-otolith size relationship of blue whiting,
          based on approximately 1000 specimen. The curve is drawn
          by hand and used for "backcalculation". Dot represents one
          and circle more than one specimen.

peak lengths, and their length growth by month is illustrated. The Figure also shows which month the yearclasses first entered the fishery. In 1982 and 1984, 0-group fish first appeared in the catches in August, while in 1983 in October and in 1985 in September. The length range of blue whiting when it first appears in the fishery is approximately from 12 to 19 cm with a peak length of 15-16 cm.

The length measurements were divided into age groups by use of age/length keys, and the monthly mean lengths by age calculated. Using von Bertalanffy's length growth equation (Ricker 1975), the growth during the three first years of life is illustrated for the 1982 and 1983 yearclasses on a <u>monthly</u> basis (Fig. 14). The data, which is not separated by sex, gave the following equations:

1982-yearclass:
$$l_t = 29.8 \ (1 - e^{-0.05(t+9.3)})$$

1883-yearclass:
$$l_t = 30.8 \ (1 - e^{-0.05(t+9.1)})$$

The material is of course incomplete in this respect, indicating a L_{inf} of only around 30 cm. The progress of the two numerous yearclasses and the comparison between them, however, are illustrated for their juvenile stage. The 1982-yearclass grew fastest the two first years, to be equalized by the 1983-yearclass during the third year of life (Fig. 14).

3) By backcalculated lengths.

A plot of fishlength against otolith size is shown in Fig. 15. The best fitted line was drawn by hand, and the graph was used to "back-calculate" fishlengths from corresponding mean values of the measured zones.

The material gave basis to study the growth up to the age of 6 years for both sexes of the blue whiting which appeared in the spawning area (Hebrides and Porcupine) in spring and in the feeding area (Norwegian Sea) in summer of 1987 and 1988.

von Bertalanffy's growth equation was also used on these "backcalcu-lated" length values. The obtained parameters, given in Table 2 show a rather great variety between the two years as well as between the two areas in question:

The lengths were subsequently fitted to curves shown in Fig. 16. The curves of male and female for the Norwegian Sea in 1988 are allmost parallel, while in the other cases an increasing diversity, which starts from around 3 years of age is evident.

In all three areas and for both sexes, the results show that the fish appearing in the samples in 1987 grew to a significantly larger size than the fish in 1988. The difference, however, was more pronounced in the Hebrides area, being 6.3 cm for between the females and 4.3 cm between the males at the age of 6 years.
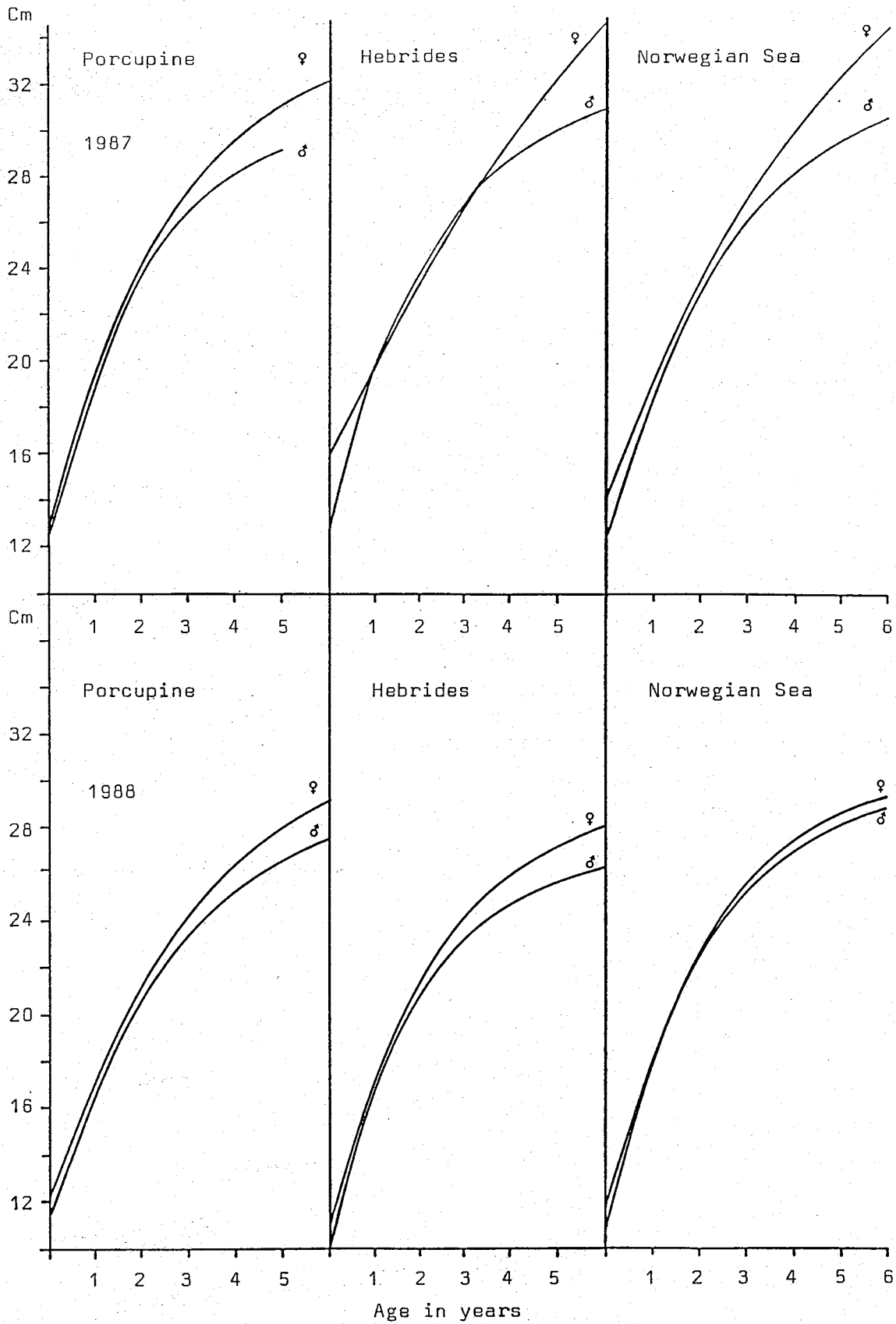
Fig. 16. von Bertalanffy's growth curves based on backcalculated
          lengths of blue whiting for the first six years of life,
          males and females, as appearing in three different areas
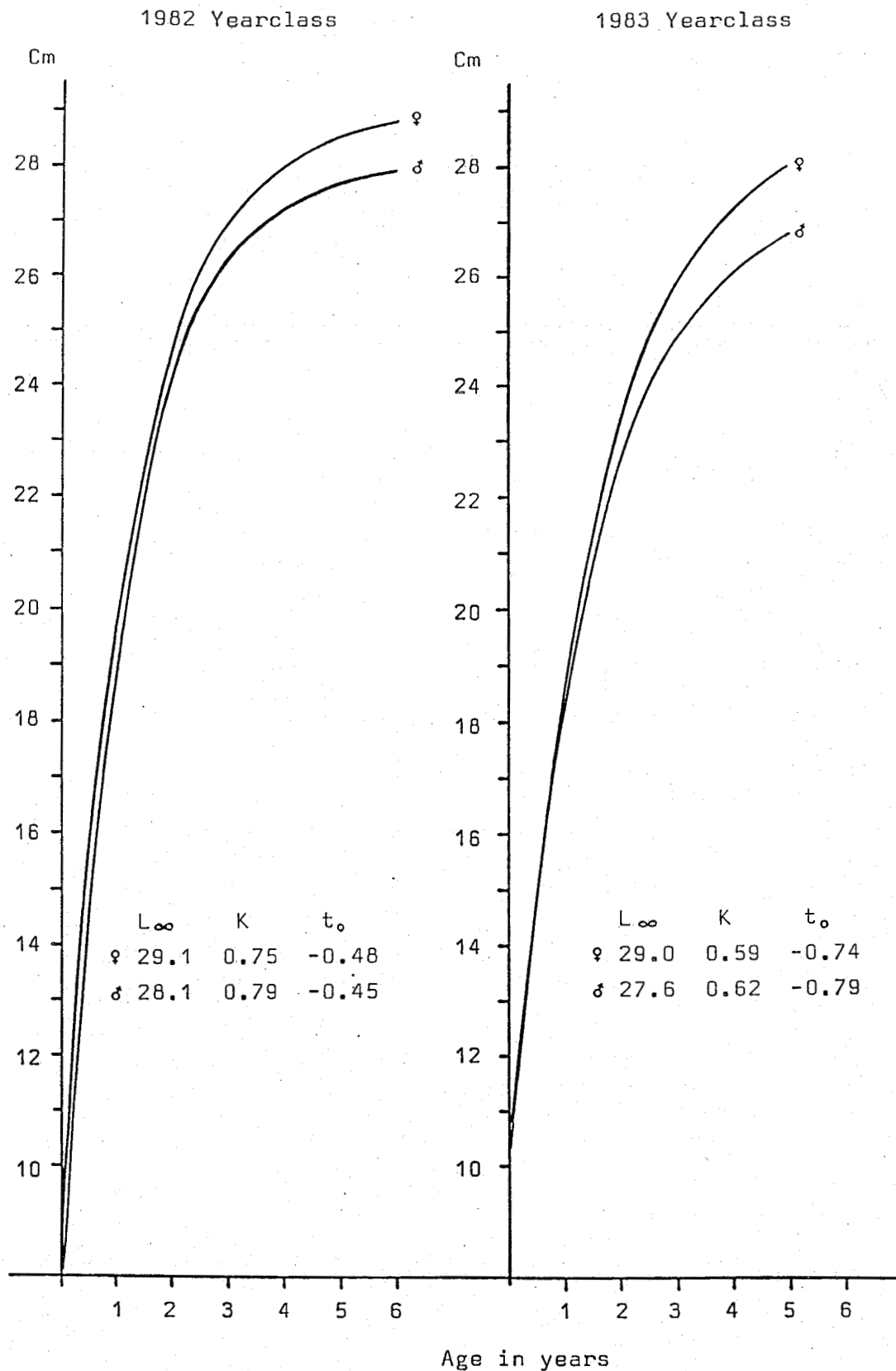   in 1987 (upper half), and in 1988 (lower half).

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Fig. 17.   von Bertalanffy's growth curves and parameters based on
          backcalculated lengths of the 1982 and 1983 year classes
          in their 6 and 5 first years of life respectively as
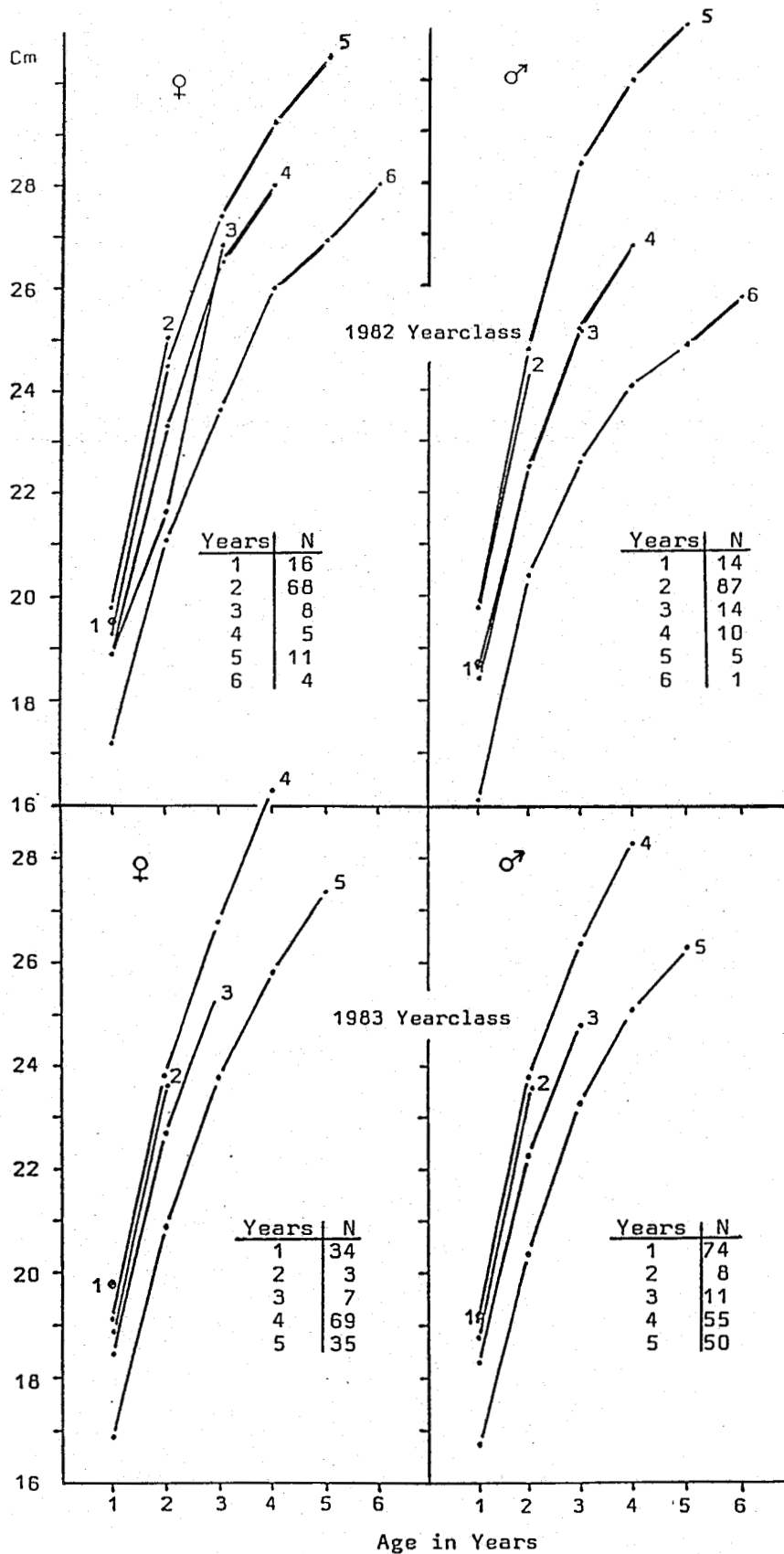   appearing in the Hebrides area.

Fig. 18. Backcalculated fish lengths of blue whiting, males and
females in the Hebrides area, separate for the 1-6 years
age groups of the 1982 year class (upper half) and the
1-5 years age groups of the 1983 year class (lower half).

The backcalculated lengths were furthermore used to study the growth
of blue whiting from the rich yearclasses of 1982 and 1983 when
appearing in the Hebrides area. Their growth curves are shown in Fig.
17 and the text table below gives the calculated growth parameters:

	1982-yearclass			1983-yearclass		
	L_{inf}	K	t_0	L_{inf}	K	t_0
female	29.1	0.75	-0.48	29.0	0.59	-0.74
male	28.1	0.79	-0.45	27.6	0.62	-0.79
combined	29.0	0.70	-0.58	27.9	0.63	-0.71

The results from this material show that the 1982-yearclass had a
better growth than the 1983-yearclass with a difference of 0.6 cm and
0.9 cm for the females and males respectively.

The opposite was observed from the material in the North Sea. Though
the difference in the growth between the two yearclasses was insigni-
ficant the 1983-yearclass had the best growth (Fig. 14).

In Fig. 18 are set up the backcalculated lengths, L_1- L_6 for the 1982-
yearclass and L_1- L_5 for the 1983- yearclass, originating from the
otolith zonal diameters, R_1- R_6 and R_1- R_5 respectively, measured from
fish at the corresponding age.

The growth of the fish of the 1982 and 1983-yearclasses measured as 5
and 4 years old respectively was significantly better than fish from
the same yearclasses measured at other ages older than 2 years. In
other words the fish from 1987 of the two yearclasses did not fit into
a pattern formed by the fish from the other years, namely an
decreasing growth with increasing age.

Bias in the sampling of some kind could be an explanation to the
difference within the two yearclasses in question, or random distri-
bution due to poor number of individuals measured. However, the dif-
ference could also be explained by influence of an other type of fish
of the same two yearclasses, appearing in the samples from the west of
the British Isles in 1978, i.e. possible blue whiting from areas more
south and southwest in the Atlantic. This is but a hypothesis which
needs more data for further studies.

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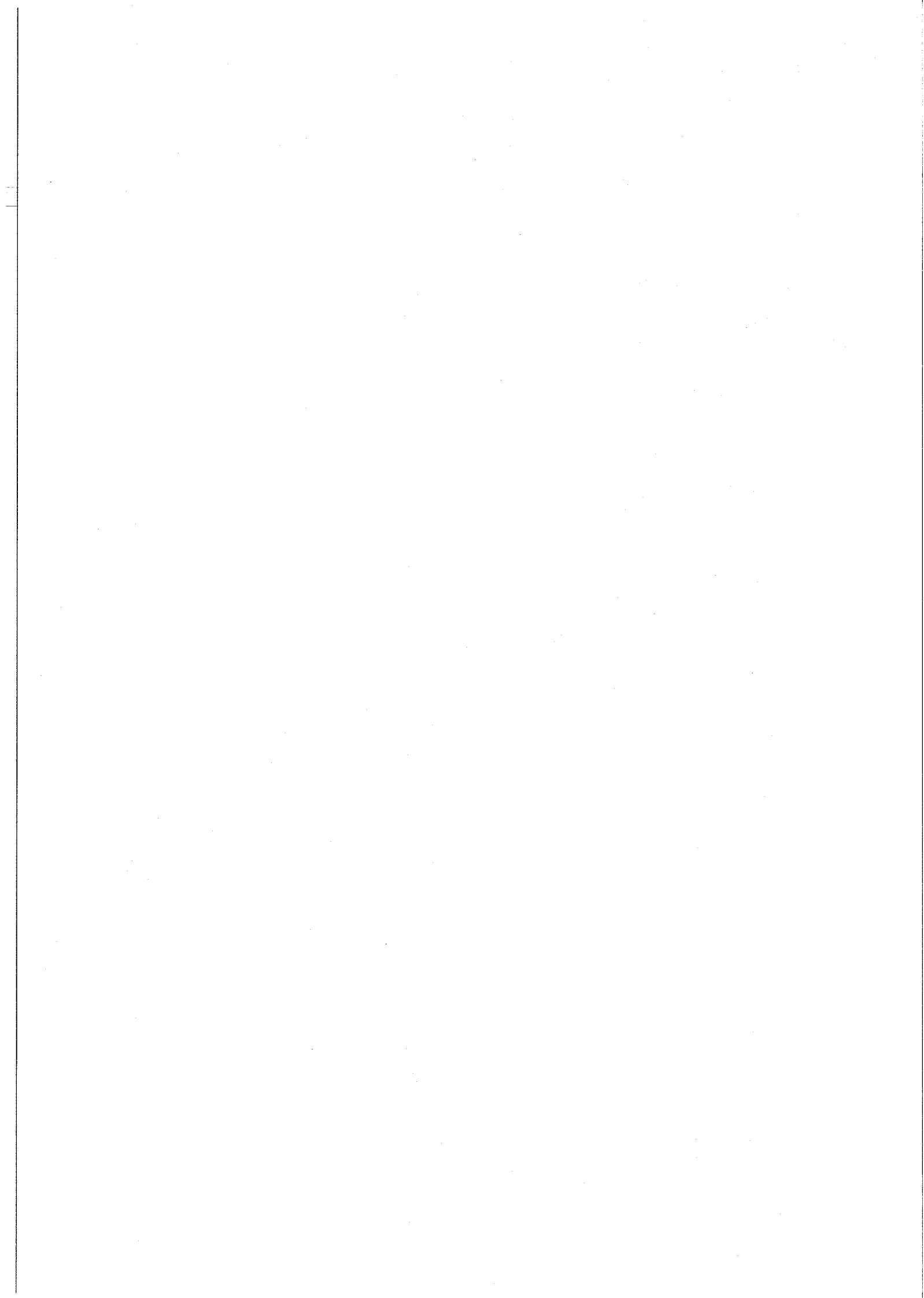
Section V: Fecundity, larvae and feeding

INVESTIGATIONS ON THE BLUE WHITING SPAWNING, LARVAL
DISTRIBUTION AND DRIFT WEST AND NORTH-WEST OF THE
BRITISH ISLES

by

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ABSTRACT

Historically the general pattern of larval blue whiting distribution
in the British Shelf area remains relatively stable. Some deviations
from the general pattern in specific years are associated with spatial
structure peculiarities of the fields of oceanographic characteristics
manifesting themselves as presence or absence of high horizontal
gradients. The dates of mass spawning start and larval abundance are
liable to considerable year-to-year fluctuations. There is a certain
correlation between spawning times and heat content of waters, larval
abundance and frequency of southwesterly winds: at a higher water
temperature spawning starts earlier; prevailing south-westerly winds
favour the appearance of strong year classes.

Variability in oceanographic conditions on the British Shelf shows a
well-pronounced quasi-two-year cyclic recurrence which is represen-
tative of the entire Northeast Atlantic.

INTRODUCTION

The present knowledge of early ontogenesis and reproduction of blue whiting in the Northeast Atlantic (Seaton and Bailey, 1971; Coombs, 1974; Bailey, 1982; Coombs and Pipe, 1978; Coombs and Hiby, 1979; Zilanov, et al., 1984) leaves some essential peculiarities of ichthyoplankton distribution, blue whiting biology and ecology to be discovered. At the same time a number of important points concerning the influence of abiotic conditions on reproduction processes, larval drift and distribution etc. still remain underdeveloped.

In recent years regular complex ichthyoplankton and oceanographic spring surveys (since 1983) in the British Shelf area yielded material forming the basis for the first step in elucidating some of these aspects.

The present paper considers the data from ichthyoplankton and hydro-meteorological surveys obtained during the spring (March-May) 1983-1988 cruises of RVs "Persey-III", "Kokshaisk", "Artemida" and "Fridtjof Nansen" and makes an attempt of estimating individual aspects of blue whiting ecology during the early stages of its life history.

MATERIAL AND METHODS

The material used incorporates the results from ichthyoplankton, hydrochemical and hydrometeorological surveys.

Larvae were sampled in layers 0-50, 0-100, 0-200, 0-300, 0-400, 0-500 and 0-600 m following a constant grid of stations. After examination the samples were preserved with 2 % formalin. The length of larvae were measured using binocular microscope to a precision of 0.1 mm.

Along with the ichthyoplankton operations temperature and salinity at standard depths from the surface down to 600 m were measured at all the stations. During the surveys a hydrological section at 53°N of 8 stations was performed with constant coordinates. During the 1984, 1987 and 1988 cruises oxygen and phosphate contents in the water were measured using standard methods.

When considering hydrological conditions, mean sea surface temperatures in April in three 5° x 5° quadrangles calculated in the USSR Hydro-meteorological Centre on the basis of numerous ship observations were applied as additional information.

Fig.1 shows the stations of the section and the position of the quadrangles.

Based on ship observations at standard time, mean frequencies of various wind directions, those of winds of force over 4, and sea of over 3 were calculated for each survey in order to estimate meteoro-logical conditions. The abundance of larval blue whiting was calculated on computer using the "IRI-Grafor" programme. The 0-group abundance is taken from the ICES Blue Whiting Working Group material (Anon. 1989).
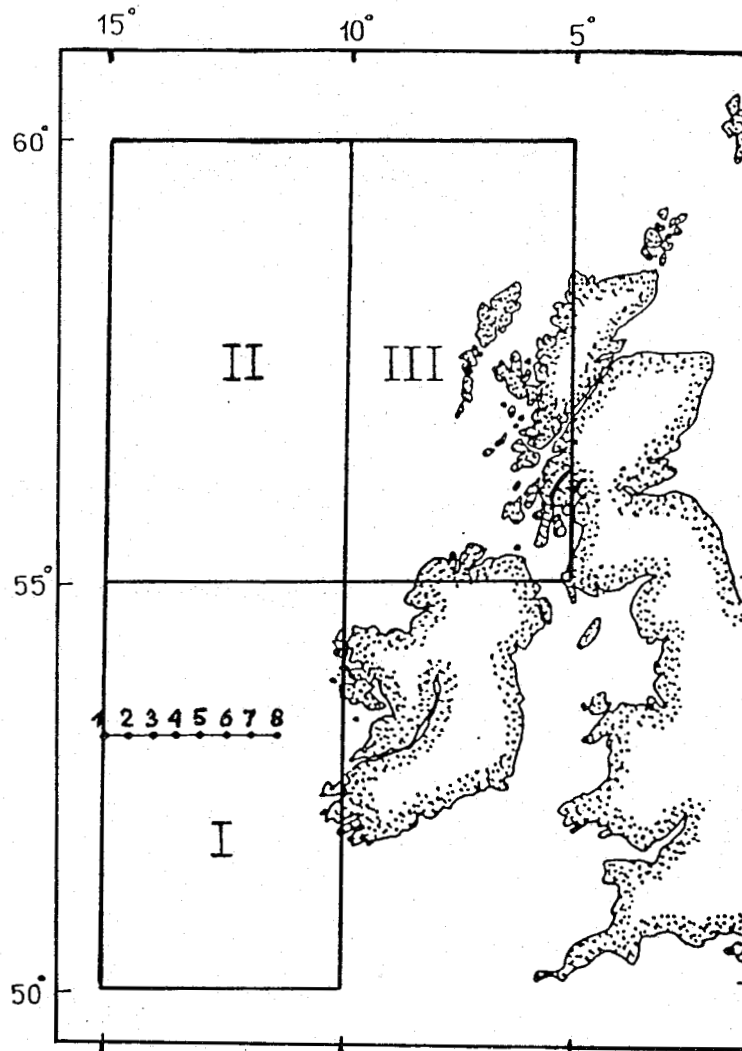
Fig.1 Stations on the section at 53°N and
       positions of 5° x 5° quadrangles.

RESULTS

Hydrometeorological and hydrochemical conditions

Nearly regular alternation of years with high vs low heat contents of
water in the productive layer is one of the peculiarities of year-to-
year variability in oceanographic conditions in the British Shelf area
(at least in the 1983-88 period). Water temperature fluctuations on
section at 53°N (Table 1) illustrate such peculiarities best. Though
the fluctuations are not synchronous at all stations, a general trend
of 2-3 year cyclic fluctuations is obvious. Gradual warming from 1983
towards 1985, marked cooling in 1986, warming again in 1987, and a
slight cooling in 1988 are the concrete manifestations of this trend.
Simultaneously some attendant changes in salinity were recorded almost
at all the stations of the section. Fluctuations in sea surface
temperatures within the 5° x 5° quadrangles have generally a similar
pattern.

The relation between year-to-year temperature and salinity variations
seems to indicate their advective nature. The fact that unidirectional

Table 1. Mean temperature (T^0C) in layer 0-200 m and mean salinity $(S \text{‰})$ at stations on the 530N section in late March - early April and mean April sea surface temperature in three 50x50 quadrangles (I, II, III) in 1983-1988.

Year		Stations on the section at 530 N								Quadrangles		
		1	2	3	4	5	6	7	8	I	II	III
1983	T^0 C	10.07	10.03	9.70	9.67	9.65	9.77	9.85	9.27	10.1	9.0	8.1
	S ‰	35.45	35.45	35.45	35.45	35.45	35.46	35.47	35.43	-	-	-
1984	T^0 C	10.69	9.96	9.78	9.76	10.03	10.19	9.97	9.77	10.3	9.6	8.5
	S ‰	35.50	35.46	35.46	35.45	35.48	35.50	35.50	35.49	-	-	-
1985	T^0 C	10.62	10.07	9.86	9.85	10.09	10.26	10.04	9.13	10.5	9.7	8.4
	S ‰	35.53	35.52	35.53	35.52	35.56	35.53	35.47	35.29	-	-	-
1986	T^0 C	10.26	10.02	9.47	9.45	9.83	9.82	9.41	8.44	10.1	9.1	8.1
	S ‰	35.44	35.45	35.46	35.45	35.48	35.48	35.44	35.34	-	-	-
1987	T^0 C	10.60	10.00	9.67	9.69	10.11	10.05	10.13	9.96	11.1	9.5	8.6
	S ‰	35.46	35.47	35.47	35.47	35.52	35.52	35.46	35.44	-	-	-
1988	T^0 C	10.13	9.96	9.69	9.67	9.78	10.05	10.06	9.37	11.0	9.6	8.9
	S ‰	35.37	35.42	35.41	35.41	35.43	35.48	35.46	35.37	-	-	-

changes occurred over a large area and therefore must have common causes supports the idea. A strengthening or weakening in the advection of Atlantic waters is such a cause in the investigated area, the hydrological pattern of which is mainly determined by the North Atlantic Current.

The largest amplitudes of year-to-year fluctuations in oceanographic characteristics occur in the eastern part of the section (station 8). In these shallow areas processes of advective changes manifest themselves more sharply. In addition, some deviations from the general area trend may be observed some years , for example in 1985, when there was a considerable drop in temperature and salinity at station 8 (Table 1), compared to a general rise over the section as a whole. This probably reflected the start of a weakening in advection which first showed in the eastern component of the North Atlantic Current, and by 1986 had spread over the whole shelf area.

Qasi-two-year cyclic fluctuations appearing in variations of oceanographic characteristics are typical for some meteorological parameters. In particular, there is a well-pronounced alternation of years with high and low frequency of southwesterly winds (Table 2). As these winds concur in direction with the general advection of the North Atlantic Current waters, their fluctuations result in corresponding variations in advection showing in temperature and salinity changes. Although there is no unambiguous relation between wind frequency and oceanographic parameters, a considerable correlation is obviously present. Table 2 shows, at least, an upward trend in temperature and salinity with high frequency of southwesterly winds, and a downward one with low frequency.

Table 2. Frequency of southwesterly winds in March-April (P),
          mean temperature on section at $53^{\circ}N$ (T), mean salinity
          (S) in layer 0-200 m in 1983-1988.

Year	P $^{0}/_{0}$	T^{0} C	S $^{0}/_{00}$
1983	16.7	9.76	35.45
1984	15.2	10.00	35.48
1985	20.1	10.07	35.50
1986	14.1	9.56	35.45
1987	18.5	9.96	35.49
1988	7.2	9.92	35.42

Year-to-year fluctuations in hydrological conditions must bring about some corresponding changes in hydrochemical parameters. Unfortunately, the data available permit only the features of oxygen and phosphate spatial distribution in three years -1984, 1987, 1988 to be estimated. However, the analysis of even these limited data indicates that the hydro chemical pattern may change markedly from year to year, and this in turn affects the spatial distribution of larvae.

Presence or absence of horizontal gradients in hydrochemical characteristics is the most essential feature of such year-to-year fluctuations. In this respect the years studied are rather exemplary.
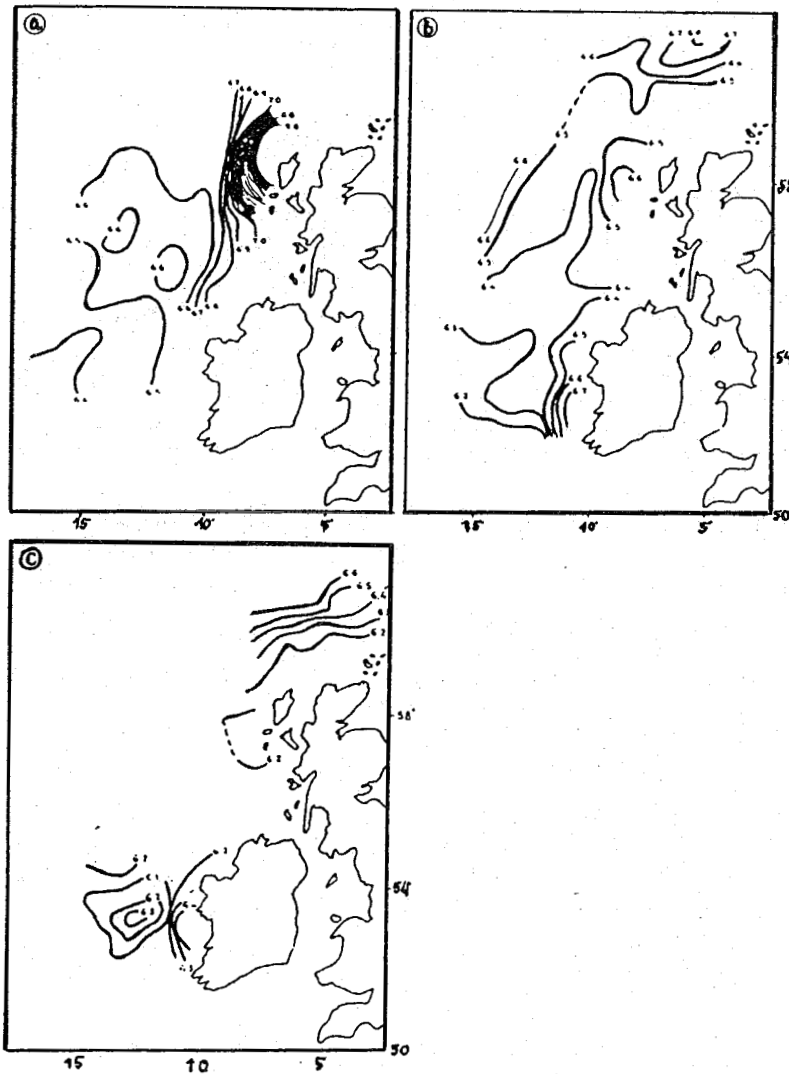
Fig.2   Oxygen distribution in surface layer (ml/l) in
        April 1984 (a), 1987 (b) and 1988 (C).

In   spring 1984 an area of considerable horizontal gradients was noted
in oxygen and phosphate fields against a   general   monotonous   spatial
distribution   west   of   the   Hebrides   (Figs.   2a,   3a).   Fluctuation
amplitudes amounted   to   3   ml/l in   oxygen,   and   0-65   µg-at/1   in
phosphates,   whereas   over   the rest of the area these values were 0.5
ml/l and 0.2 µg-at/1 respectively. In 1987 the whole   shelf   area   was
even   and   homogeneous   as for hydrochemical conditions. In accordance
with the   general   latitudinal   regularity   there   was   but   a   slight
increase   in   oxygen   and   phosphate   concentrations   from   the   south
northwards (Figs. 2b, 3b). Nearly the same   pattern   was   observed   in
1988, except that compared to the previous year, the absolute value of
oxygen content decreased over the whole area by 0.2-0.3 ml/1, and that
of phosphates - by 0.1-0.2 µg -at/1 (Figs. 2c, 3c).

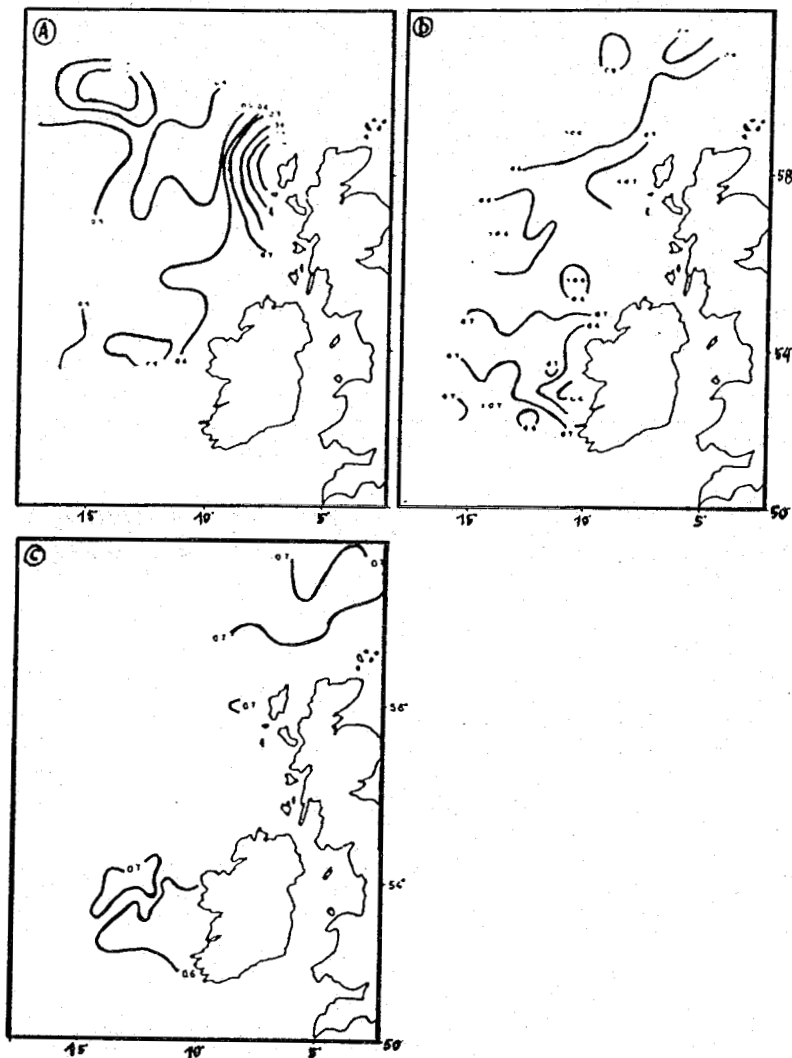Fig.3 Phosphate distribution (µg -at/1) in surface
layer in April 1984 (a), 1987 (b) and 1988 (c).

Larval distribution

Analysis of the data available from ichthyoplankton surveys allows the
conclusion that the general pattern of larval distribution in March-
May remains relatively stable in year-to-year terms, though some
features deviate in particular years due to the influence of abiotic
conditions and other factors. The basic features of this pattern are
that in the early postspawning period (March-early April) larvae
prevail west of Ireland with maximum concentrations on the Porcupine
Bank, where the main spawning occurs and then move (in April-May)
towards the northwestern British Shelf (Figs. 4a-h).

The distinguishing features of larval distribution in each particular
year appear to be formed to a great extent by oceanographic factors.
Spatial peculiarities of fields of hydrochemical conditions, such as
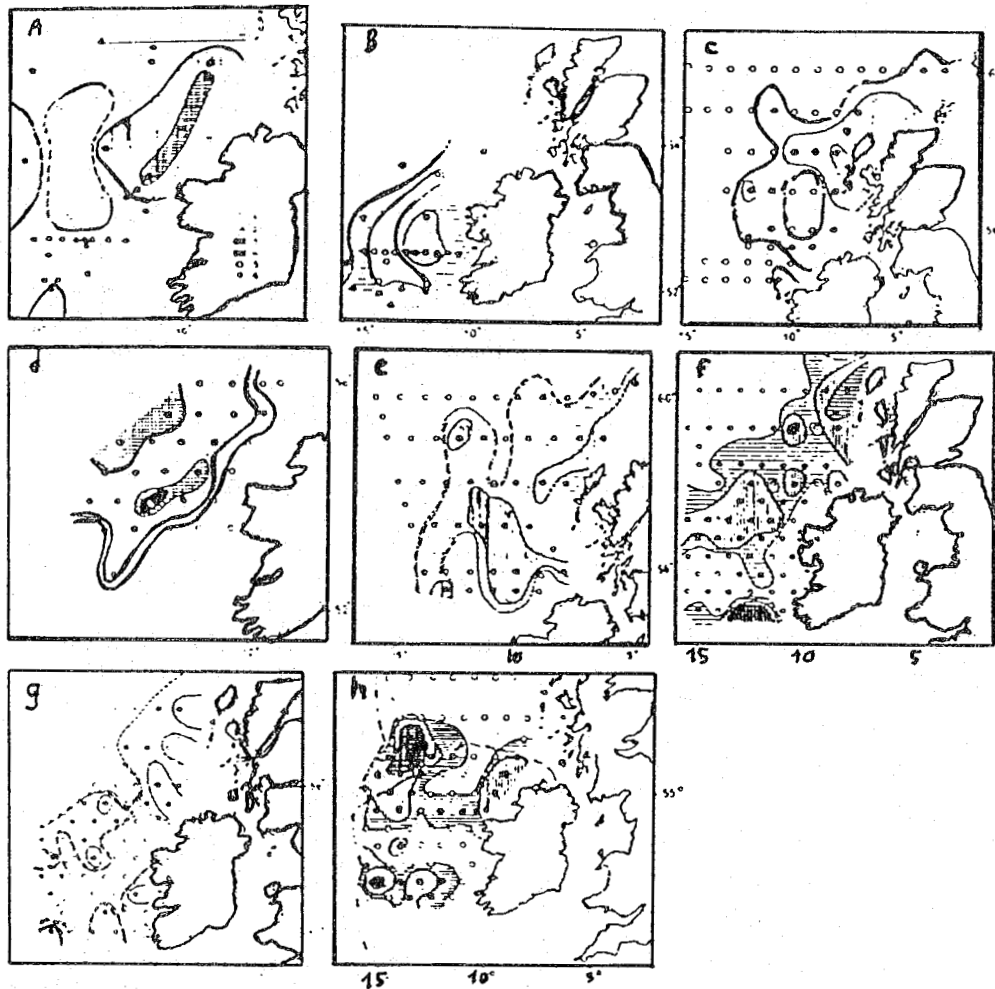presence or absence of areas with high horizontal gradients may be

Fig.4   Distribution of larval blue whiting in March-April 1983 (a),
        March 1984 (b), April-May 1984 (c), March-April 1985 (d),
        April-May 1985 (e), April 1986 (f), March-April 1987 (g),
        March-April 1988 (h). 1.-1-10 spec.; 2.-11-100 spec.;
        3.-101-1000 spec.; 4.-1000 spec.; 5.-negative catch;
        6.-positive catch

such a factor. Joint analysis (Figs. 2, 3, 4) shows that high density
ichthyoplankton concentrations centre around these points, and in
"blurred" hydrochemical fields with homogeneous spatial structure,
there occurs a scattered larval distribution over a large area. The
1984, 1987 and 1988 data are a good illustration of this point.

In late April - early May 1984 peak catches of larvae were recorded
west of the Hebrides (Fig. 4c), when there were well-pronounced
gradient areas in surface oxygen and phosphate distribution (Figs. 2b,
3a). During the 1987 spring survey, when an exceptionally homogeneous
spatial oxygen and phosphate distribution free of gradient areas was
observed (Figs. 2b, 3b), ichthyoplankton distribution was also rather
scattered without any high density concentrations (Fig.4c). Nearly the
same pattern was found in 1988 with relatively dense larval
concentrations in March-April in the Porcupine Bank area only, where
an area with slight horizontal gradients in the oxygen field was noted

Table 3. Abundance of larvae (N), 0-group (0-gr), spawning stock
          individuals (Q), mean temperature (T) and salinity (S)
          in layer 0-200 m along the section at 53°N, frequency of
          southerly winds (P), winds of force over 4 (V), and sea
          of over 3 (W).

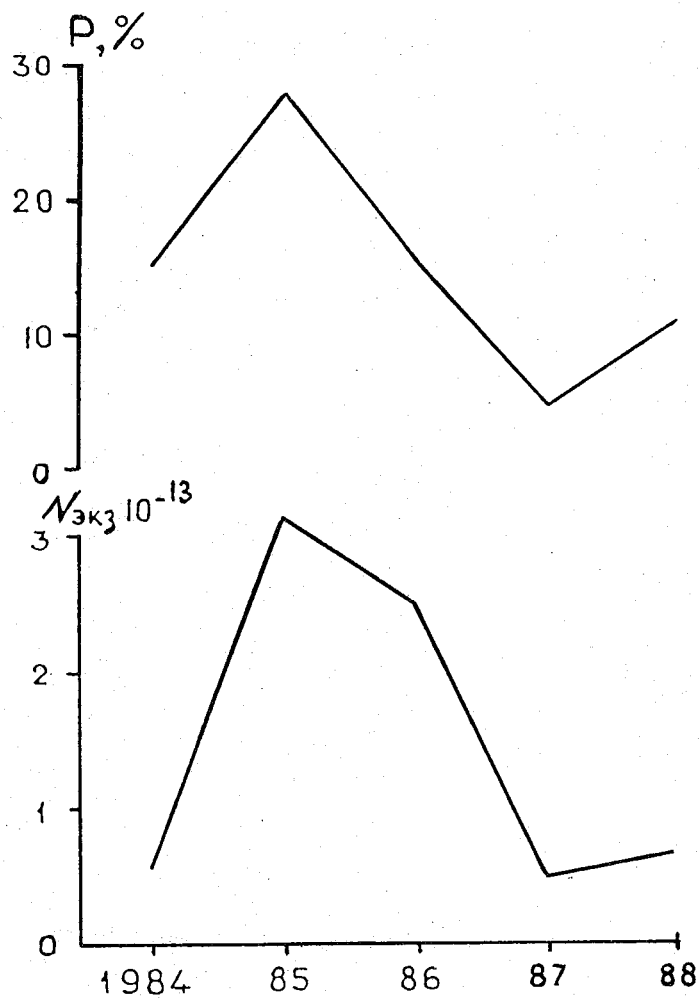| Year	N spec. 10^{-13}	0-gr. spec. 10^{-9}	Q spec. 10^{-9}	T^0 C	S $^0/_{00}$	P $^0/_0$	V $^0/_0$	W $^0/_0$
1983		40.9	17.9	9.76	35.45	16.7	26.9	43.8
1984	0.54	17.7	22.3	10.00	33.48	15.2	7.7	6.4
1985	3.13	17.3	30.2	10.00	35.50	28.0	10.9	14.7
1986	2.51	6.9	37.1	9.56	35.45	15.2	35.9	38.0
1987	0.49	24.8	33.1	9.96	35.49	4.4	29.5	40.7
1988	0.64			9.92	35.42	10.8	33.6	36.2

Fig.5 Variations in abundance of larval blue whiting (N), and in
       frequency of southerly winds (P) in 1984-1988.

(Fig. 2c), and northwest of it near the slope (Fig. 4). No larvae were
found west and northwest of the Hebrides. Along with oceanographic
factors, a general decrease in larval abundance in 1987 and 1988
seems to be one of the causes of such a distribution.

Larval abundance

Larval sampling shows marked variations in abundance from year to year
So far the causes of these variations are unclear, but a certain
influence of abiotic factors is likely to exist. At least, the fact
that top larval abundance (during the studies' period) is associated
with maximum strengthening of advection (in 1985) is evident, though
no unambiguous correlation is present here (Table 3). Nor is there a
direct relation between larval abundance and frequency of south-
westerly winds, but the appearance of stronger year classes under the
dominance of these winds (and vice versa) is obvious. (In this case
southerly winds prove to be more representative compared to south-
westerly ones used in analysis for temperature and salinity
variations). This is shown in Table 3 and Fig. 5.

At the same time, Table 3 does not show a more or less definite
dependence of 0-group abundance on larval abundance and oceanographic
conditions in spring, or any relationship between abundance and
biomass of the spawning stock and larval abundance. Survival from
larval stage to 0-group is probably conditioned by abiotic factors of
the following period, and the spawning stock size effect on year class
strength is determined in a complicated manner by environmental
conditions.

Spawning times

As shown in a paper by Kuznetsov and Kolpikov (1981) and supported by
subsequent observations (Belikov, 1985; Belikov et al.,1986), the
dates of mass spawning start of blue whiting on the British Shelf are
directly dependent on thermal conditions: with a high heat content of
waters spawning starts earlier, with a low one - later. This
regularity is obvious in the 1983-1987 data (Table 4). However, the
1988 data disagree with this regularity: the temperature and salinity
observed are almost the same as the previous year, whereas the
spawning started about 2 weeks in advance. It may be related to the
considerable westward shift of the main spawning fish concentrations.

Table 4.   Rough dates of mass spawning start of blue whiting on the
            Porcupine Bank, mean temperature (T) along the section at
            53°N, and mean salinity (S) in layer 0-200 m in March
            1983-1988.

Year	Start of spawning	T, °C	S, %
1983	08-10 March	9.76	35.45
1984	25-26 February	10.00	35.48
1985	15-16 February	10.07	35.50
1986	22-24 March	9.56	35.45
1987	10-11 March	9.92	35.49
1988	24-26 February	9.92	35.42

According to observations by Norwegian and Soviet scientists (T. Monstad, pers.comm.), in spring 1988 the general distribution of the spawning blue whiting was the most westerly for the period since 1983 (Fig.4). This shift may be assumed to have occurred due to an anomalous westward migration or meandering of one of the warm branches washing the shelf, causing blue whiting to search for more favourable conditions. As a result, they concentrated in warmer waters and spawned earlier.

DISCUSSION

The relatively stable pattern of larval blue whiting distribution in March-May mentioned above seems to be conditioned by the fact that the main traditional spawning grounds generally do not change, and subsequently ichthyoplankton is dispersed from these spawning grounds by the North Atlantic Current running steadily north-northeast (Schmidt, 1909; Bailey, 1974).

At the same time, oceanographic conditions vary considerably from year to year, affecting to this or that extent various aspects of the blue whiting ecology and biology (spawning times, larval abundance, survival at early stages etc.). Processes of large-scale interactions between ocean and atmosphere, backed by smaller-scale fluctuations due to local conditions, appear to be responsible for these variations. The quasi-two-year cyclic pattern showing in the variability of hydro meteorological parameters on the British Shelf is also present in other northeast Atlantic seas, and is a distinguishing feature of the entire North Atlantic region (Nikiforov, Shpaikher 1980, Sukhovei 1977).

In terms of practice, large-scale relations between individual links of the shelf ecosystem are of prime interest. They allow fishery conditions to be estimated in good time, and form a basis for studies of recruitment dynamics.

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POPULATION FECUNDITY
AND YEARCLASS STRENGTH OF BLUE WHITING
IN THE NORTHEAST ATLANTIC

by

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ABSTRACT

Observations for 1970-1988 showed that the population fecundity of blue whiting varied within a wide range from peak values in the second half of the 1970's to minimum ones in the 1980's. These variations were associated with reduction in average age of the spawning population and decline of its number.

Survival rate (SR) (per cent ratio of numerical strength of 3-yr-olds to the population fecundity) varied from 0.0011 to 0.00011. Considering survival rate to be an integrated index of survival in early ontogenesis, different levels of population fecundity were established: a guaranteed level of PF (GPE) -2759 x 10^{12}, minimum tolerance level (MTPF) -1739 x 10^{12}, critical level (CPF) -978.4x10^{12} eggs, with a corresponding spawning stock biomasses of 5.5, 3.5 and 2.0 mill. tonnes.

Rational management of the blue whiting stock can be implemented by maintaining the spawning stock biomass at a level of not less than 3.5 mill. tonnes.

INTRODUCTION

Annual blue whiting surveys provide evidence of pretty large variations in numbers and biomass of this stock. However, until now it is not ascertained, which factors, natural or anthropogenic, exert the greatest effects on the abundance of blue whiting stock.

Population fecundity (PF) or, in other words, the total number of eggs spawned by females during the spawning season in a given year, is a most important characteristic of stock reproductive ability (Anokhina,; 1969 Polyakov, 1971).

Notwithstanding certain difficulties, attempts were repeatedly made at estimating the PF value, Anokhina (1969) and Ojaveer (1974) attempted estimating the PF in Baltic herring, O. Dragesund and O. Nakken (1973) estimated the PF in Atlanto-Scandian herring, Garrod (1973), A. Hylen and O. Dragesund (1973) were close to obtain estimates of the PF for commercially important fish species. Daan (1975) estimated the PF for North Sea cod, and Sahrhage and Wagner (1978) had done the same for haddock. Serebryakov et al. (1984, 1985) estimated the PF level in Arcto-Norwegian cod, Barents sea capelin and Atlanto-Scandian herring (Serebryakov, 1988).

In most cases such indirect PF indices as biomass or abundance of the spawning stock are used in studies of the recruitment/stock size relationship (Ricker, 1954; 1958; Beverton and Holt, 1957; Chapman, 1973; Cushing and Harris, 1973).

The VPA methodology currently widely used for stock assessment purposes and, in particular, for evaluation of the numerical strength of every age group in the spawning stock, affords estimation of the PF level for blue whiting.

MATERIAL AND METHODS

Data collected by PINRO research vessels west of Ireland and Great Britain and south of the Faroes in February-April 1981-1988 were used to evaluate the PF level for blue whiting. Gonads at maturity stage IV and IV-V from 390 females were examined.

Individual absolute fecundity was determined by converting the number of eggs in a portion of gonads to their whole weight, without accounting for the membrane weight. Only eggs with the diameter of 0.3 mm and larger were counted, because smaller eggs belonged to next year's generation.

All estimates of population fecundity and survival rate were derived in accord with methods suggested by Serebryakov (1988). Population fecundity was determined from the formula:

$$PF = \sum_{i=3}^{n} C_F$$

Table 1. Contribution to PF(eggs$\times 10^{12}$) value of every age group 1970-1988.

Age	Year									
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
3	110.7	168.3	356.7	925.7	102.1	123.0	644.5	353.0	362.8	-
4	325.0	254.3	565.2	501.6	607.6	395.6	747.5	351.8	514.3	19.8
5	992.4	297.7	628.5	330.8	992.4	512.7	569.0	400.3	428.4	41.3
6	346.0	288.3	288.3	134.5	576.6	422.8	269.1	249.9	315.2	65.3
7	274.4	431.2	352.8	58.8	411.6	540.9	172.5	199.9	247.0	174.4
8	100.3	325.9	100.3	25.1	301.0	401.4	160.6	192.7	130.4	258.9
9	110.4	132.5	33.1	22.1	121.4	485.7	17.7	198.7	37.5	240.7
10	43.8	65.8	8.8	15.3	11.0	197.2	17.5	155.6	11.0	876.8
11	4.7	11.7	-	11.7	23.4	164.0	-	89.0		707.6
12	5.1	5.1	-	5.1		50.6	-	108.8		275.7
13	4.9	2.5	-	-		73.6	-	24.5		268.4
14						19.3	-	27.1		90.9
15										22.0
PF	2317.7	1983.3	2333.7	2030.7	3147.1	3386.8	2598.4	2351.3	2046.6	3041.8

Age	Year								
	1980	1981	1982	1983	1984	1985	1986	1987	1988
3	11.1	5.8	6.6	11.4	23.9	870.9	198.2	61.9	95.7
4	11.3	15.3	28.0	19.5	30.4	202.4	684.2	617.0	181.3
5	19.8	51.5	56.3	164.4	90.3	87.3	239.5	497.2	828.1
6	117.2	64.9	90.6	163.3	320.0	92.0	123.9	89.9	335.0
7	333.2	116.0	123.9	227.9	181.9	92.1	107.4	49.6	238.7
8	541.8	208.7	169.8	422.0	241.2	154.8	333.9	102.3	49.0
9	613.8	286.3	219.3	257.2	175.4	176.5	261.8	153.9	87.1
10	569.9	589.0	267.9	187.3	183.9	209.9	231.1	66.7	23.1
11	276.5	244.0	134.6	71.7	71.4	69.9	117.0	86.5	
12	202.4	132.3	158.5	55.8	21.5		102.5	71.3	
13	98.2	52.9	45.9	26.3	23.8		79.8		
14	7.7	19.7	28.8	5.3	-				
15		7.9	9.4	4.0	-				
PF	2802.9	1794.3	1339.6	1616.1	1363.7	1955.8	2479.3	1796.3	1838.0

Table 2. Population fecundity (PF), year class strength (abundance of 3-year-olds) and survival of blue whiting in early ontogenesis in 1970-1988.

Year	Amount of mature fish, ind. x 10^9 (VPA)	PF eggs x 10^{12}	Abundance of 3-year-olds, ind. x 10^6	Year class strength	Survival to age 3, %	Survival conditions
1970	29.5	2317.7	13057	rich	0.00056	average
1971	35.4	1983.3	11897	rich	0.00060	favourable
1972	41.3	2333.7	11602	rich	0.00050	average
1973	47.5	2030.7	9797	average	0.00048	average
1974	51.2	3147.1	7331	average	0.00023	unfavourable
1975	52.1	3386.8	6568	average	0.00019	unfavourable
1976	52.7	2598.4	5796	average	0.00022	unfavourable
1977	47.7	2351.3	5259	average	0.00022	unfavourable
1978	43.2	2046.6	7502	average	0.00037	average
1979	37.9	3041.8	4199	weak	0.00014	unfavourable
1980	30.1	2802.9	3121	weak	0.00011	unfavourable
1981	23.4	1794.3	4392	weak	0.00024	unfavourable
1982	18.1	1339.6	14741	rich	0.00110	extremely unfavourable
1983	17.7	1616.1	10762	rich	0.00066	favourable
1984	23.4	1363.7	6599	average	0.00048	average
1985	31.1	1955.8	6860	average	0.00035	average
1986	35.4	2479.3				
1987	32.9	1796.3				
1988	28.2	1838.0				

where   PF - population fecundity, number of eggs,
         i=3 - age at recruitment to the spawning stock,
         n   - number of age groups,
         C_F - a contribution to the PF value by all fish
from a given age group, is estimated as

$$C_F = F \cdot N \cdot m \cdot R$$

where   F - mean individual fecundity of fish in a given
              age group,
         N - number of fish in a given age group,
         m - proportion of mature fish in a given age group,
              estimated from the maturity ogive,
         R - proportion of females, i.e. sex ratio in a given
              age group.

Data on abundance and biomass of the spawning stock were borrowed from
reports of the Blue Whiting Assessment Working Group (Anon., 1986,
1988, 1989).

DISCUSSION

The peak level of the PF was observed in the 1970's when the spawning
stock was composed mainly of older fish with high individual
fecundity. The amount of mature fish in 1971 and 1979 was estimated to
be approximately identical (35.4 and 37.9 x 10^9 fish, respectively),
however, in 1971 individuals at age 4-8 were major contributors to the
PF, whereas in 1979 these were 10-11-year-olds. Changes in the age
structure of blue whiting spawning stock were responsible for an
increase in the PF in 1979 against 1971 (Table 1).

In the 1980's only the 1986 PF value exceeded the long-term mean level
(Table 2).

During the period of observation rich yearclasses (the number of three
year olds exceeding 10 x 10^9 fish) were produced only 5 times: in
1970-1972, 1982 and 1983. Average year classes (the number of three
year olds from 5 to 10 x 10^9 fish) appeared 9 times: in 1973-1978,
1984-1986. Weak yearclasses (the number of three-year-olds below 5 x
10^9 fish) emerged 5 times:in 1979-1981, 1987 and 1988 (Table 3). It
should be noted that rich year classes were produced in years when the
PF was a little above or below the MTPF level. The SR however, was
always high. Weak year classes at two instances (1979 and 1980)
appeared when the PF was high, at the GPF level. The SR however, was
very low, and in three cases (1981, 1987 and 1988) at a minimum
tolerance PF level, with the SR being 0.00023 to 0.00024. Average year
classes in most cases were produced in years with a high PF (only in
1984 the PF was below the MTPF level), when the survival conditions
were average or unfavourable. In the period investigated the numerical
strength of three-year-olds varied from 3121 x 10^6 to 14741 x 10^6
fish, and the mean survival rate of fish to age 3 was 0.00039.

Considering the year class strength of blue whiting in relation to
survival conditions (Table 4) one can see, that under favourable
conditions (SR>0.0006) even at a low PF only rich year classes were
produced. Under average conditions (SR = 0.0003-0.0006) both rich and
average year classes can be produced, depending on the amount of eggs
deposited. Under unfavourable conditions (SR<0.0003) even at a high PF
only average and weak year classes appeared.

Table 3. Blue whiting year classes ranked by strength (abundance of three-year-olds).

Rich				Average				Weak			
Abundance of 3-year-olds, ind. x 10^6	PF, eggs x 10^{12}	SR	Year	Abundance of 3-year-olds, ind. x 10^6	PF eggs x 10^{12}	SR	Year	Abundance of 3-year-olds ind. x 10^6	PF, eggs x 101^2	SR	Year
13057	2318	0.00056	1970	9797	2031	0.00048	1973	4199	3042	0.00014	1979
11897	1983	0.00060	1971	7331	3147	0.00023	1974	3121	2803	0.00011	1980
11602	2334	0.00050	1972	6568	3387	0.00019	1975	4392	1794	0.00024	1981
14741	1340	0.00110	1982	5796	2598	0.00022	1976				
10762	1616	0.00066	1983	5259	2351	0.00022	1977				
				7502	2047	0.00037	1978				
				6599	1364	0.00048	1984				
				6860	1956	0.00035	1985				

Table 4. Blue whiting year classes ranked by surviving conditions, R - rich yearclass, A - average yearclass, W - weak yearclass.

Favourable					Average					Unfavourable				
SR 0.0006	Abundance of 3-year olds ind.x10^6	PF eggs x 10^{12}	Year	Strength	SR 0.0006-0.0003	Abundance of 3 year olds ind.x10^6	PF eggs x 10^{12}	Year	Strength	SR 0.0003	Abundance of 3-year olds ind.x10^6	PF eggs x 10^{12}	Year	Strength
0.00060	11897	1983	1971	R	0.00056	13057	2318	1970	R	0.00023	7331	3147	1974	A
0.00110	14741	1340	1982	R	0.00050	11602	2334	1972	R	0.00019	6568	3387	1975	A
0.00066	10762	1616	1983	R	0.00048	9797	2031	1973	A	0.00022	5796	2598	1976	A
					0.00037	7502	2047	1978	A	0.00022	5259	2351	1977	A
					0.00048	6599	1364	1984	A	0.00014	4199	3043	1979	W
					0.00035	6860	1956	1985	A	0.00011	3121	2803	1980	W
										0.00024	4392	1794	1981	W

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Under unfavourable conditions rich year classes of blue whiting can appear at a PF equal to 2759×10^{12} eggs (GPF level), under average survival conditions for a rich year class to be produced the PF should be equal to 1739×10^{12} eggs (MTPF level). A critical level of the PF at which only under extremely favourable survival conditions a rich year class may be expected, corresponds to 978.4×10^{12} eggs. At lower PF values production of a rich year class is impossible.

Varying levels of population fecundity are supported by corresponding biomasses of the spawning stock: guaranteed level - 5.5 mill. t, minimum tolerance level - 3.5 mill.t, critical level - 2.0 mill.t.

CONCLUSIONS

In the period investigated the abundance of the blue whiting spawning stock varied from 17.7 to 52.7 $\times 10^9$ fish, population fecundity from 1340 to 3387×10^{12} eggs, with the number of eggs deposited depending both on the abundance and age structure of the spawning stock. Due to changes in the size-age structure and decline in number of the spawning stock in the 1980s, the population fecundity was well below the long-term mean level, except in 1986.

Rich year classes of blue whiting were produced in years when the population fecundity was at the long-term mean level or slightly lower, at high SR values. Under unfavourable survival conditions even at high PF levels only average and weak year classes appeared.

Spawning stock biomasses corresponding to the GPF, MTPF and CPF levels were estimated at 5.5, 3.5 and 2.0 mill.t, respectively.

In rational blue whiting fishery the spawning stock biomass is required to be not less than 3.5 mill.t. If a critical level is approached (2.0 mill.t), the fisheries should be put under a ban until at least two rich or 4-5 average year classes are produced.

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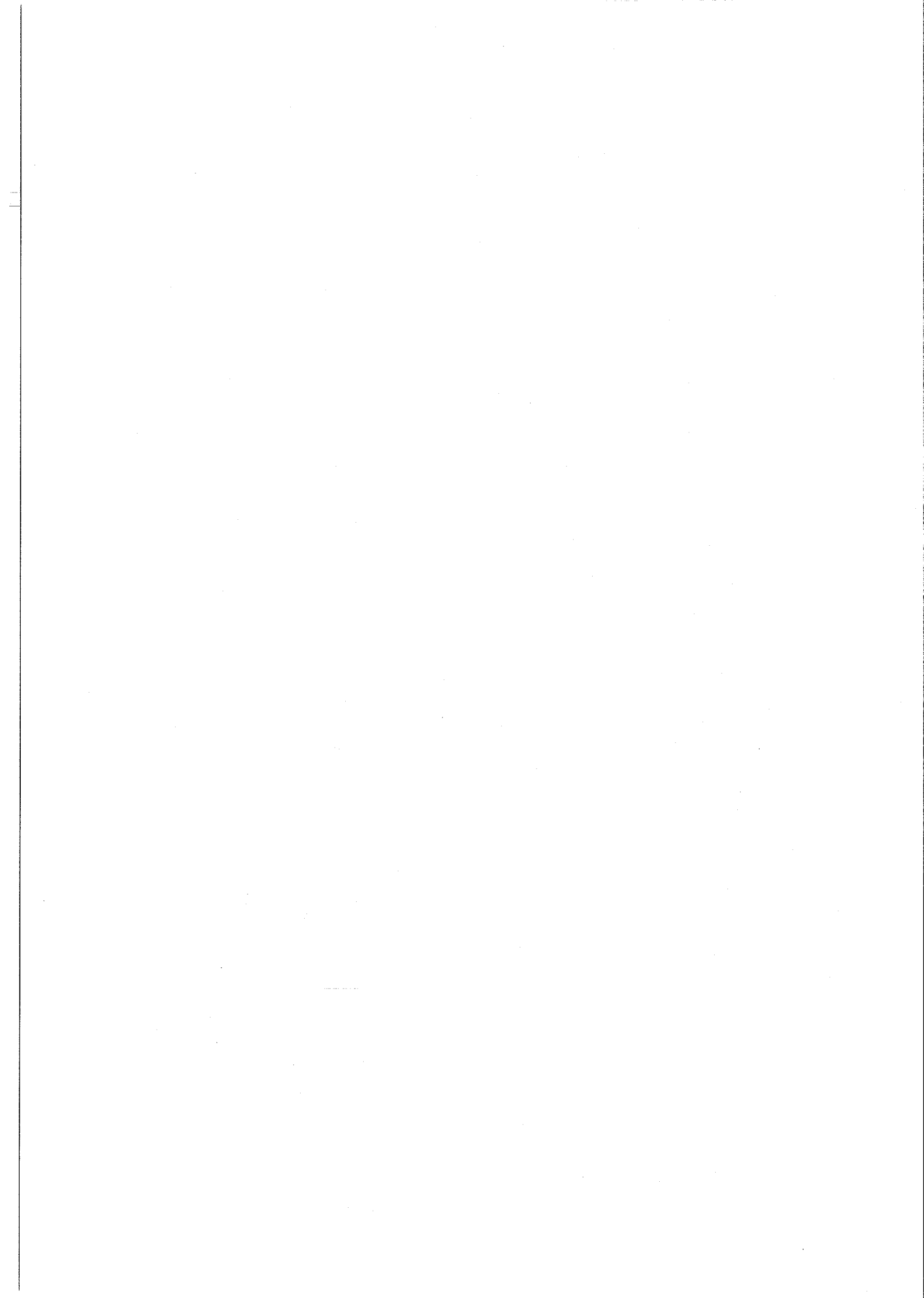
THE CONDITION OF BLUE WHITING FEEDING IN THE NORWEGIAN SEA IN THE SPRING-SUMMER PERIOD 1980-1987

by

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ABSTRACT

The analysis of feeding conditions and blue whiting distribution in the spring-summer period was made using the results of plankton oceanographic surveys and field analyses of blue whiting feeding in 1980-1987.

The investigations show that the most favorable conditions for feeding in these years were in the Atlantic and mixed waters in the southern and central Norwegian Sea.

A certain dependance of start and duration of blue whiting feeding on copepods in the spring-summer period on times of calanus mass develpoment, age-length composition of fish, fish abundance and biomass was noted, as well as correspondance of areas where fish prey copepods to areas of plankton concentrations with a biomass ranged from 500 to 1000 mg/m^3 and more and calanus in copepodite stages IV-V with abundance of 500 to 1000 specimens/m^3 and more.

INTRODUCTION

The Norwegian Sea is an area of pelagic fishes (herring, blue whiting, mackerel) feeding migrations in the spring-summer period. The study of prey distribution over the sea and their influence on the fish behaviour during the feeding season is very important for predicting times and areas of feeding fish concentrations formation in summer period.

In G.V Nikolsky's view (1965), abundance and biomass of fish population depend, to a great extent, on food supply determined by amount, quality and accessibility of food in the sea, duration of feeding season and abundance of feeding populations.

Herring were observed to feed on spring-summer plankton (adult euphasiids and copepods, which had moved to upper layers to spawn), and made feeding migrations to the North and North-West keeping on the whole in the mixed waters. Peak feeding on copepods was in May. (Pavshtiks, 1960; Pavshtiks, Rudakova, 1962).

Blue whiting, in contrast to herring, began to feed later, keeping in the Atlantic and mixed waters; peak feeding on copepods was in June (Plekhanova, Soboleva, 1981, 1982).

According to A.V. Shevchenko and N.A. Isaev (1983); A.V. Shevchenko (1981); (Shevchenko and Isaev, 1983; Shevchenko, 1984) blue whiting fishing areas in spring-summer 1979-1980, 1982-1984 had the eastern orientation, but in 1981- the western one. The cause of changes in fishing conditions in these years, to their mind, was variability in the thermal background and space structure field of water temperatures. However, the temperature frontal zones, first of all, influence the feeding conditions formation and they, in their turn, determine behaviour of stocks - their concentration, activity and stability in feeding period.

The paper makes an attempt of determining the role of food plankton in the North Sea and, first of all, that of copepods in the blue whiting diet and behaviour in the spring-summer period 1980-1987.

MATERIAL AND METHODS

The results of qualitative and quantitative treatment of plankton collected with Juday net (gauze No 38, with a 37 cm diametre of entrance opening) in the layers 0-50, 50-100, 100-200m during oceanographic surveys in June 1980-1987 and data from field analyses of blue whiting feeding in the same years were used in this paper.

The material was collected and processed by using the methodology adopted at PINRO (Instructions and directions, 1980; Directions on the determination of the food objects and zones of pelagic fishes feeding in the Barents and Norwegian Seas, 1986). Analysis of feeding conditions status in the Norwegian Sea involves plankton in the layer 0-50 m, as the major concentrations in the spring-summer period are recorded here. A complete plankton analysis was given both over the whole sea and by the coastal, Atlantic, mixed and eastern-Icelandic water masses.
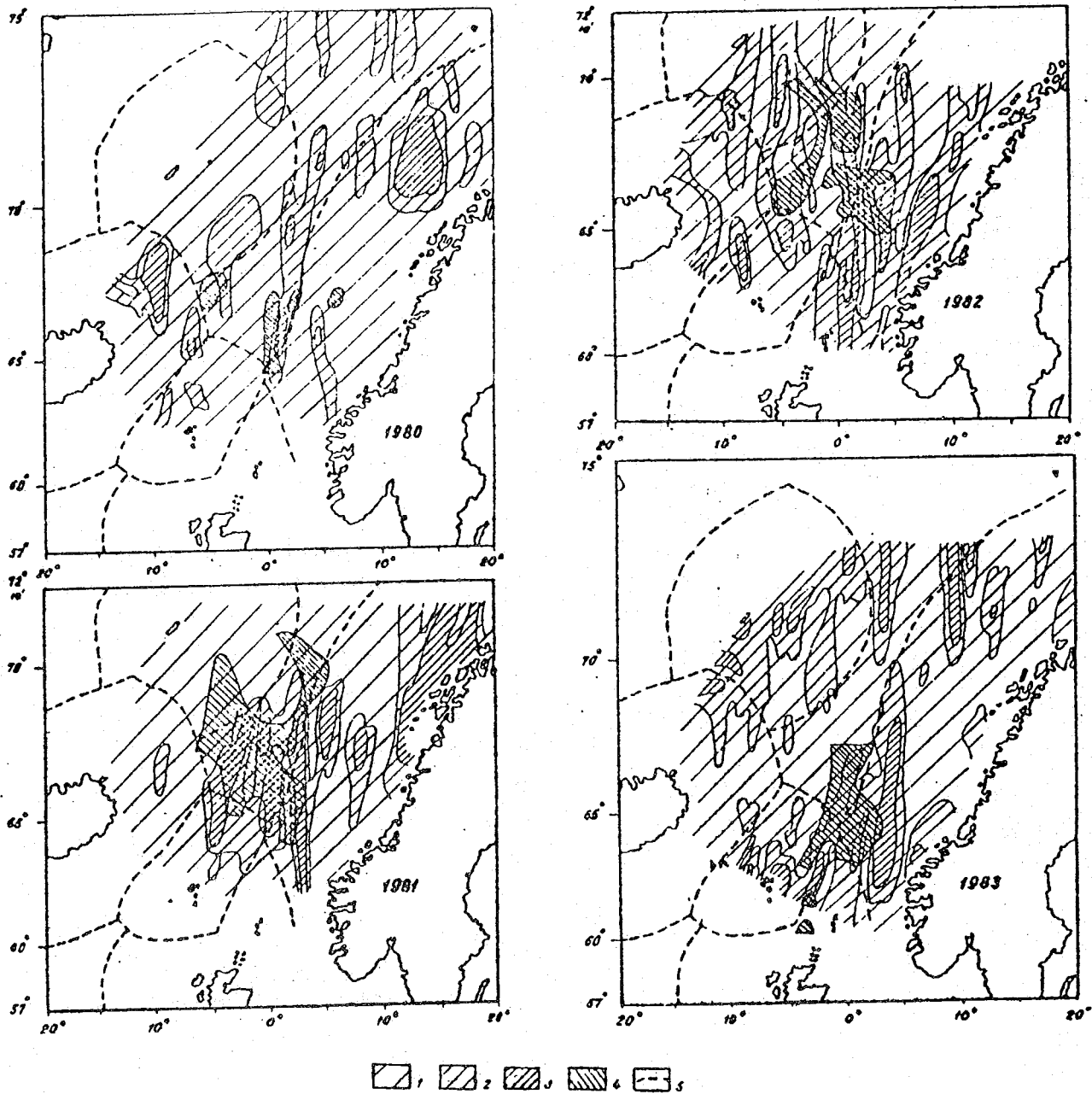
Fig. 1. Plankton biomass distribution in the layer 0-50 m and
areas of blue whiting feeding on copepods in June 1980-
1983. Legends: Plankton biomass in mg/m^3,
1 - 1-500, 2 -501-1000, 3 - from 1000 and more, 4 - the
area of blue whiting feeding on copepods with copepods
frequency of occurrence in blue whiting stomachs over
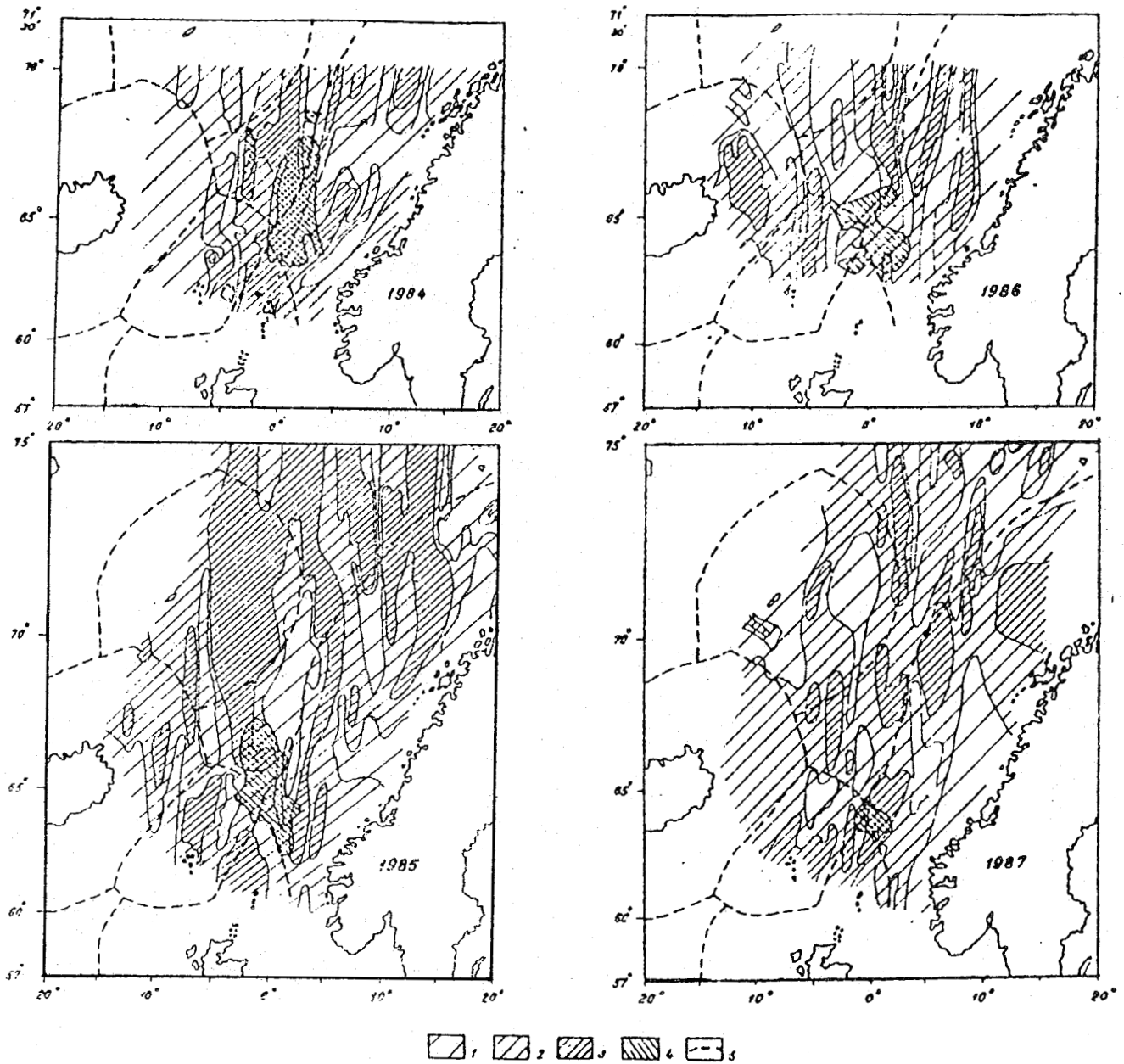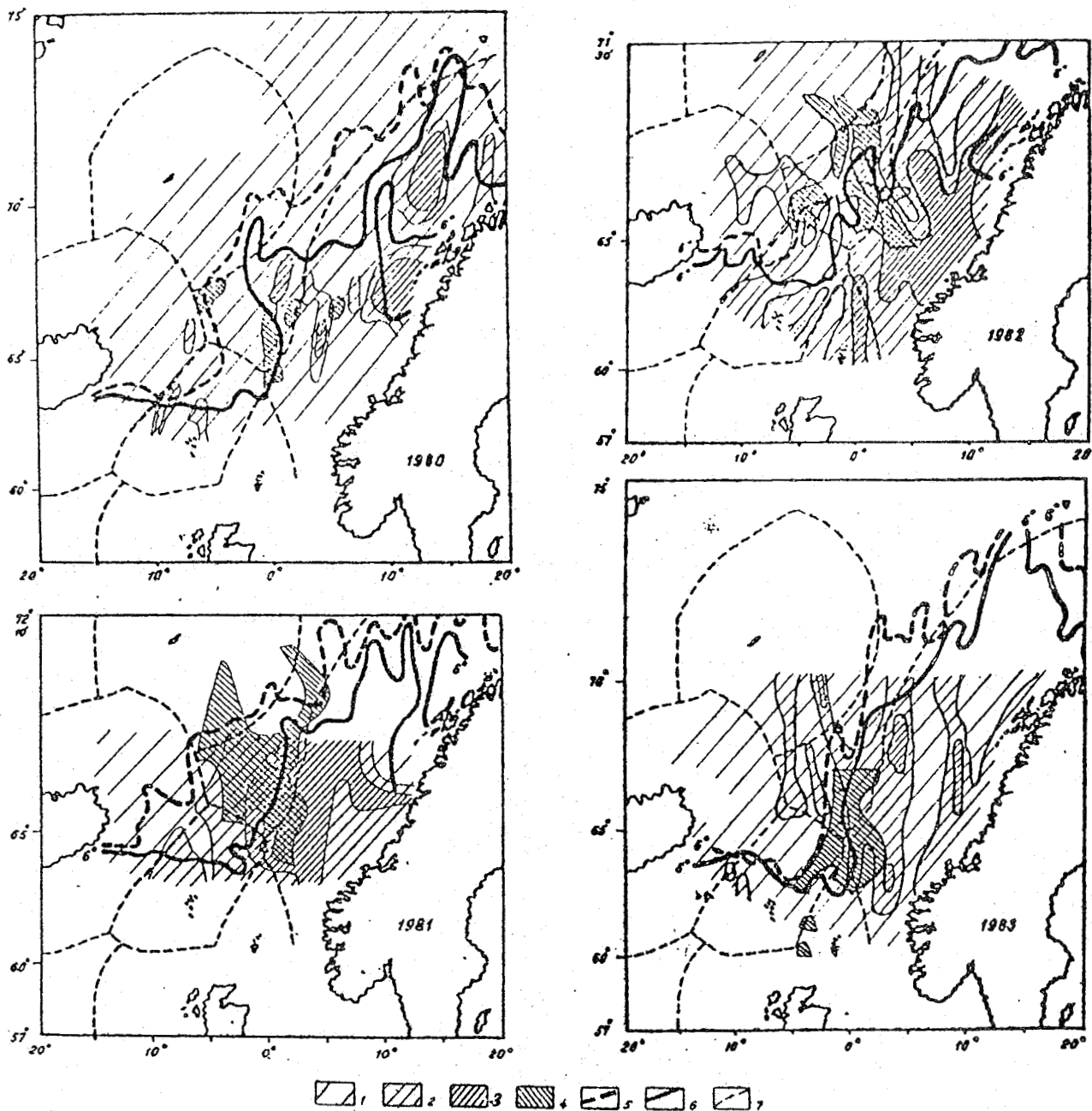50%

Fig. 2. Plankton biomass distribution in the layer 0-50 m and
        areas of blue whiting feeding on copepods in June 1984-
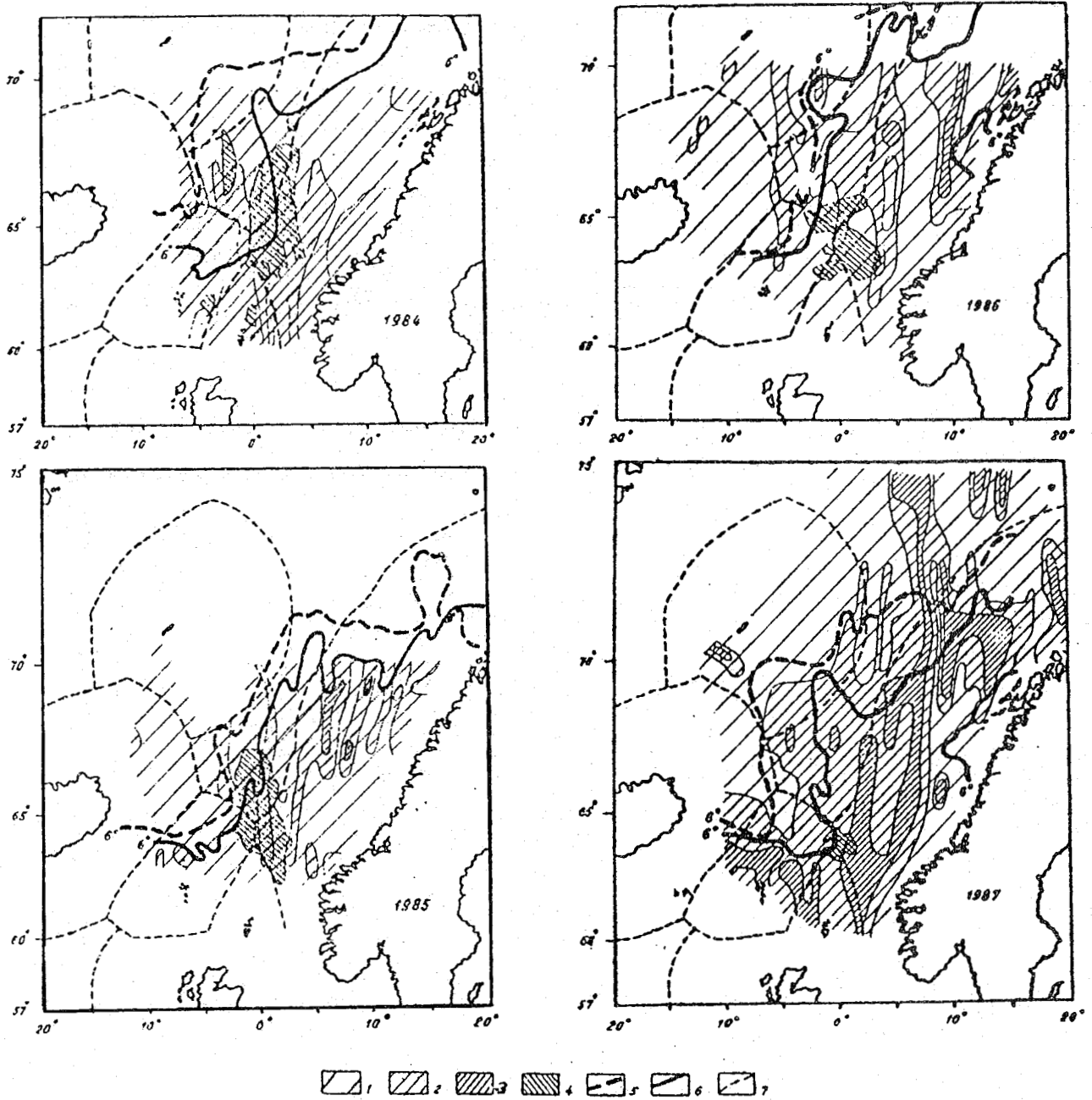   1987. Legends as in Fig.1.

Fig. 3. Distribution of calanus (IV-V copepodite stages) in the
        0-50m layer and areas of blue whiting feeding on cope-
        pods in June 1980-1983.
        Legends: Calanus abundance (IV-V copepodite stages) in
        fish/m^3 1 - 1-500, 2 - 501-1000, 3 - from 1000 and more,
        4 - the area of blue whiting feeding on copepods whith
        copepods frequency of occurrence in their stomachs over
        50%, 5 - isotherm 6^0 on the sea surface in June, 6 -
        isotherm 6^0 at the 50 m layer in June.

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Fig. 4. Distribution of calanus (IV-V copepodite stages) in the
         0-50m layer and areas of blue whiting feeding on cope-
         pods in June 1984-1987. Legends as in Fig. 3.

Table 1. The plankton biomass in the layer 0-50 m of the Norwegian
Sea in June 1980-1987, in mg/m^3.

Water masses	1980	1981	1982	1983	1984	1985	1986	1987	Mean
East-Icelandic	333	411	493	424	630	784	639	734	533
Mixed	262	404	378	579	710	865	406	757	558
Atlantic:	367	537	558	525	910	1075	655	944	693
North-western branch	665	214	692	511	388		434	733	506
Western branch	438	913	475	474	841	1078	346	1028	762
Central branch	413	228	324	596	812	985	754	755	636
Eastern branch	288	587	843	548	730	1069	739	662	680
Coastal	312	377	904	425	511	774	652	412	527
Mean for the sea	356	511	561	502	772	986	614	831	631

The particularities of blue whiting feeding are considered over the entire sea as well as by the various sea areas (southeastern, southern and central parts of the sea). The parts, where the copepods accounted for 50% or more in the blue whiting diet were taken for the feeding areas of blue whiting on copepods. The mean stomach fullness in this case was 1 and more.

RESULTS

Feeding conditions in the spring-summer period 1980-1987.

In the survey years, due to lower heat content of waters in the southern and southeastern Norwegian Sea, the biological spring ("bloom", calanus mass spawning) in the southern and southeastern sea was observed in April-May, later than mean long-term average in March-April; in 1980-1981, 1986 - in the last ten days of April; in 1982-1984, 1987 - in the last ten days of April - the first ten days of May, in 1985 - in the 1st and 2nd ten days periods of April.

The basic plankton concentrations in the spring-summer period were in the layer 0-50 m. The greater part of them was represented by copepods (90-96%). Calanus finmarchius and Oithona similis were most abundant. Plankton biomass consisted mainly of large organisms. They were adult copepods - Calanus finmarchius, C.hyperboreus; euphasids - Thysanoessa longicaudata, hyperiids - Parathemisto abyssorum, P.libelulla; chaeto-gnats - Eukrohnia hamata. The maximum values of calanus and total zoo-plankton abundance and biomass were noticed in June. The Atlantic and mixed waters in the southern, southeastern, eastern and central sea areas (Table 1) were most productive these years, especially the southern and southeastern parts. The densest total concentrations of plankton and calanus occurred from $61^0 00'N$ to $70^0 00N$ and from $05^0 00'E$ to $05^0 00'W$ and were distributed maily in the meriodinal direction, conforming to the direction of the Norwegian Sea water masses (Figs.1-4). Plankton biomass here amounted to 500-1000 mg/m^3 and more; calanus abundance to 500-1000 Specimens/m^3. Due to different terms of the main zooplankters development in 1980-1987 their places of concentrations were distributed in a different manner in 1980, 1982-1987 and especially in 1982 , to the south and east of the mean long-term distribution; in 1981, 1985 to the west. It is noted that under the southern and eastern distribution of large concentrations of plankton a high abundance of calanus (I-V copepodite stages) from new generations was observed in the Atlantic water and the abundance of their nauplii - in the Atlantic and coastal waters (along $67^0 30'N$ and $65^0 45'N$). Under the western distribution of productive parts a high abundance of calanus (I-V copepodite stages) and their nauplii was recorded in the Atlantic and mixed waters. (Pavshtiks E.A., Plekhanova N.V., Soboleva M.S., 1989).

The mean long-term biomass of plankton in 1980-1987 was rather at a high level and differed by years not more than within two-three times (Tab.1). The largest biomass of plankton was recorded in 1985, probably because of the strengthening of the Norwegian Current Western Branch. For these years the mean historical biomass of plankton equaled 631 mg/m^3.

The role of plankton in the blue whiting feeding and distribution in the spring-summer period 1980-1987.

Table 2, part 1.

The main feeding indices of blue whiting in the Norwegian Sea in 1980-1987.

Month	Number of stomachs								Empty stomachs, per cent							
	1980	1981	1982	1983	1984	1985	1986	1987	1980	1982	1982	1983	1984	1985	1986	1987
January	1393	67	100	–	100	100	275	670	75	48	67	–	88	26	61	70
February	600	242	500	3996	1048	298	3556	67	45	50	33	29	71	75	54	83
March	3206	243	724	3186	2839	633	1429	125	25	66	32	73	83	85	67	89
April	2469	3857	3112	2717	1302	1991	3066	323	40	61	45	74	66	59	49	74
May	3148	8010	3936	7989	1763	3228	2890	1616	22	43	40	39	47	43	38	31
June	7384	5974	6512	4331	1952	2573	3361	2251	30	23	19	20	20	28	26	44
July	4742	4350	1036	2452	2646	1945	2644	3240	42	45	21	32	29	38	31	41
August	3152	3750	1000	586	1248	2056	3328	2458	63	38	16	26	37	42	19	44
September	1875	4628	372	100	425	300	749	688	69	51	33	35	11	7	22	34
October	1825	650	250	–	800	–	834	5	52	40	33	–	34	–	46	38
November	650	550	548	100	–	–	3238	–	71	57	58	14	–	–	53	–
December	–	–	–	–	–	–	1032	–	–	–	–	–	–	–	48	–
Total per year	30444	32321	18340	25457	14123	13124	26402	22338	42	42	31	41	48	44	41	49

Table 2, part 2.

Month	Mean index of stomach fullness								Frequency of occurence in % of copepods							
	1980	1981	1982	1983	1984	1985	1986	1987	1980	1982	1982	1983	1984	1985	1986	1987
January	0.32	0.62	0.45	–	0.17	1.56	0.78	0.43	0	6	0	–	–	–	–	0.7
February	1.07	0.74	1.71	1.46	0.44	0.34	0.98	0.33	0	0	1	0	2	–	–	1.5
March	1.58	0.45	1.74	0.32	0.24	0.24	0.60	0.19	+	0	0	–	2	3	17	–
April	1.06	0.65	1.13	0.34	0.62	0.66	1.00	0.52	3	+	1	+	38	6	29	16
May	1.79	1.05	0.92	1.10	1.08	1.19	1.39	1.18	67	26	12	11	53	60	81	68
June	1.65	1.50	1.81	1.57	1.65	1.39	1.45	1.18	86	72	70	58	77	72	77	67
July	1.11	0.88	1.53	1.17	1.48	1.08	1.35	1.10	71	53	11	41	76	68	46	36
August	0.69	1.17	1.94	1.45	1.37	1.13	1.47	0.95	48	6	14	13	29	52	46	31
September	0.50	0.78	1.26	1.25	1.95	2.29	1.67	1.62	10	0	0	11	3	66	28	4
October	0.58	0.88	0.85	–	1.23	–	0.85	1.10	3	5	6	–	16	–	33	40
November	0.34	0.68	0.54	1.71	–	–	0.68	–	38	0	8	–	–	–	3	–
December	–	–	–	–	–	–	0.87	–	–	–	–	–	–	–	5	–
Total per year	1.19	1.02	1.40	1.07	1.04	1.07	1.14	0.96	50	37	33	28	50	55	39	40

Table 2, part 3.

	Frequency of occurence in %														
	Euphausiids								Hyperiids						
Month	1980	1981	1982	1983	1984	1985	1986	1987	1980	1982	1982	1983	1984	1985	1986	1987
January	95	92	82	–	–	90	75	75	–	0	6	–	17	1	5	4
February	48	91	89	96	58	63	90	70	–	1	9	1	–	–	2	3
March	83	80	87	79	21	84	62	56	1	0	4	–	–	–	5	2
April	75	85	83	85	50	90	54	62	6	2	10	–	2	–	33	1
May	23	53	77	79	42	48	25	52	32	2	17	2	4		10	6
June	17	24	45	32	30	20	29	35	20	5	10	17	9	1	21	20
July	32	21	39	43	49	18	30	38	28	26	45	27	9	35	53	34
August	22	49	85	63	35	37	44	44	50	51	25	31	66	46	49	35
September	50	78	92	98	80	75	70	78	38	16	2	20	6	54	38	55
October	82	76	74	–	64	–	19	40	19	9	15	–	6	56	19	–
November	53	70	87	98	–	–	5	–	10	6	0	10	–	–	5	–
December	–	–	–	–	–	–	4	–	–	–	–	–	–	–	4	–
Total per year	42	48	64	67	44	41	24	46	21	14	14	9	13	27	24	26

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The analysis of material on feeding shows that blue whiting feed
during the whole year and the most intensive feeding is associated
with the spring-summer period when the mass development of food
objects is observed.

As reported earlier (Plekhanova, Soboleva, 1981, 1982; Zilanov, 1984)
euphausids, copepods and hyperiids prevailed in the blue whiting diet.
Blue whiting feed on euphausids all year long with a maximum in
January-February; on copepods only in the spring-summer period with a
maximum in June (Fig.5); on hyperiids - in late summer - in autumn
(Tab. 2). We tried to show the role of copepods in fish distribution
in this period, because blue whiting feed mainly in the spring-summer
period, when copepods (frequency of occurrence from 50 to 100%)
predominate in the fish feeding. Comparing the material on blue
whiting feeding and distribution in April-August with data on the
development and distribution of calanus finmarchius - a mass copepod
representative for the period mentioned, we notice that the fish
feeding was intensive and short-term (1-2 months) in the calanus
intensive spawning years (1981); and long-term in prolongated spawning
years (1980, 1984-1987), and especially in 1985, when the largest for
all survey years plankton biomass and the longest feeding were
observed. Some years (1982-1983) under the poor development of
copepods, blue whiting consumed these organisms for 1-2 months and
passed on earlier to feed on euphausids.
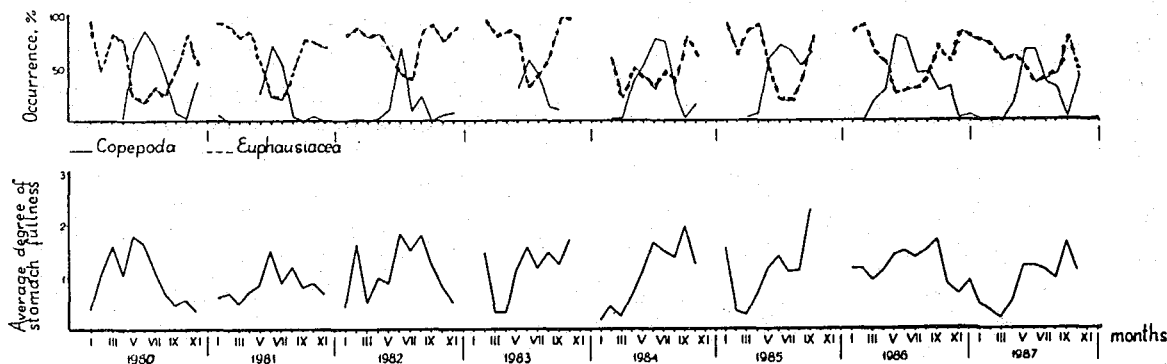
Fig. 5. Frequency of occurence of copepods and euphausiids in
        blue whiting stomachs and a mean index of stomach
        fullness.

The maximum consumption of copepods was recorded in June, in the
period of peak abundance and biomass of these prey organisms.

It should also be noted that juvenile blue whiting from 20 to 25 cm
and adults from 30 to 35 cm in length predominating in 1981-1983
(Belikov, 1984) did not feed on copepods for a long time (1-2 months),
but intensively; mean length fish, from 25 to 30 cm, prevailing in
1980, 1984-1987 - for a long time - 3-5 months, but poorly.

The areas of feeding on copepods corresponded to the places of high
plankton biomass from 500 to 1000 mg/m^3 and dense concentrations of
calanus IV-V copepodite stages of new generation (Figs.1 - 4).
Commercial fish concentrations were observed here too (Figs. 6 and 7).
Blue whiting feeding varied by areas; it was more intensive in the
southeastern and central parts of the sea, and poorer in the southern,
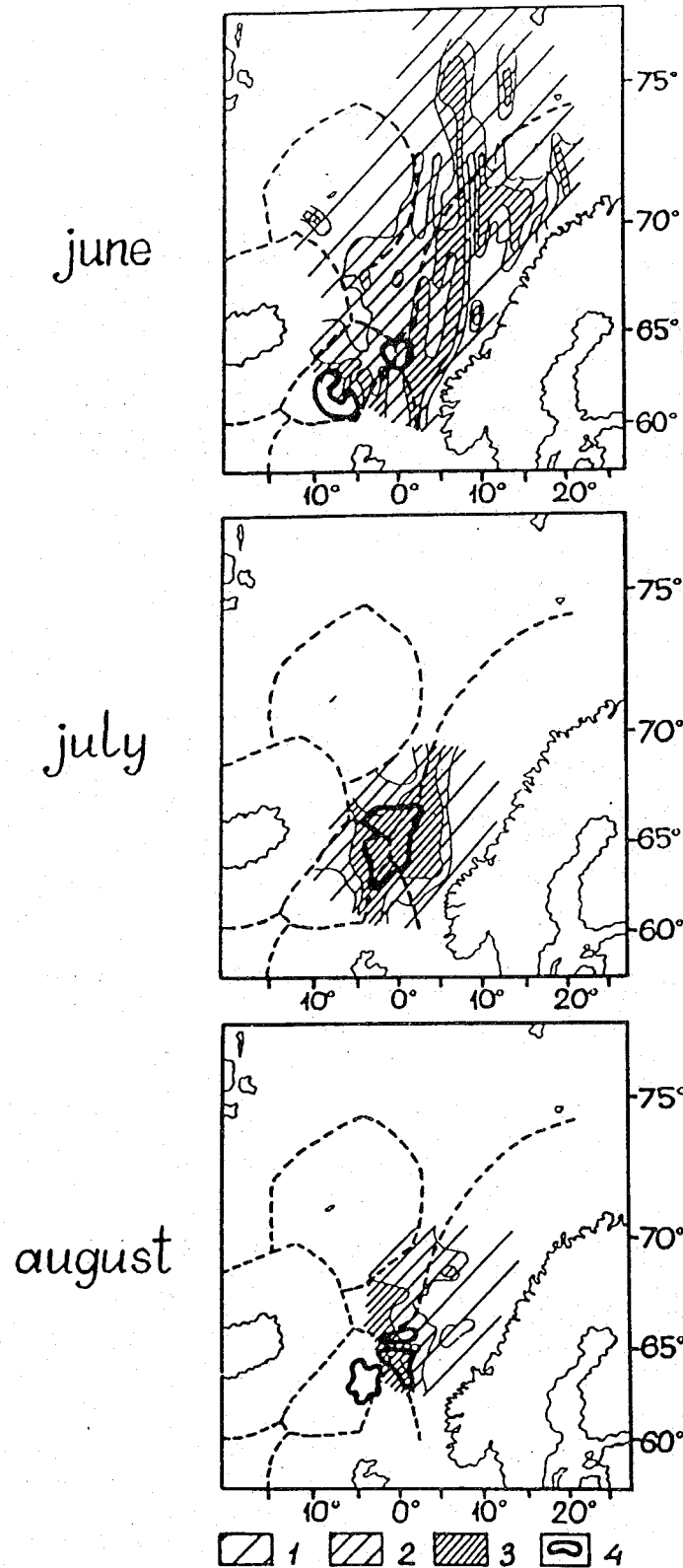where euphausiids are preferred (Fig.8).

Fig. 6. Distribution of calanus abundance (IV-V copepodite stage))
       in the 0-50m layer and the areas of blue whiting fishery
       in June-August 1987.
       Legends: calanus abundance, specimens/m^3,
       1 - 1-500, 2 - 501-1000, 3 - from 1000 and more, 4 - the
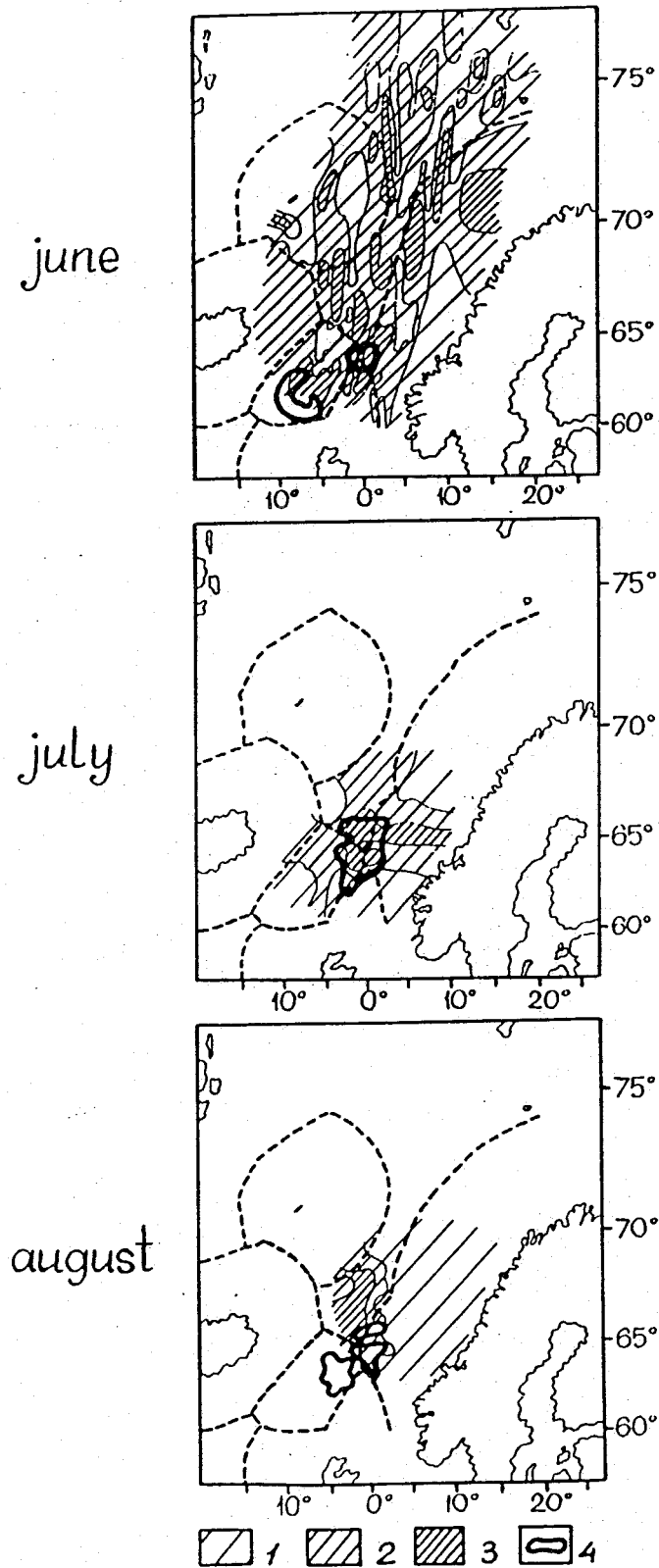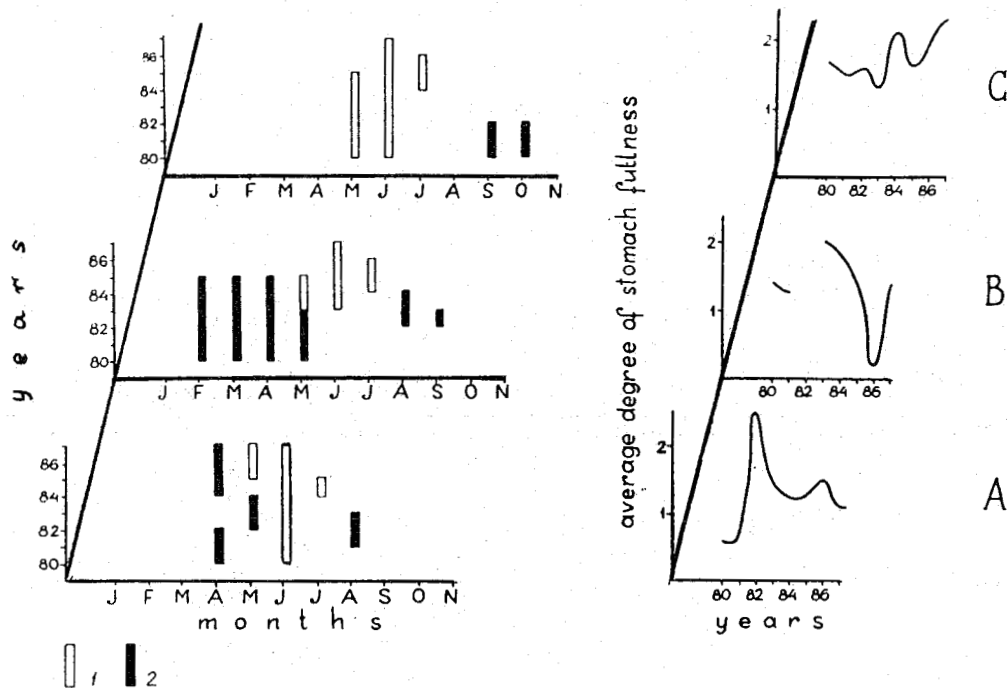   area of blue whiting fishery.

Fig. 7. Distribution of plankton biomass in the layer 0-50m and
        blue whiting fishery areas in June-August 1987.
        Legends: plankton biomass in mg/m^3,
        1 - 1-500, 2 - 501-1000, 3 - from 1000 and more, 4 - the
        area of blue whiting fishery.

Fig. 8. Main peculiarities of copepod (1) and euphausiids (2),
        consumption in the southeastern (A), southern (B) and
        central (C) parts of the sea in 1980-1987.

CONCLUSIONS

The start of the blue whiting feeding on copepods corresponded to that
of the formation of I-IV copepodite stages dense concentrations and
principally of calanus in IV-V copepodite stages.

The duration of the blue whiting feeding on copepods is determined by
the period of mass copepod development and age composition of fish.

In these years the blue whiting feeding areas occurred in the southern
and central parts of the sea.

The places where blue whiting fed on copepods (with the copepod
frequency of occurrence in blue whiting stomachs more than 50%)
conformed to the calanus concentrations of IV-V copepodite stages from
500 to 1000 specimens/m³ and more, and plankton concentrations from
500 to 1000 mg/m³.

Dense concentrations of all plankton and calanus from elder age groups
may serve as one of the indicators of large concentrations of pelagic
fishes in spring-summer period.

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Section VI: Parasites, mortality and migration

ECOLOGICAL AND GEOGRAPHICAL ANALYSIS OF THE NORTHEAST ATLANTIC
BLUE WHITING PARASITIC FAUNA

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ABSTRACT

Geographical variations in the parasitic fauna of blue whiting,
Micromesistius poutassou, from 15 sub-regions covering practically the
entire area of the species' distribution, were studied using the
mathematical set theory methods. Altogether about 16.000 fish were
examined and 36 species of parasites (including those described in
literature) were revealed.

The parasitic fauna of blue whiting from the North Sea, the Rockall
area and Biscay Bay is characterized by the maximal originality.
Groups of sub-regions in which the blue whiting parasitic fauna shows
the maximum similarity are also described.

In total the analysis conducted allowed us to determine the parasitic
fauna of blue whiting of other geographic areas from the Biscay Bay
and Celtic Sea blue whiting. The ecological-geographical analysis data
testify to a non-uniformity of the Hebrido-Norwegian stock of blue
whiting.

INTRODUCTION

A study of parasite fauna of fishes allows us to obtain valuable data
on various aspects of the host's biology, including its habitat,
feeding habits, migrations, relations within its environment. Of
particular interest is the fish local communities study based on
parasitological data. But a successful determination and
differentiation of ichthyofauna representatives on the basis of
parasitological methods of populations is possible only if a set of
ecological and parasitological observations is carried out. An
important role among those observations belongs to the ecological-
geographic analysis of parasitic fauna (Gayevskaya, Kovaleva,1986).

Parasitological investigations of blue whiting, Micromesistius
poutassou, have more than one hundred years of history, and since the
very first mentionings (Olsson, 1868, 1869; v. Beneden, 1871 and
others) until present (Polyansky, 1955; Gayevskaya, 1978; Mackenzie,
1979; Kusz, Treder, 1980; Karasev, 1984 and others) they have been
carried out in the best studied areas of the Northeast Atlantic.
Altogether we managed to find and analyse about 40 scientific papers
which contained various pieces of information concerning the blue
whiting parasites, but no ecological-geographic analysis of the
parasitic fauna within the vast area of the host distribution was
given in those. The main objective of this paper is to make up for a
deficiency in our knowledge.

MATERIAL AND METHODS.

Ichthyological data and parasitological samples from blue whiting
taken in the Northeast Atlantic in the period 1973-1986 (Fig.1) were
used as a database for this paper. Altogether 1210 individuals of blue
whiting aged from 1 to 16 were examined by method of complete
parasitological dissection (Dogiel, 1933; Bykhovskaya-Pavlovskaya,
1985), and 14460 individuals of the same ages were examined by method
of incomplete dissection (Table 1).

An analysis of the blue whiting parasite fauna's geographical
variations was carried out using the mathematical set theory in
accordance with the procedure suggested by Andreev and Reshetnikov
(1978).

Individual specificity of the blue whiting parasitic fauna in each
sub-region was judged upon by a degree of parasites inclusion (i.e.per
cent or portion of common species within the two sub-regions compared
from the number of species found in one of those). This degree of
inclusion (or parasite-mix) was calculated by the formula:

$$W(R_i R_j) = \frac{m(R_i \Omega R_j)}{m(R_j)} \cdot 100\%$$

where
$m(R_i \Omega R_j)$ - the number of common species of the blue
           whiting parasites in two areas compared, R_i
           and R_j,
$m(R_j)$ - the number of species of the blue whiting para-
           sites in the area R_j relative to which a degree of
           inclusion for the R_i area was calculated.
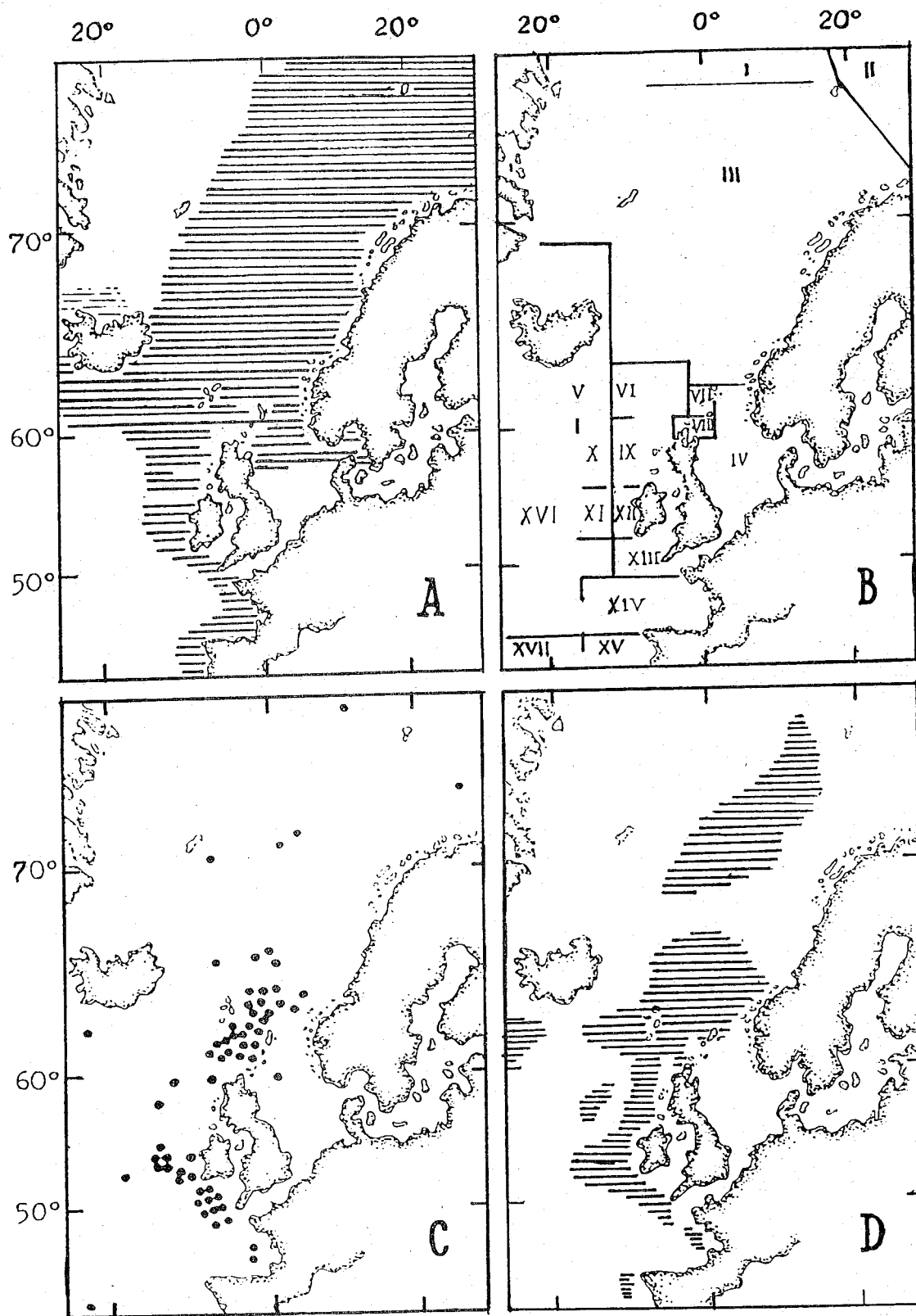
Fig. 1. Blue whiting distribution area (Zilnov, 1984) (A); Northeast
        Atlantic subregions used in the paper (B); Locations of comp-
        lete (C) and incomplete (D) parasitological dissections.
        Names of subreions are given in Table 1.

Table 1. Number of parasitological dissections made in various sub-
          regions of the Northeast Atlantic (1973-1968).

SUB-REGION	Complete dissection		Incomplete dissection	
	Fish length cm	Fish Nos. ind.	Fish length cm	Fish Nos indiv.
Spitsbergen (I)	27.1-35.4	25	-	-
Barents Sea (II)	32.0-37.0	10	-	-
Norwegian Sea (III)	23.3-45.0	504	17.0-45.0	1910
North Sea (IV)	13.5-36.0	4	-	-
Iceland (V)	25.0-35.2	43	19.0-28.0	40
Faroes (VI)	15.8-39.4	203	17.0-42.0	3685
Shetland (VII)	18.0-36.5	36	16.0-41.0	1410
Orkney (VIII)	-	-	17.0-36.0	125
Hebrides (IX)	31.0-41.0	25	17.0-41.0	1772
Rockall Bank (X)	19.0-34.5	29	-	72
Porcupine Bank (XI)	24.0-38.5	85	17.0-47.0	1990
Irish shelf (XII)	22.5-36.0	65	17.0-42.0	1136
Celtic Sea (XIII)	18.1-27.7	72	17.0-38.0	1152
Biscay Bay (XIV)	13.0-22.0	65	13.0-28.0	250
Pyrenean Pen. (XV)	-	-	21.0-33.0	18
West Europ. Dp (XVI)	28.0-39.0	25	21.0-41.0	900
Azores (XVII)	22.5-43.0	19	-	-
Northeast Atlantic	13.0-45.0	1210	16.0-47.0	14460

For both in-pair and group similarities of parasitic fauna in study
areas a degree of similarity was determined by the coefficient of
Sørensen-Chekanovsky:

$$L_0(R_i R_j) = \frac{2m(R_i \Omega R_j)}{m(R_i) + m(R_j)} \cdot 100\%$$

where:

$m(R_i \Omega R_j)$ - number of common species of the blue whiting
               parasites in two areas compared, R_i and R_j.

$m(R_i)$ - number of species of the blue whiting parasites
               in area R_i.

$m(R_j)$ - ditto in area R_j.

A dendrogram of blue whiting parasite fauna in areas of the Northeast
Atlantic was plotted on the basis of the Sørensen-Chekanovsky
coefficient using the "weighted pair-group method" (Bailey, 1970).

Dividing the Northeast Atlantic into sub-regions we used the ICES
Areas system as the background, but considered it expedient to
subdivide those areas into smaller parts (sub-regions). This was
conditioned by a wish to bring these conventional sub-regions closer
to specific features of the bottom topography, oceanography and
distribution of blue whiting within a particular subregion during
different periods of their life cycle (Fig. 1).

RESULTS

As a result of our study, 36 species of parasites (including
those described in literature) were registered in blue whiting. The
geography of parasite findings is presented in Table 2.

At first sight the parasite fauna of blue whiting shows no variety. In each separate subregion it consists of a" nucleus" formed by 6-8 species (Goussia clupearum, Pleistophora sp., Diclidophora minor, Diphyllobothrium sp.1., Monorygma sp.1., Bucephaloides gracilescens mtc., Anisakis sp., Hysterothylacium aduncum) with some episodic findings of other parasites. In general, the number of parasites characteristic for blue whiting in a particular sub-region varies from 7 (Azores sub-region) to 17 (North Sea and Faroes sub-regions). After a proper treatment of the list of parasites we obtained material illustrating the parasite-mix by sub-regions, their affinity, and then a dendrogram of the sub-regions similarity in the blue whiting parasite fauna composition was drawn.

The individual specificity of blue whiting distribution areas (compared to each other) was judged upon by the fish parasite fauna composition backgrounded on the parasite-mix analysis. The most specific is the parasite fauna of blue whiting from the North Sea, Rockall Bank and Biscay Bay. For instance, such species as Neoparvicapsula ovale, Cucullanus cirratus, Lernaeocera branchialia were registered only in the North Sea; Hemiurus communis - only in the Biscay Bay and Rockall area; Spinitectus sp. - only in the Biscay Bay; Caligus elongatus - in the Biscay Bay and North Sea. At the same time in the areas mentioned there are parasites which are registered also in the adjacent waters, but they are not as widely distributed over the whole area investigated. All those findings makes it difficult to reveal a relation between the areas mentioned and other ones at the threshold of the parasites fauna inclusion τ =100%, which nevertheless, does not mean that they are completely isolated (Fig.2). When this threshold is lower (τ=70-80%) the relations become more pronounced and the whole picture more complicated. Interpretation of the relations at various values of τ points to specificity of the blue whiting parasite fauna composition especially in the North Sea, Rockall area and Biscay Bay. In other sub-regions the parasite fauna does not reveal individual specificity. Of those, the most "commonplace" is the blue whiting parasite fauna from Spitzbergen, West-European Deep and Azores sub-regions. Analysing a trend of relations within this large united group of areas it is easy to notice that the most original here is the parasite fauna in the Faroes and the Porcupine Bank sub-regions, i.e. in the area of feeding and spawning.

Along the boundaries of the blue whiting habitat the parasite fauna is noticeably poorer and represented by those species which form its nucleus throughout the whole Northeast Atlantic.

By the degree of similarity of their parasite fauna the Shetland and Porcupine sub-regions are the closest (L=88%). Less similar are the Biscay and Azores sub-regions (L=45%), the least similarity with other sub-regions reveals the parasite fauna of the Biscay Bay blue whiting. By the degree of similarity of the blue whiting parasite fauna, all the sub-regions may be grouped into 3 groups (Fig.3):
    1. Spitzbergen, Barents Sea, Iceland;
    2. Norwegian Sea, the Faroes, the Hebrides;
    3. Porcupine Bank, Irish shelf, Celtic Sea, Biscay Bay and the Shetland Isles sub-region (possibly the parasite fauna from the last sub-region is characterized by high similarity with the preceding ones only in the composition of parasites because the ways of its formation in abandoned geographical areas may be different).

Table 2. (cont.)

	AREAS										
	I	II	III	IV	V	VI	VII	IX	X	XI	XII
NEMATODA											
24.Anisakis simplex (Rud.,1802),1.	+	+	+	+	+	+	+	+	+	+	+
25.Hysterothylacium aduncum(Rud.,1802)ad.et l	+	+	+	+	+	+	+	+	+	+	+
26.Contracaecum sp. 1.	-	-	-	-	-	-	-	+	+	-	-
27.Pseudoterranova decipiens (Krabbe, 1878),1	-	-	-	-	+	-	-	-	-	+	+
28.Cucullanus cirratus (Müller,1777)	-	-	-	+	-	-	-	-	-	-	-
29.Ascarophis morhuae v.Beneden, 1870	-	-	+	-	-	+	-	+	-	-	-
30.Spinitectus sp.	-	-	-	-	-	-	-	-	-	-	-
ACANTHOCEPHALA											
31.Echinorhynchus gadi (Zoega in Muller,1776)	-	+	-	+	-	+	-	-	-	+	+
CRUSTACEA											
32.Caligus elongatus v.Nordmann,1832	-	-	-	+	-	-	-	-	-	-	-
33.Lernaocera branchialis (L.,1767)	-	-	-	+	-	-	-	-	-	-	-
TOTAL	8	12	16	17	9	17	11	16	13	14	14

NOTES:
1. Blue whiting parasite species is present:"+" or absent:"-".
2. Names of sub-regions - see Table 1.
3. Blue whiting parasite species, occurrence of which is doubtful i
   Diclidophora luscae (v.Beneden et Hessé, 1964) registered i n the North
   1868 and Brinkmann, 1942; Pyramicocephalus phocarum (Fabricius, 1780) r
   Norwegian Sea by Kusz, Treder, 1980, and also Pomphorhynchus teretico
   reg. in blue whiting by Golvan, 1969 without mentioning the area, are

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Table 2. Blue whiting parasitic fauna composition in various areas of the Northe

Parasite species	I	II	III	IV	V	VI	VII	IX	X	XI	XII
FUNGI											
1.Ichthyophonus hoferi(Plehn et Mulsow,1911)	-	-	-	-	-	-	-	+	+	-	-
COCCIDIOMORPHA											
2.Goussia clupearum (Thélohan,1889)	+	+	+	-	+	+	+	+	+	+	+
MICROSPORIDEA											
3.Pleistophora sp.	-	-	+	-	-	+	+	+	+	+	+
MYXOSPOREA											
4.Zschokkella hildae Auerbach, 1910	-	-	-	-	-	+	-	+	+	-	+
5.Neoparvicapsula ovale Gaevskaya,											
Kovaleva & Schulman, 1982	-	-	-	+	-	-	-	-	-	-	-
6.Myxobolus aeglefini Auerbach, 1906	-	-	-	-	-	-	-	-	-	+	+
MONOGENEA											
7.Diclidophora minor (Olsson,1868)	+	+	+	+	+	+	+	+	+	+	+
CESTODA											
8.Diphyllobothrium sp.1.	+	+	+	+	+	+	+	+	+	+	+
9.Monorygma sp.1.	+	+	+	+	+	+	+	+	+	+	+
10.Tylocephalum sp.1.	-	-	+	-	-	-	-	-	-	-	-
11.Scolex pleuronectis (Müller,1788)	+	+	+	+	+	+	+	-	+	-	-
12.Hepatoxylon trichiuri (Holten,1892),1.	-	-	-	-	-	+	-	-	-	-	-
13.Grillotia erinaceus (v.Beneden,1858),1.	-	-	+	+	-	+	+	+	-	+	+
14.Lacistorhynchus tenuis (v.Beneden,1858),1.	-	-	-	-	-	-	-	-	-	-	-
TREMATODA											
15.Bucephaloides gracilescens (Rud.,1802)mtc	-	+	+	+	-	+	+	+	+	+	+
16.Staphanostomun pristis Looss, 1901	-	-	+	-	-	+	-	+	-	-	-
17.Podocotyle atomon (Rud.,1802)	-	-	-	+	-	-	+	-	-	+	-
18.P. reflexa (Creplin, 1825)	-	+	-	-	-	-	-	-	-	-	-
19.Hemiurus communis Odhner, 1905	-	-	-	-	-	-	-	-	+	-	-
20.H. levinseni Odhner, 1905	+	+	+	+	-	+	-	+	-	-	-
21.Lecithaster gibbosus (Rud.,1802)	-	-	-	+	+	-	-	-	-	-	+
22.Derogenes varicus (Müller,1784)	-	+	+	+	-	+	-	+	-	+	-
23.Progonus muelleri (Levensin,1881)	-	-	+	-	-	-	-	-	-	-	-

DISCUSSION

The data obtained prove that in all areas of the Northeast Atlantic the blue whiting parasite fauna is represented by a common nucleus consisting of 6-8 species. Two of them (Pleistophora sp. and Diclidophora minor) are purely blue whiting parasites, one (Bucephaloides gracilescens mtc.) is common for all Gadidae, and the rest are found in various marine fishes. The occurrence of those parasites in all areas characterizes the parasite fauna of blue whiting as an integrated community. Nevertheless, occurrence of other parasite species, some of which are infrequent or purely single, allows us to divide the host's habitat into two main areas:
    1. The Celtic Sea and Biscay Bay, and
    2. Spitzbergen, Barents Sea, Norwegian Sea, Faroes, Shetland and Hebrides, Porcupine, Irish shelf, West European Deep, Azores and Iceland.

The blue whiting parasite fauna in the Celtic Sea and Biscay Bay incorporates species which form the nucleus of the general parasite fauna of blue whiting; it is characterized by occurrence of such species as Myxobolus aeglefini, Lecistorhynchus tenuis l., Spinitestus sp., Caligus elongatus. This list is supplemented with some other species which are not widely distributed in blue whiting over the whole habitat. The total amount of parasites species here is 17. Some of those are extremely rare but, most probably, not accidental. For instance, it is not by accident that we here found L. tenuis, the final hosts of which are more related to warm and temperate waters. The fish from this area are ecologically related to the bottom and the fact that they are infested with M. aeglefini testifies to this. That is why the most probable here is the occurrence of parasites specific for bottom-pelagic fishes. Hence, it is also not by accident that H. communis were found in the Biscay area blue whiting. On the other hand, blue whiting from those areas are devoid of Pleistophora sp. which infest the fish in more northerly areas. No sign of Hemiurus levinseni was found in blue whiting from the Celtic Sea and Biscay Bay because that species prefer more temperate and Arctic waters.

Not only the qualitative composition of parasites testifies to individual particularities of blue whiting distributed in the Celtic Sea and Biscay Bay. The fish from these areas are practically free from Diphyllobothrium sp.l. (the only one found was in the Celtic Sea). Blue whiting of more northerly areas are infested with plerocercoids of this parasite by 13-88%. This testifies to an absence (or minor significance for blue whiting feeding) of copepods - the intermediate hosts for Diphyllobothriids. A lower level of infestation with larval Anisakis simplex is observed in the Celtic Sea and Biscay Bay, but on the other hand, the level of their infestation with Bucephaloides gracilencens metacercariae is higher. All this emphasizes the ecological abandonment of blue whiting distributed there, and their bent on the bottom.

The data on specificity of the blue whiting parasite fauna in the Celtic Sea and Biscay Bay are in good correspondance with a conception that there exists a Biscay host population. The fish belonging to this community do not undertake long northerly migrations. This fact is confirmed by the absence of fish infested with parasites widespread in the northern part of the area, on one hand, and by the presence of parasites not found in the north, on the other. Most probably the blue whiting of the Biscay population are bent on temperate and warm waters specific for this area of the Northeast Atlantic.
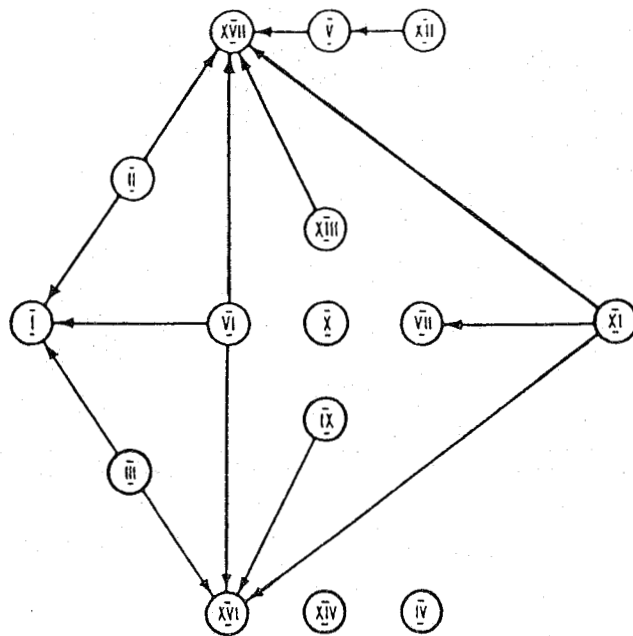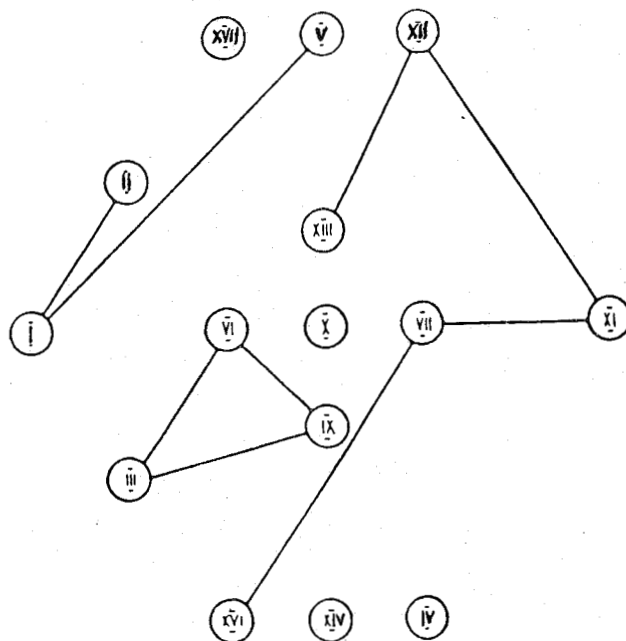
Fig. 2. Oriented graph drawn in accordance with the pattern of blue
whiting parasite fauna levels of inclusion (parasite-mix) for
15 sub regions of the Northeast Atlantic, and relations bet-
ween them at τ = 100. (See the paper for details).

Fig. 3. Non-oriented graph drawn in accordance with the pattern of
blue whiting parasite fauna levels of inclusion (parasite-
mix) for 15 subregions of the Northeast Atlantic, and rel-
ations between them at τ =80. (See the paper for details).

The parasite fauna of blue whiting in the neighbouring sub-regions of the Irish shelf is of an intermediate character. The occurrence of such species as <u>Pleistophora sp.</u>, <u>Zschokkelia hildae</u>, <u>Pseudoterranova decipiens l.</u>, <u>Echinorhynchus gadi</u> does not allow us (according to the method of analysis applied) to relate those fish to the Celtic Sea sub-region.But the fact that some parasites were found on the Irish shelf (first of all <u>Myxobolus aeglefini</u>) allows us to conclude that there is a close relation between these areas. The similarity of the blue whiting parasite fauna from the Irish shelf with the one from the Celtic Sea is rather high (L=80%), with the one in Biscay Bay lower (L=62%), but highest with the one on the Porcupine Bank (L=86%).

The second group of sub-regions (Fig. 4) includes the rest of the sub-regions except the North Sea. This group covers a vast area of the Northeast Atlantic. The total parasite species number registered in blue whiting distributed in this area is 26. Within the study sub-regions this number varies from 7 (Azores) to 17 (Faroes). A number of geographically separated sub-regions were combined on a regular basis.
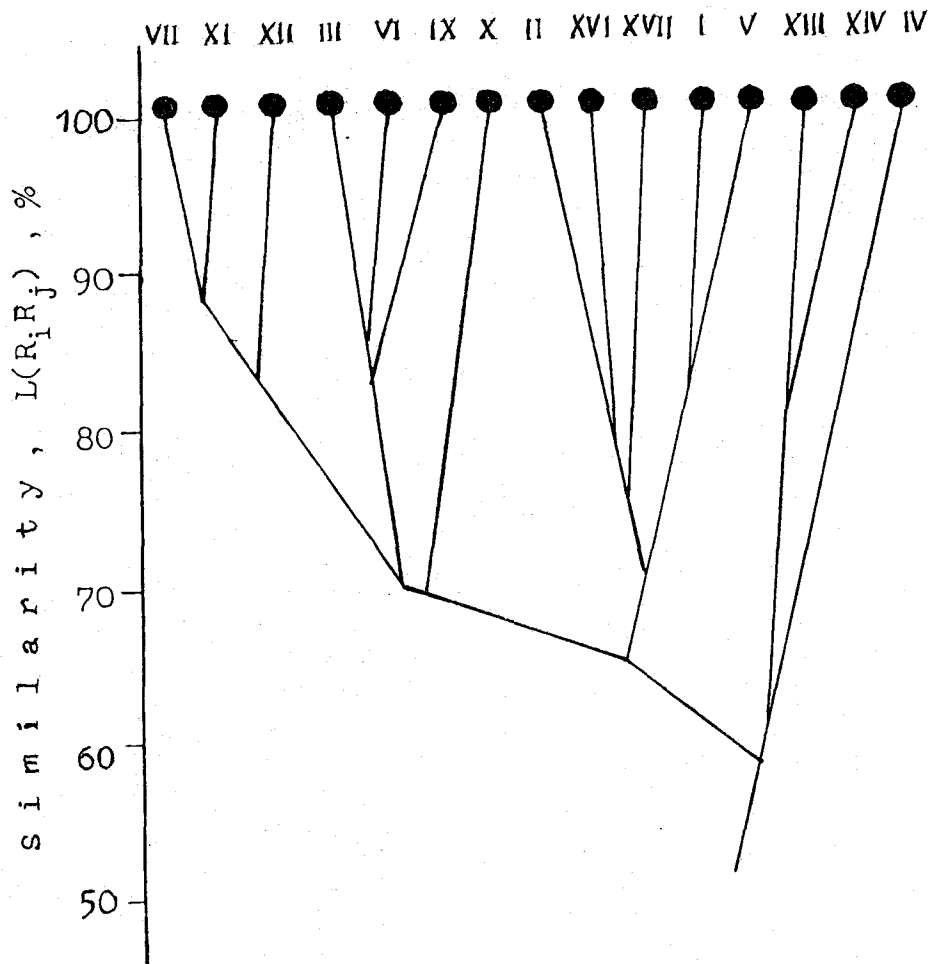
Fig. 4. Blue whiting parasite fauna similarity dendrogram for 15 subregions of the Northeast Atlantic.

It is known that the Hebrido-Norwegian population of blue whiting is distributed over this vast area; this population is known for its long spawning/feeding migrations. The spawning grounds are located on the Irish shelf (sub-region XII), Porcupine Bank (XIII), Hebrides sub-region (IX); the feeding grounds - in the Faroes sub-region (VI), the Shetland Isles (VII) and the Norwegian Sea (III). In the West European Deep sub-region (XVI) blue whiting form prespawning concentrations. Comparing the blue whiting parasite fauna in all the sub-regions mentioned , one may note that they are characterized by a high similarity (L=80% and more). It is quite regular that long migrations of blue whiting within the boundaries of those sub-regions determine the affinity of the species' parasite fauna and provide its high similarity.

But as the dendrogram on Fig. 4 shows, there are several sub-groups within this large group of sub-regions:

     1. Sub-regions VII, XI, XII;
     2. Sub-regions III, VI, IX, X;
     3. Sub-regions I, II, V, XVI, XVII.

As may be seen, the first and second sub-groups cover the central areas of the blue whiting habitat, and the third one includes the peripheric sub-regions. This undoubtedly testifies to a non-uniformity of the stock distributed over the areas mentioned.

The North Sea sub-region stands apart from the others. Here the maximum amount of parasite species per sub-region (17) was registered. Besides, the parasite fauna there was very specific. In the North Sea blue whiting we found parasites which we never found in blue whiting from other areas - Neoparvicapsula ovale, Cucullanus cirratus, Lernaeocera branchialis, or found only in some areas but not everywhere - Lecithaster gibbosus (Celtic Sea, Biscay Bay, Iceland), Caligus elongatus (Biscay Bay). But at the moment we may state only the fact of maximal isolation of the North Sea blue whiting parasite fauna, as we had samples taken from 4 fishes only (12 species of parasites). Five more species are included on the list from literature,besides, there are such species infrequent in blue whiting as Podocotyle atomon, Cucullanus cirratus, Caligus elongatus, Lernaeocera branchialis and some others.

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SOME ASPECTS OF MORTALITY, CONDITION FACTORS AND LIVER STATE WITH ANISAKIS-INFECTION IN BLUE WHITING IN THE NORTH-EAST ATLANTIC

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ABSTRACT

Total mortality coefficients of blue whiting in the spawning area as well as in the feeding area, were obtained for various years and for various yearclasses, by calculating the regressions of the natural logarithms of age frequency against age. Together with established fishing mortality coefficients, a mean value of 0.18 was calculated for the natural mortality coefficient; compared to 0.2 used by the Blue Whiting Assessment Working Group.

The index of the larval Anisakis parasite on the liver surface of blue whiting was found to increase with host's age. The burden of accumulation of this parasite did not seem to affect neither the condition factor nor the length growth in blue whiting. While the condition factor increased with age in the spawning area, the contrary was observed in the feeding area.

INTRODUCTION

The majority of the adult blue whiting (<u>Micromesistius poutassou</u>) stock in the north-east Atlantic migrates every early spring from the feeding area in the Norwegian Sea to spawn along the continental shelf west of the British Isles. During late spring and early summer it returns again and disperses over vast areas on the warmer side of the Norwegian Sea, with congregations mostly in the temperature front areas.

Estimates of annual mortality rates for blue whiting, for fully recruited age groups, show a great variability. Bailey (1982) gives values from different areas, years and obtained by different methods. The instantaneous mortality coefficient, Z, was found to be higher than 0.9 in the period 1969-70 based on catch per unit of effort for the same yearclasses. However, based on plot of ln percentage frequency against age in the period 1967-70 an average of 0.75 was calculated , and for a later period 0.51, even which is a rather high value.

The Scottish data was recalculated using samples from pelagic trawl catches only, and a mean value of Z=0.34 for the period 1973-78 was then calculated (Bailey 1978). In 1980 the ICES Blue Whiting Working Group calculated an average value of Z= 0.27 for Norwegian samples from pelagic trawl catches for the period 1973-79 (Anon. 1980).

The variety between different years may be due to some uncertanties in aging the otoliths, but also because of the possibility of samples representing different components of the population. In the present paper the mortality rates are studied for the period 1980 - 1988 both in the spawning area and in the feeding area. The mortalities within some of the yearclasses are also dealt with.

Blue whiting is infected by a number of different parasites (Høygaard 1980) The nematode larva of Anisakis sp. is found in the visceral cavity, the muscles and on the liver surface. In some specimen it is found in such a number that several authors have thought it might influence the condition of the host. However, no such evidence has been stated. The larva of Anisakis, like most other parasites is acquired from the previous intermediate host (euphasiids) in food, and the final host is normally a marine mammal (Bailey 1982). Some relationships of Anisakis-infection of the liver surface are dealt with by age and yearclasses in various areas, as well as the condition factors and liver size.

MATERIAL AND METHODS

Samples were obtained from the surveys carried out in the spawning area as well as in the feeding area and, in some cases collected from commercial catches. They were grouped after area of origin shown in Fig. 1.

While analysing the samples, regular observations like length, weight, sex, maturity stage were made in addition to collection of otoliths. In most cases additional observations of the liver size in relation to the body size were also made by subjective judgement at a scale from 1 to 4 , and the infection rate by Anisakis on the liver surface at a scale of 0 to 4 (Anon. 1989).
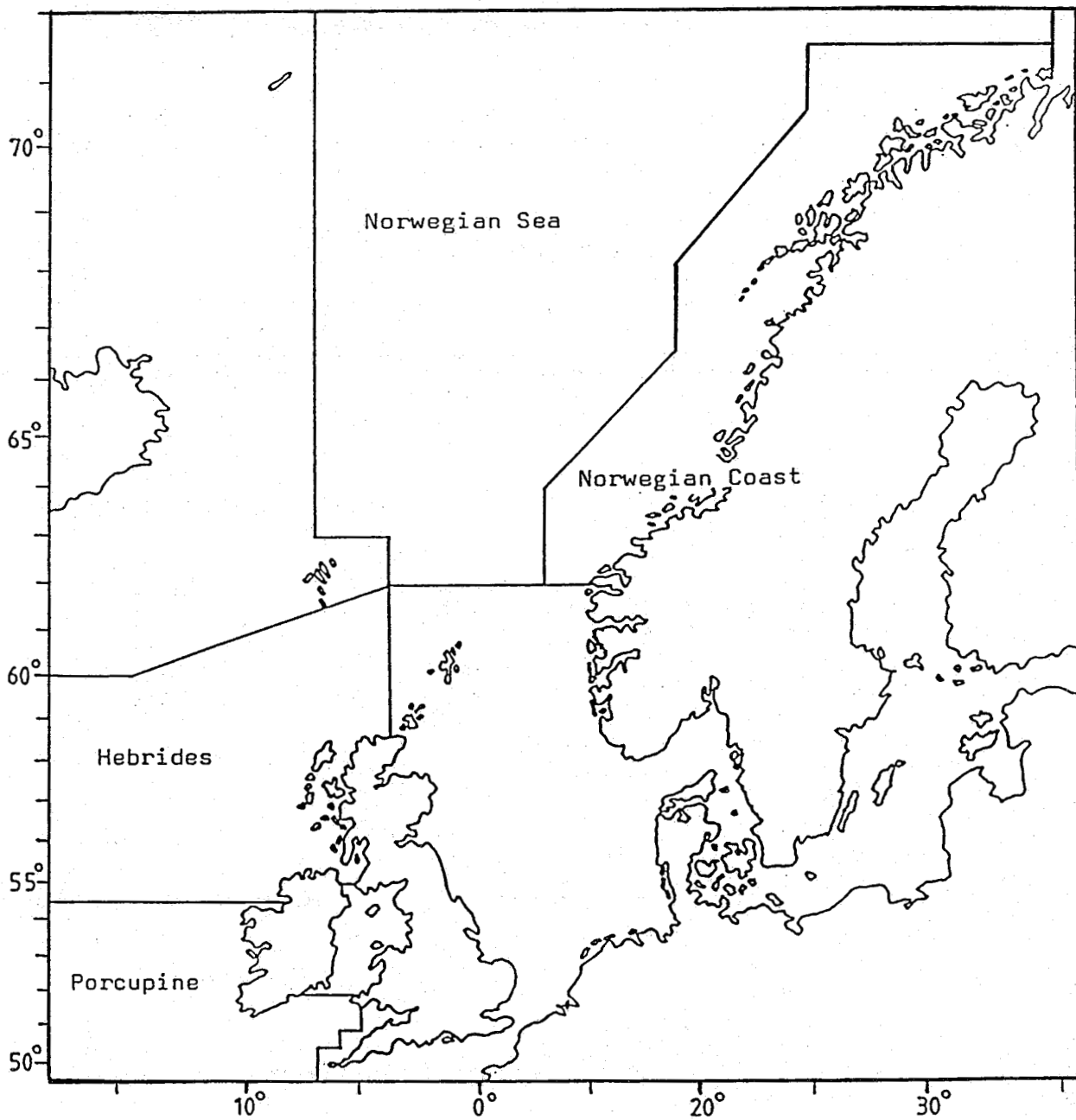
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Some aspects of mortality, condition factors and.......

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Fig. 1. Borders of areas mentioned in the text.

Some aspects of mortality, condition factors and.......

Table 1. Age composition (N %) of the blue whiting spawning
stock based on Norwegian survey estimates.

age	1980	1981	1982*	1983	1984	1985**	1986	1987	1988
1	0.6	0.4	5.4	0.1	1.4	0.1	0.6	6.3	0.6
2	10.0	6.4	5.7	1.1	53.0	4.6	5.3	9.4	12.0
3	11.1	20.3	7.4	7.9	7.3	36.2	39.5	18.5	15.1
4	12.2	8.7	16.1	10.2	7.8	4.8	40.3	51.5	21.0
5	16.8	9.8	11.4	24.3	8.3	7.6	6.4	10.8	34.7
6	15.5	12.3	12.4	14.0	9.0	16.1	2.1	0.7	12.6
7	14.3	12.5	11.5	13.7	5.5	12.8	1.4	1.0	1.2
8	9.2	9.8	11.4	11.8	2.7	7.4	2.0	0.9	1.1
9	4.5	7.0	7.9	8.5	2.1	3.2	0.8	0.4	0.6
10	1.9	4.8	4.5	4.4	1.7	2.4	1.0	0.1	0.7
11	2.1	3.6	2.3	2.0	0.4	2.1	0.4	0.3	0.2
12	1.1	2.4	1.6	1.3	0.6	1.5	0.1	0.1	0.2
13	0.3	1.0	0.5	0.3	0.1	0.6	+	+	-
14	0.2	0.6	1.4	0.3	0.1	0.3	+	-	+
15+	0.1	0.4	0.6	0.1	-	0.3	0.1	+	-
Nx10^9	33	37	-	27	21	-	18	43	58

*   Weighted by echo indices only.
** Norw. comm. samples weighted by echo indices from Faroes survey.

Table 2. Age composition (N%) of the blue whiting stock in the Norw.
Sea observed during the international surveys in summer.

Age	1980*	1981*	1982	1983	1984	1985	1986	1987**	1988*
0	-	-	16.0	23.0	3.8	4.8	18.0	11.4	36.5
1	2.5	0.7	0.8	62.1	62.0	12.7	8.3	29.3	20.8
2	18.2	2.8	2.0	1.1	28.4	50.8	8.5	14.4	12.0
3	8.1	17.4	5.4	1.3	1.7	26.6	25.8	18.5	11.0
4	8.4	14.9	20.5	2.1	0.8	1.4	24.8	19.9	14.5
5	12.6	10.3	15.7	3.9	1.1	0.9	6.7	4.3	3.8
6	14.7	10.9	13.6	1.6	1.1	0.4	3.4	0.8	0.5
7	12.4	11.4	10.1	1.3	0.7	0.5	1.2	0.6	0.4
8	9.7	10.6	7.3	1.2	0.1	0.3	1.1	0.2	0.1
9	4.8	7.9	3.8	0.9	0.1	0.8	0.5	0.3	0.2
10	3.2	5.0	1.8	0.6	0.1	0.3	0.7	0.1	-
11	3.3	4.2	1.1	0.3	0.1	0.1	0.2	0.1	+
12	1.0	1.8	1.2	0.2	0.1	0.1	0.5	+	0.1
13	0.5	1.4	0.4	0.1	-	0.2	0.1	-	+
14	0.5	0.4	0.2	+	-	0.1	+	-	-
15+	0.1	0.3	0.1	+	-	-	0.1	-	-
Nx10^9	56	26	23	36	49	47	28	28	24

*   Norwegian surveys only
** Combined result of Norwegian and GDR surveys

The liver status for the scale used is described as follows:

Stage 1) Thin and neglectable, 2-4 mm thick.
  "   2) Easy to spot by eye, but thin; fills 1/4 of the cavity.
  "   3) Voluminous with lobes; fills ca. 1/2 of the cavity.
  "   4) Swollen, fills 3/4 or more of the cavity.

The infestation scale of Anisakis on the liver surface is likewise
described:

Stage 0) No visible parasites
  "   1) From 1 to a few parasites.
  "   2) Ca. 1/2 of the liver is covered.
  "   3) Ca. 3/4 of the liver is covered.
  "   4) The liver surface is completely covered.

The condition factors used is calculated after the definition:

$$C = 1000 \times weight(g)/length(cm)^3$$

The method used for estimation of the instantaneous mortality
coefficient, Z, is described by Ricker (1975), and is all based on age
compositions from which a plot of ln frequency or percentage frequency
against age was made. The various age compositions used are based on
the same material as used and described by Monstad (1989).

RESULTS AND DISCUSSION

Mortality

Age compositions of the spawning stock, based on Norwegian survey
results, for the years 1980 - 1988 are given in Table 1, and of the
stock in the Norwegian Sea during summer, based on international
surveys, in Table 2. The graphic illustrations of the same data are
given in Monstad (1989).

The natural logarithms of the age frequency were calculated for each
year, and their mean values for the period plotted against age are
shown in Fig.2 A-B. On an average there is of course the difference of
fully recruited yearclasses in the spawning stock and in the stock in
the Norwegian Sea.

The spawning stock had a high recruitment level of the yearclasses
already from the age of 3-4 years mainly because of the influence of
the rich 1982- and 1983-yearclasses. However, while plotting each year
separately (Fig.3) the variance is more clearly illustrated, with the
difference from 1983 to 1984 especially notable. Based on these
plottings the total mortality coefficient of the various years was
obtained from the regressions calculated from 7 to 14 years old for
1980-1985, and from 4 to 14 years for 1986-1988.

The plotting of the mean ln (%N) for the stock in the Norwegian Sea
indicates high recruitment to the yearclasses already from the age of
zero. This is also due to the influence of the 1982- and 1983-
yearclasses. Likewise, plottings for each year show the individual
differences in this area as well (Fig.4). In order to obtain the total
mortality coefficient for the Norwegian Sea, the regressions based on
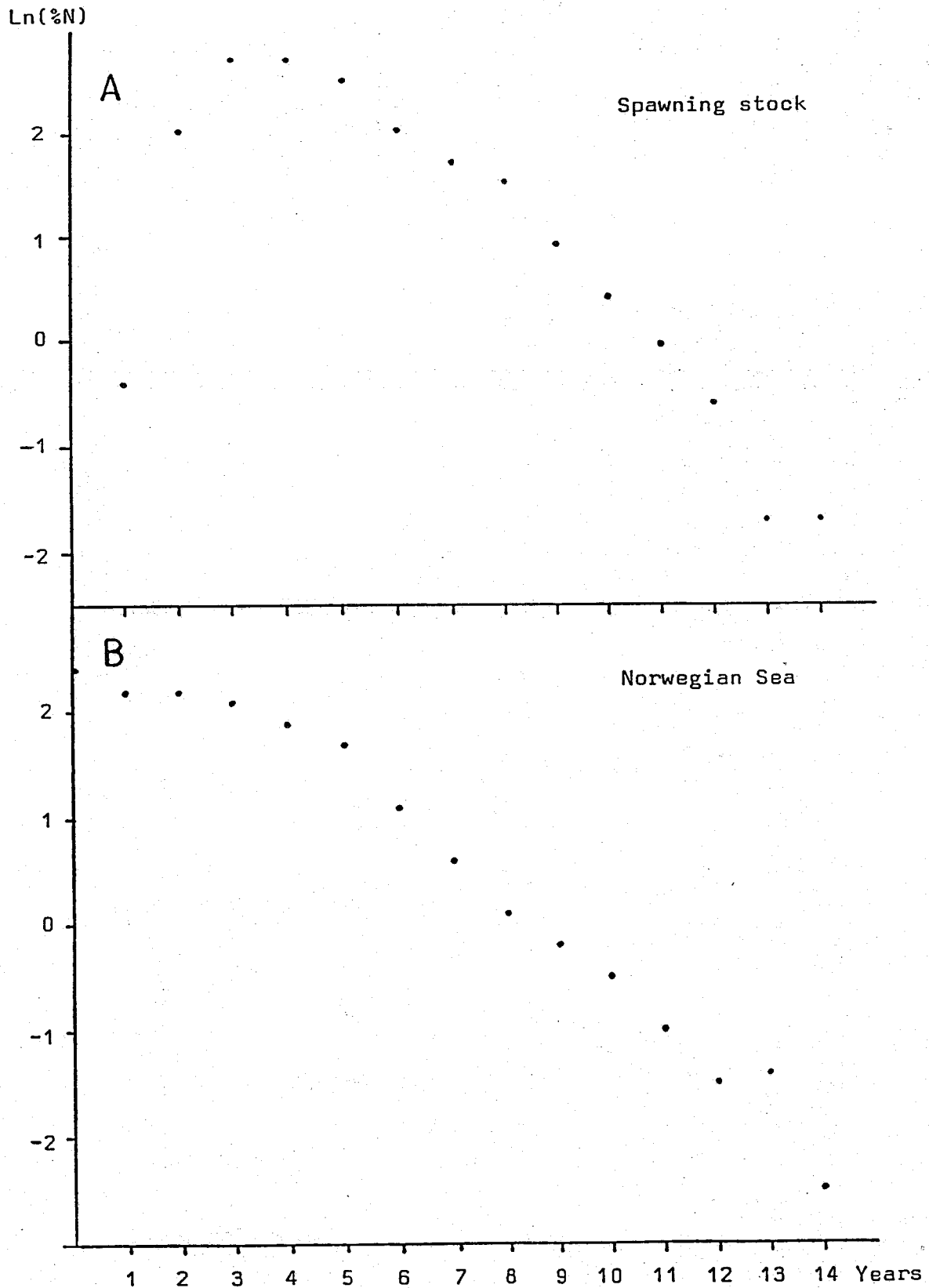these plottings were calculated from the age of 2 to 14 years.

Fig. 2. Mean of natural logarithms of percentage contribution of
         various age groups against age of blue whiting, 1980-1988.
         A) In the spawning stock during spring, B) in the stock
         observed in the Norwegian sea during summer.

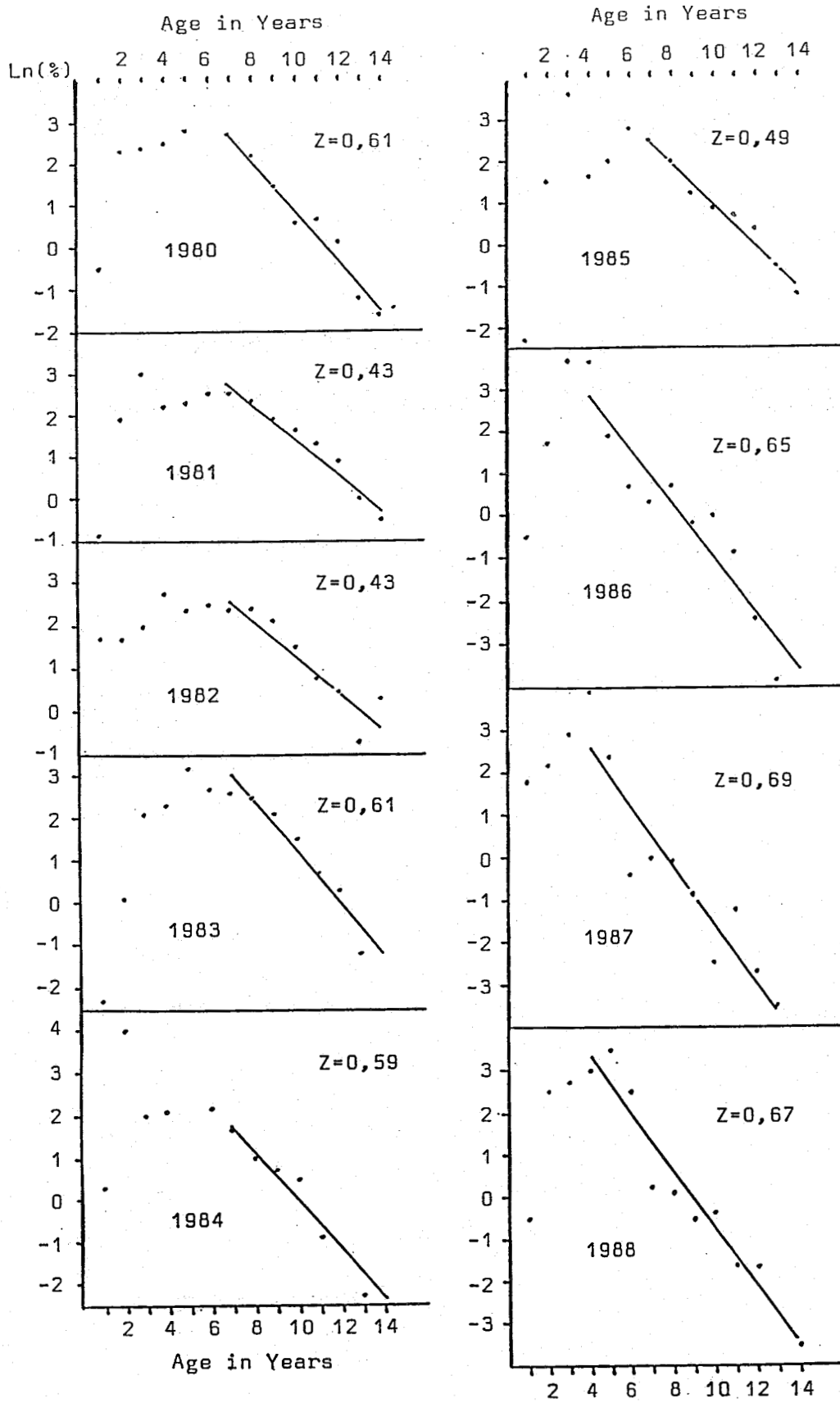Some aspects of mortality, condition factors and.......

Fig. 3. Natural logarithms of percentage age composition against age
in the blue whiting spawning stock during spring 1980-1988,
with regression lines fitted to data for ages 7-14 years
(1980-85) and ages 4-14 years (1986-88).

From the table of fishing mortality coefficient F, given in the
Working Group Report of 1988 (ANON. 1989), the F's of corresponding
years and age groups for the various Z's, were calculated. The various
values of F and Z for the spawning stock and for the stock observed
while in the Norwegian Sea are shown in the text table below:

Year	Spawning stock			Norwegian sea		
	Z	F	age-groups	Z	F	age-groups
1980	0.61	0.47	7-14	0.28	0.35	2-14
1981	0.43	0.56	"	0.21	0.40	"
1982	0.43	0.43	"	0.28	0.30	"
1983	0.61	0.33	"	0.31	0.26	"
1984	0.59	0.29	"	0.50	0.24	"
1985	0.49	0.32	"	0.43	0.26	"
1986	0.65	0.47	4-14	0.50	0.41	"
1987	0.69	0.37	"	0.70	0.33	"
1988	0.67	0.30	"	0.63	0.26	"
Mean	0.57	0.39		0.43	0.31	
M = 0.18				M = 0.12		

For the spawning stock the Z-values vary from 0.43 to 0.69 in seperate
years. As mentioned above such differences could be a result of bias
in the sampling or in the ageing of the otoliths. The F-values also
have large differences in individual years, and in some cases thye are
even higher than the corresponding Z-values, thus indicating the
uncertanties. The mean values of F and Z may give a useful result for
the natural mortality : M = 0.57 - 0.39 = 0.18.

In the Norwegian Sea the F- and Z-values also show great differences
from year to year. Here too the F-values are higher in some cases than
corresponding Z-values. The mean values could be used to calculate a
natural mortality of: M = 0.43 - 0.31 = 0.12.

This "catch-curve" method of calculating Z's, actually gives values
that reflect the mean mortality in previous years, and not the
mortality in any individual yea. To rely on this method, the
population needs to be in an equilibrious state, or close to such a
state. Variations in recruitment may reduce the reliability for
individual years, as f.ex. the contributions of the numerous 1982- and
1983-yearclasses. Likewise changes in the fishery may distort the
equilibrious state and hence reduce the usefulness of the method.
However, a mean of Z-values over a number of years may be a basis for
consideration of M.

The Z mean value of 0.57 for the spawning stock in the years 1980-1988
is more than the double of the Z-value, 0.27, calculated by the
Working Group using the same method, for the years 1973-1979 (ANON.
1980a). The Scottish result of mean Z-value was 0.34 for the years
1973 -1978 (Bailey 1978).

The fishing rate increased largely from 1975 onwards, and may to some
extent have affected the age composition and the state of equilibrium.
However, the fishing mortality was anyhow considered to be rather low

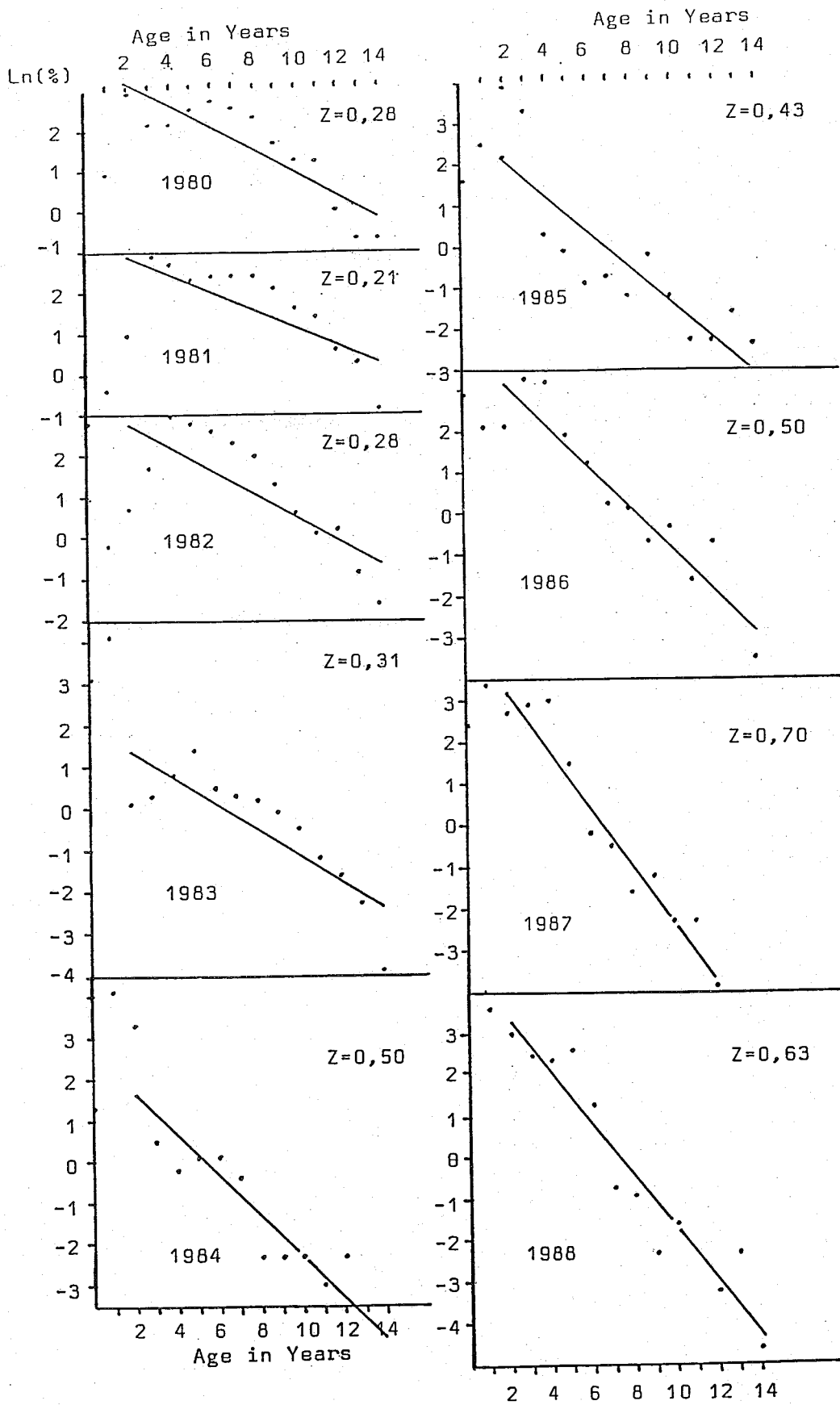Some aspects of mortality, condition factors and.......

Fig. 4. Natural logarithms of percentage age composition against age
in the blue whiting stock observed in the Norwegian Sea
during summer 1980-1988, with regression lines fitted to
data for ages 2-14 years.

Some aspects of mortality, condition factors and.......

Table 3. Abundance ($N \times 10^{-6}$) at various ages of the 1978 - 1985-yearclasses as observed in the Norwegian Sea during summer.

	Yearclasses							
Age	1978	1979	1980	1981	1982	1983	1984	1985
0	-	-	-	-	3 731	8 403	1 857	2 246
1	-	1 378	184	188	22 629	30 547	6 003	2 320
2	10 181	740	455	416	14 007	23 950	2 389	4 052
3	4 578	1 254	456	826	12 525	7 201	5 185	2 838
4	4 778	779	393	682	6 924	5 582	2 587	-
5	1 425	534	418	1 863	1 217	3 423	-	-
6	544	203	962	235	903	-	-	-
7	245	348	168	120	-	-	-	-
8	317	066	091	-	-	-	-	-
9	079	017	-	-	-	-	-	-
10	055	-	-	-	-	-	-	-

compared to the natural mortality, at least up to 1978, and the estimation of mean Z was taken as a first approximation of natural mortality. It could of course be an overestimate, but M was agreed upon to be in the range of 0.2 - 0.3 (Anon. 1980a).

In 1979 the exploitation rate increased very much, and up to 1982 the total catch was at a very high level, more than 1 mill. tonnes in 1979 as well as 1980 or approximately twice that catch of 1978 (Anon. 1988, Monstad 1989). This must have distorted the equilibrium of the stock notable, and may be reflected in the difference of the calculated F's of the two periods.

The Working Group has later used M = 0.2 while running the VPA of the stock, and the assuming of this value was done after several trials with different values within the range. (Anon. 1983).

Calculations of the F-values used also include this M-value, and therefore the results are only suggestions in the consideration of an appropriate M. The value of 0.18, however, seems to justify the previous assumption of 0.2.

The "catch-curve" method was also used to study the total mortality of separate yearclasses from data collected in the Norwegian Sea during the summer surveys in 1980-1988. In Table 3 the abundance estimates of the yearclasses 1978-1985 are shown split on age groups. The coverage of the blue whiting stock during the feeding period is to a large extent incomplete, and the estimates which are clearly underestimates, consequently are taken as indices only (Anon. 1985).

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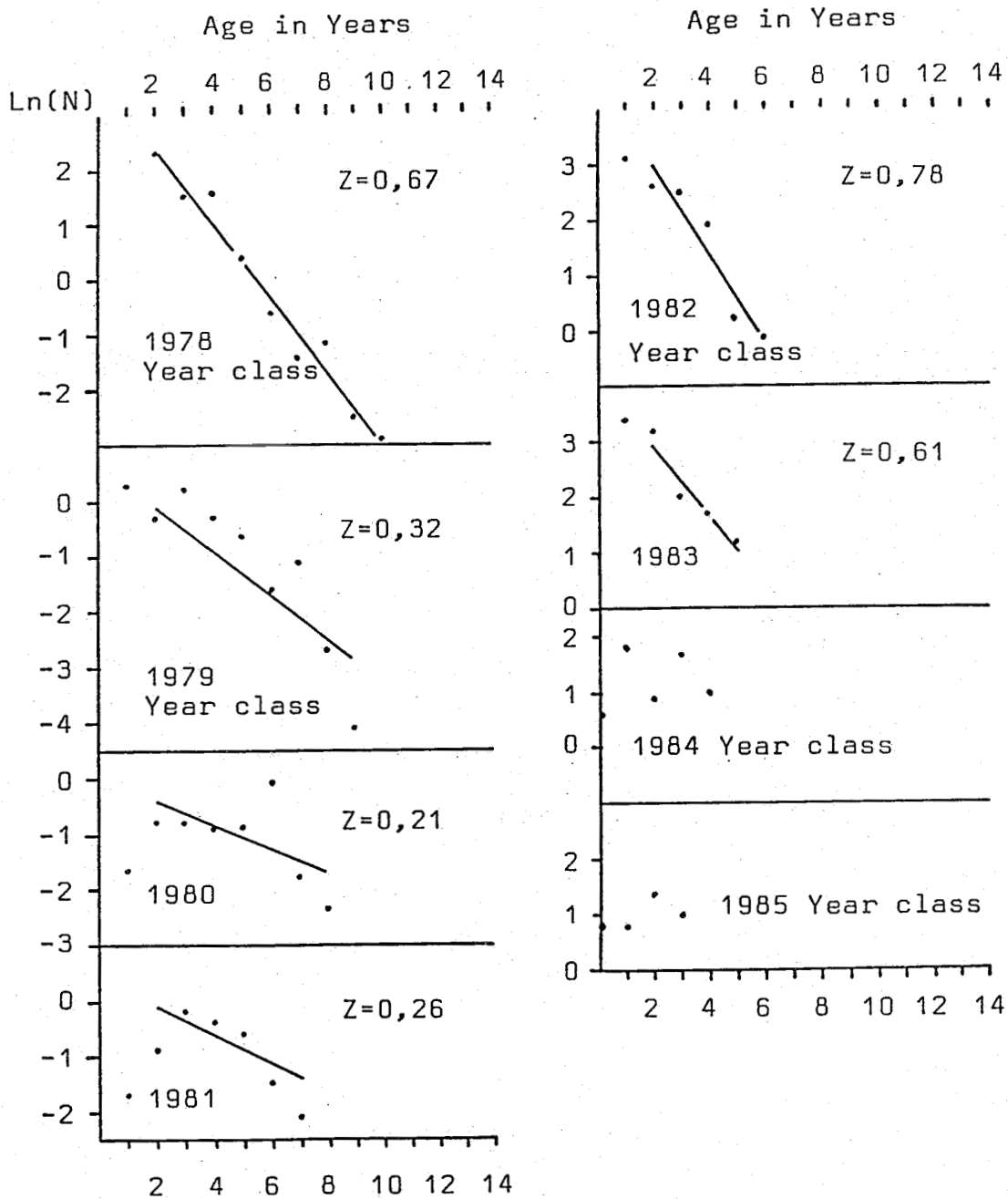Some aspects of mortality, condition factors and.......

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Fig. 5. Natural logarithms of age composition ($N \times 10^{-9}$) against age for the 1978-1985 year classes of blue whiting as observed in the Norwegian Sea during summer. Regression lines fitted to data for 2 years and older age groups for the year classes of 1978-1983.

Plot diagrams of ln frequency (N) against age for all of the year-classes are shown in Fig. 5. The regressions for the 1978 - 1983-yearclasses were calculated from the age of 2 years to the oldest, i.e. their respective age in 1988. The results are given below together with corresponding F's calculated from the Working Group report (Anon. 1989).

Yearclass	Z	F	age-groups
1978	0.67	0.22	2-10
1979	0.32	0.21	2-9
1980	0.21	0.18	2-8
1981	0.26	0.18	2-7
1982	0.78	0.12	2-6
1983	0.61	0.12	2-5
Mean	0.48	0.17	

Great differences are found between the various yerclasses. The highest total mortalities were calculated for the 1978-, 1982- and 1983-yearclasses, which are also the three most abundant yearclasses for the period (Monstad 1989). The average natural mortality for these yearclasses in the period 1980 - 1988 can be calculated to 0.31.
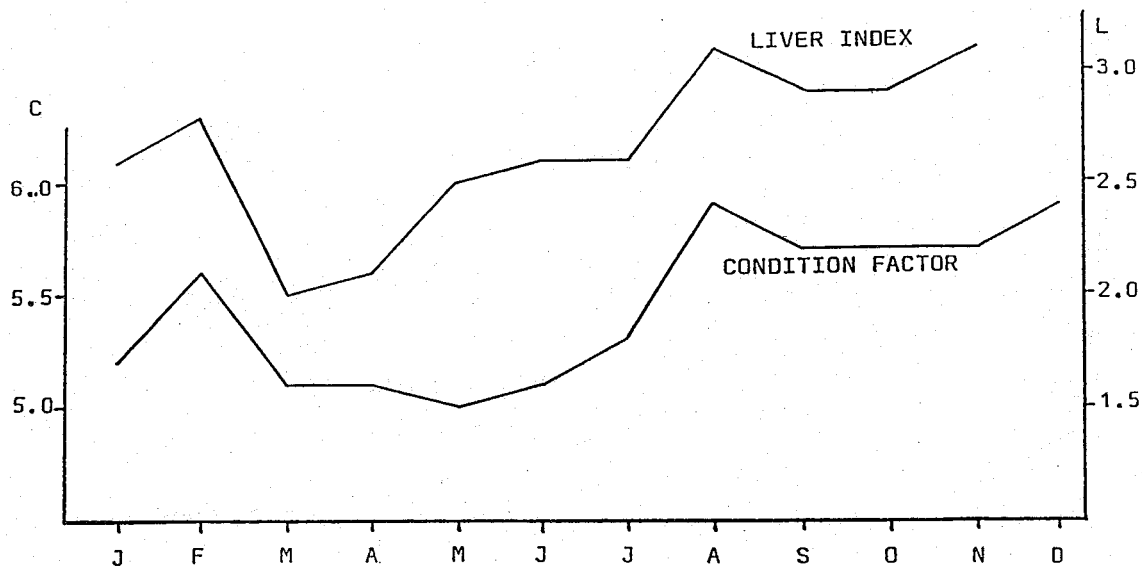
Fig. 6. Monthly mean values of the liver index L and the condition factor C of blue whiting over the period 1982-1988.

The fishing mortality increases with increasing age, especially from the age of 7 - 8 years, i.e. after full recruitment. For the yearclasses in question, the F's therefore came out as rather low, especially for the 1982-and 1983-yearclasses. Taking into account that these two yearclasses have been a main basis for the fishery in recent years, one should expect higher values. An explanation might be that they could be even stronger than recorded.

Again, the method used is not reliable enough for estimation of the mortality. Neither is the material sufficiently accurate, and the results can only give indications of trends in this matter.

Condition factor, liver state and parasite infection

The monthly mean values of the liver indices in the period 1982 - 1988 give a picture of the annual cycle (Fig.6). The data used should represent the main part of the north-east Atlantic stock, migrating within the area from southwest of Ireland to the Barents Sea, but in some cases the proper age groups were not available in the samples.

The liver mass varies a great deal both within a sample and within a month. The lowest values were observed in March-April when spawning takes place. The energy stored in the liver is then "transformed" to spawning product. Highest values is found in summer and autumn when the fish are feeding and building up new reserves.

The difference in the liver indices between male and female was not of a significant character (Fig.7). Dumke (1986) found the liver-weight in percentage of body weight to be highest in September and the values were 9.5 and 8.8 for male and female respectively.
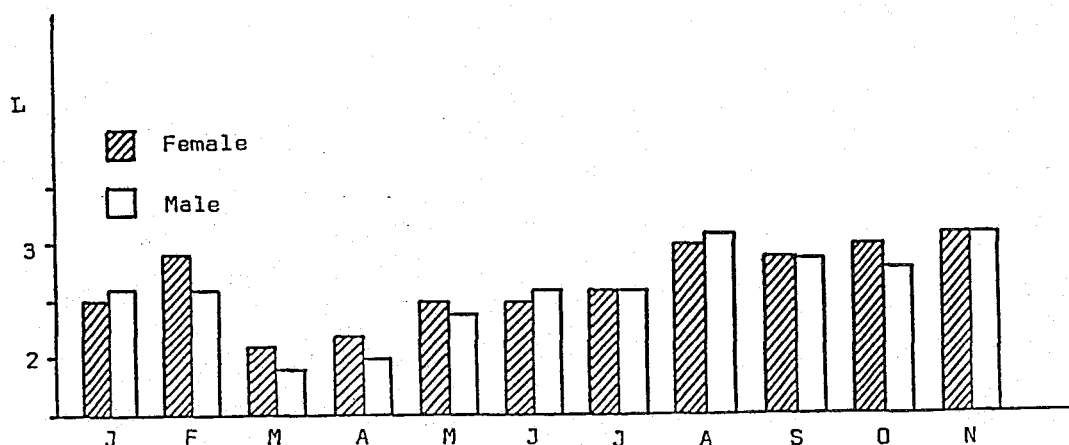
Fig. 7. Monthly mean values of the liver index L by sex of blue whiting over the period 1982-1988.

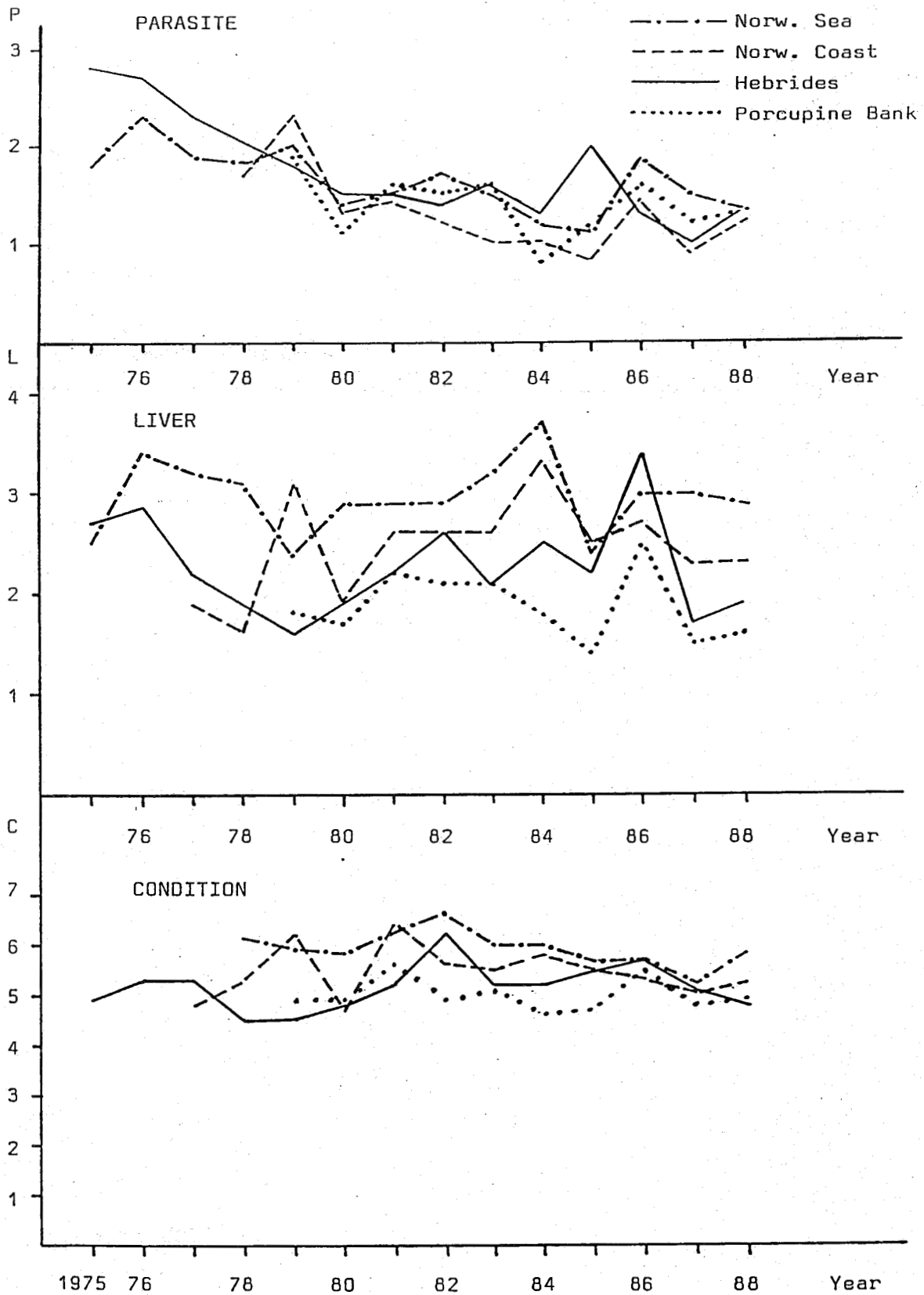Some aspects of mortality, condition factors and.......

Fig. 8. Annual mean values of the parasite index P (larval Anisakis
         on liver surface), the liver index L and condition factor C
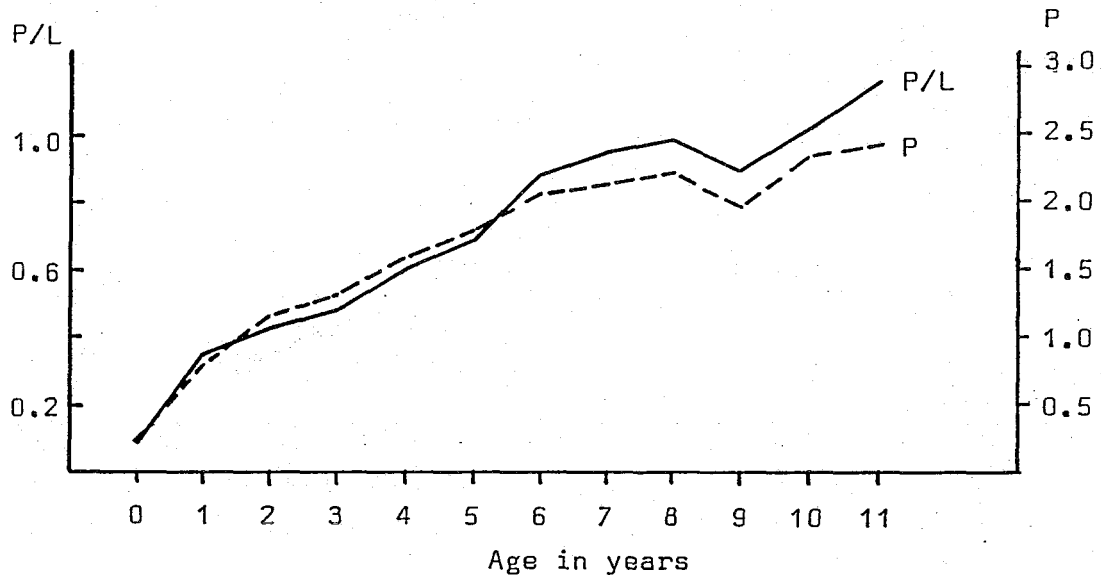   of blue whiting in various areas (Fig. 1) 1975-1988.

Fig. 9. Mean values of the parasite index P and the ratio between
the parasite and liver indices P/L by age of blue whiting.

The condition factor, expressing how well nourished the fish are, show
a cycle almost parallel to the liver indices (Fig.6). The minimum
value is observed in May and the maximum in August. Significant
changes takes place in the spawning period and decreases of up to 25 %
have been observed (Bailey 1982). The build-up of reserve takes place
gradually through the summer and autumn with most rapid increase
observed in July and August. The drop in both condition factor and
liver indices observed for September - November and again for January,
may be due to bias in the sampling.

In Fig.8 are shown the year to year variations of parasite indices
(Anisakis), liver indices and condition factors from 1975 to 1988 in
the areas of Porcupine, Hebrides, Norwegian Sea and Norwegian Coast
(Fig.1). For the Hebrides and Porcupine the annual mean values
represent February-May and for Norwegian Sea and Norwegian Coast June-
September.

For the parasite indices only minor variations between the areas were
observed, but there is a decreasing tendency up to the middle of the
1980's. Except for 1979 less parasites were found in the Norwegian
Coast area all of the years. This indicate a part of the population
which only to a certain extent mix with fish from the other three
areas. In these areas the indices varied in a regular way and
alternatively show the highest value from year to year.

The liver indices, however, show great variations between the various
areas as well as from one year to another. Lowest value of 1.4 was
observed in Porcupine in 1985 and highest value of 3.7 in Norwegian
Sea in 1984. The condition factors show significantly smaller
variations, and have a congruent tendency, also towards the middle of
the 1980's.

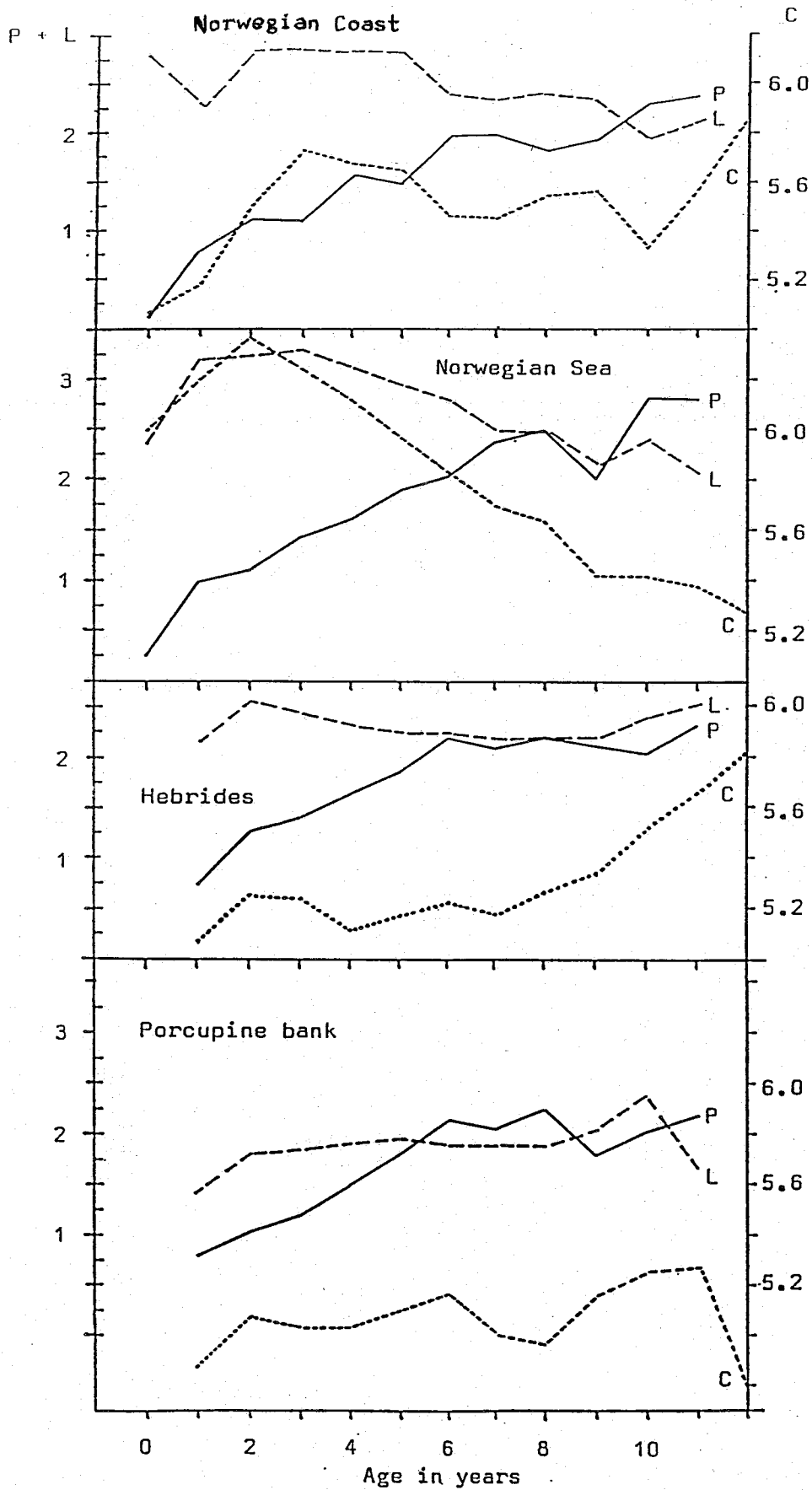Some aspects of mortality, condition factors and.......

Fig. 10. Parasite index P, liver index L and condition factor C by
         age of blue whiting in various areas 1970-1987.
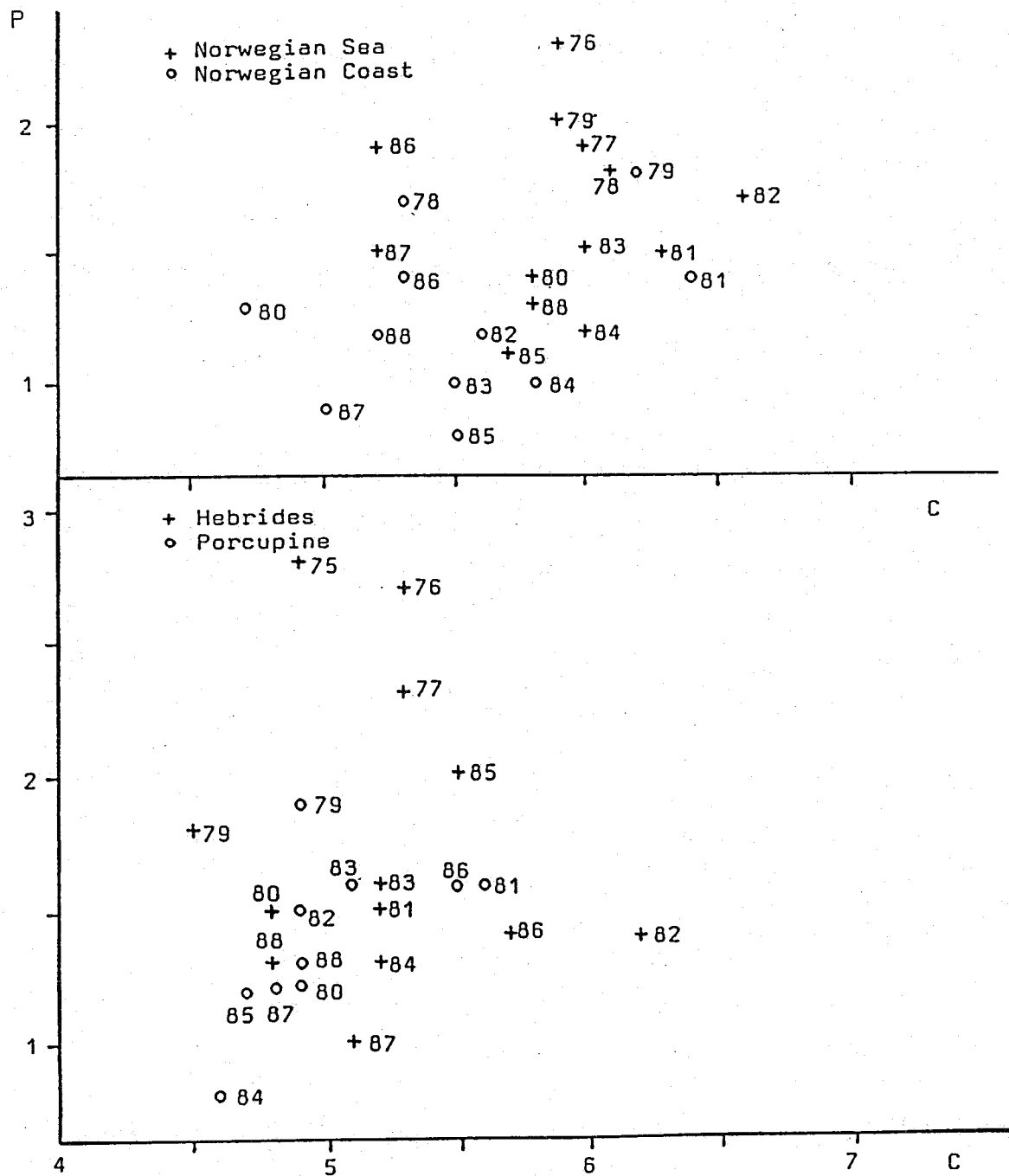
Fig. 11. Annual mean values of the parasite index P against condition
         factor C of the blue whiting in the Norwegian Sea and the
         Norwegian Coast areas (upper), and the Hebrides and the
         Porcupine areas (lower).

Some aspects of mortality, condition factors and.......

The larval form of Anisakis which accumulates on the liver surface, also infects the visceral cavity probably by being expelled from the liver. The index value, however, is subjectively set in relation to the liver size, which varies through the year and from year to year (Fig.8). In order to see how this would affect the parasite index, its value by age was compared to corresponding ratio of parasite and liver indices, P/L, by age (Fig.9). These overall mean values for the areas in question show the infestation rate increasing with host age.

Up to the age of 5 years the difference was neclectable if any. For the older age groups the difference was noticeable, with the parasite index being slightly lower when not related to the liver size.

Parasite indices by host's age in the 4 areas are shown in Fig.10 together with the corresponding liver indices and condition factors.

Table 4. The growth parameters of von Bertalanffy's equation (L_{inf}, K and t_0), parasite index of larval Anisakis, liver index (L) and ratio of parasite and liver indices (P/L) of the 1971-1983 -blue whiting yearclasses at 1-6 years old in the Hebrides area.

	Yearclasses						
	1971	1972	1973	1974	1975	1976	1977
L_{inf}	30.82	30.55	31.56	35.14	32.03	31.82	34.72
K	0.59	0.73	0.58	0.28	0.59	0.60	0.33
t_0	-0.86	-0.24	-0.68	-2.41	-0.45	-0.81	-1.73
Parasite	1.95	1.98	2.02	2.14	1.78	1.45	1.44
Liver	2.73	2.86	2.62	2.42	2.18	2.18	2.18
P/L	0.71	0.69	0.77	0.88	0.82	0.67	0.66

	Yearclasses					
	1978	1979	1980	1981	1982	1983
L_{inf}	33.35	36.08	35.18	32.93	33.93	33.01
K	0.20	0.34	0.41	0.46	0.29	0.36
t_0	-2.83	-1.32	-0.99	-1.21	-2.13	-1.48
Parasite	1.30	1.40	1.52	1.22	1.02	0.86
Liver	2.20	2.03	2.28	2.28	2.17	2.28
P/L	0.59	0.69	0.67	0.54	0.47	0.38

In all areas the amount of Anisakis on the liver increases with
increasing age, and the highest value was observed in the Norwegian
Sea for the 10 and 11 years olds. Smith and Wotten (1978) also found
increasing number of Anisakis with age of the blue whiting host, and
no significant difference between the sexes. Bussmann and Ehrich
(1978), however, found that the infestation was decreasing in the
highest length groups.

The liver index and the condition factor to a great extent follow each
other after the youngest age groups. In the Hebrides and the Porcupine
areas they are observed to be rather even for most age groups, but
after 8 years old the condition factor increases significantly with
age in the Hebrides area. The liver index show only a slight increase
for the oldest age groups, indicating that the spawning products
naturally are more significant in the older than in the younger age
groups of the spawning stock. In the Porcupine area this phenomenon
was not obvious to the same extent.

On the contrary, in the Norwegian Sea area the condition factor
decreases significantly with age from 2 years old. The liver index was
also observed to decrease with age, but at a lesser rate. In the
Norwegian Coast area the same tendency could be traced, but the rapid
increase of the condition factor of the oldest age groups, alter the
pattern of the Norwegian Sea area.

While the spawning product mass rear the condition factor in the
spawning period, the oldest, and hence the largest specimen, seem to
need more food proportionally per body length unit to gain a condition
equal to the smaller specimen during the feeding period.

The increasing parasite index with age could give reason to belive
that the accumulation of the larval Anisakis on the liver surface
would in some way affect the blue whiting host, and hence explain the
decreasing condition factor with age during the feeding period.
Bussmann and Ehrich (1978) and Smith and Wotten (1978), however, show
that in blue whiting the relation between weight and length, i.e. the
condition factor, is not affected by the appearence of the larval
Anisakis parasite.

In order to verify this non-relationship the mean values of the
parasite indices for the years 1975 - 1988 were plotted against
corresponding condition factors for each separate area (Fig. 11). The
random distribution shown on the graph could not justify a regression
for the relationship.

Data available for the Hebrides area permitted a further study of this
matter, and a comparison was made between the growth parameter K (von
Bertalanffy's) of the yearclasses 1971 - 1983 and their Anisakis
parasite index. The material and method for the growth calculations
are described in Monstad (1989). To avoid a bias due to influence of
older age groups in some of the yearclasses, the growth parameter as
well as the parasite index were based on 1 - 6 years old fish only.
The parameters of von Bertalanffy's length-growth equation for the
various yerarclasses are given in Table 4 together with corresponding
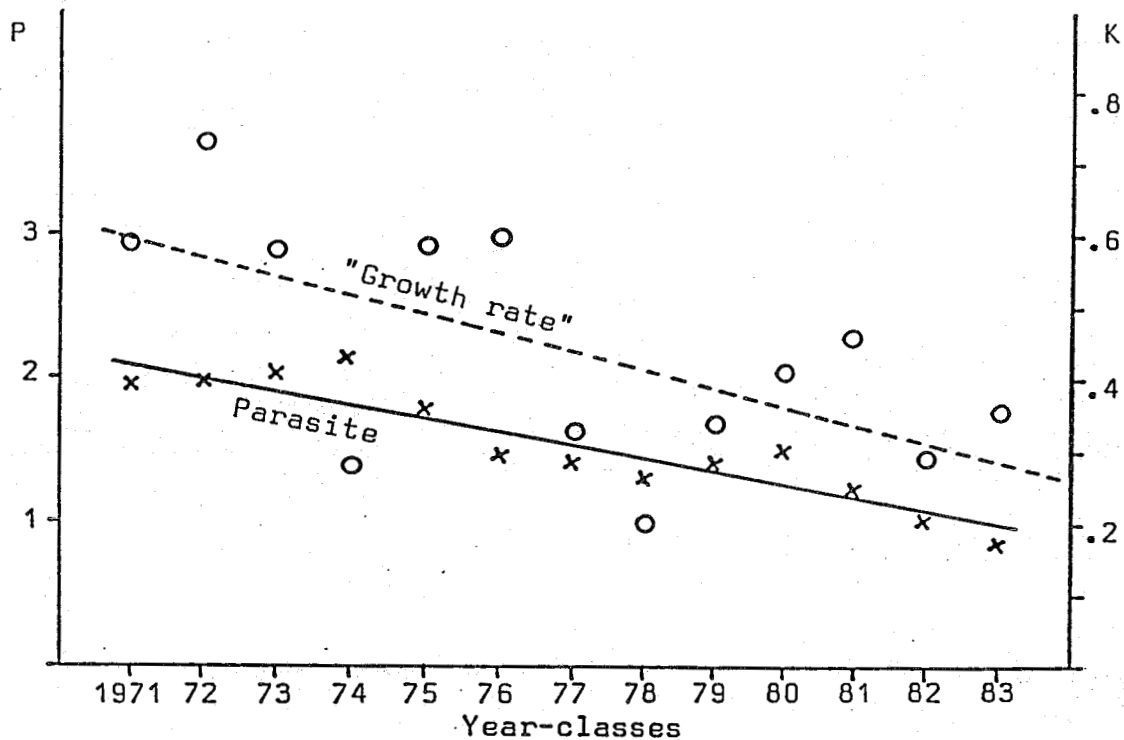parasite and liver size indices.

Fig. 12. Regression of growth parameter K (von Bertalanffy), circle
         and stippled line, and of parasite index P, cross and full
         line, against year classes of blue whiting in the Hebrides
         area during spring, based on values for the six first
         years of life.

The regressions illustrated in Fig. 12 were calculated to:

$$y_K = -0.03 \cdot x_{yearclass} + 0.6$$

for the growth, and

$$y_P = -0.10 \cdot x_{yearclass} + 2.2$$

for the parasite index.

The lines were almost parallel with decreasing values with increasing
yearclasses.

Although there is variaton in the yearclass' K-values, this analysis
gives no reason to believe that the burden of larval Anisakis para-
sites on the liver surface affects the blue whiting host, regarding
the length growth in the first six years of life.

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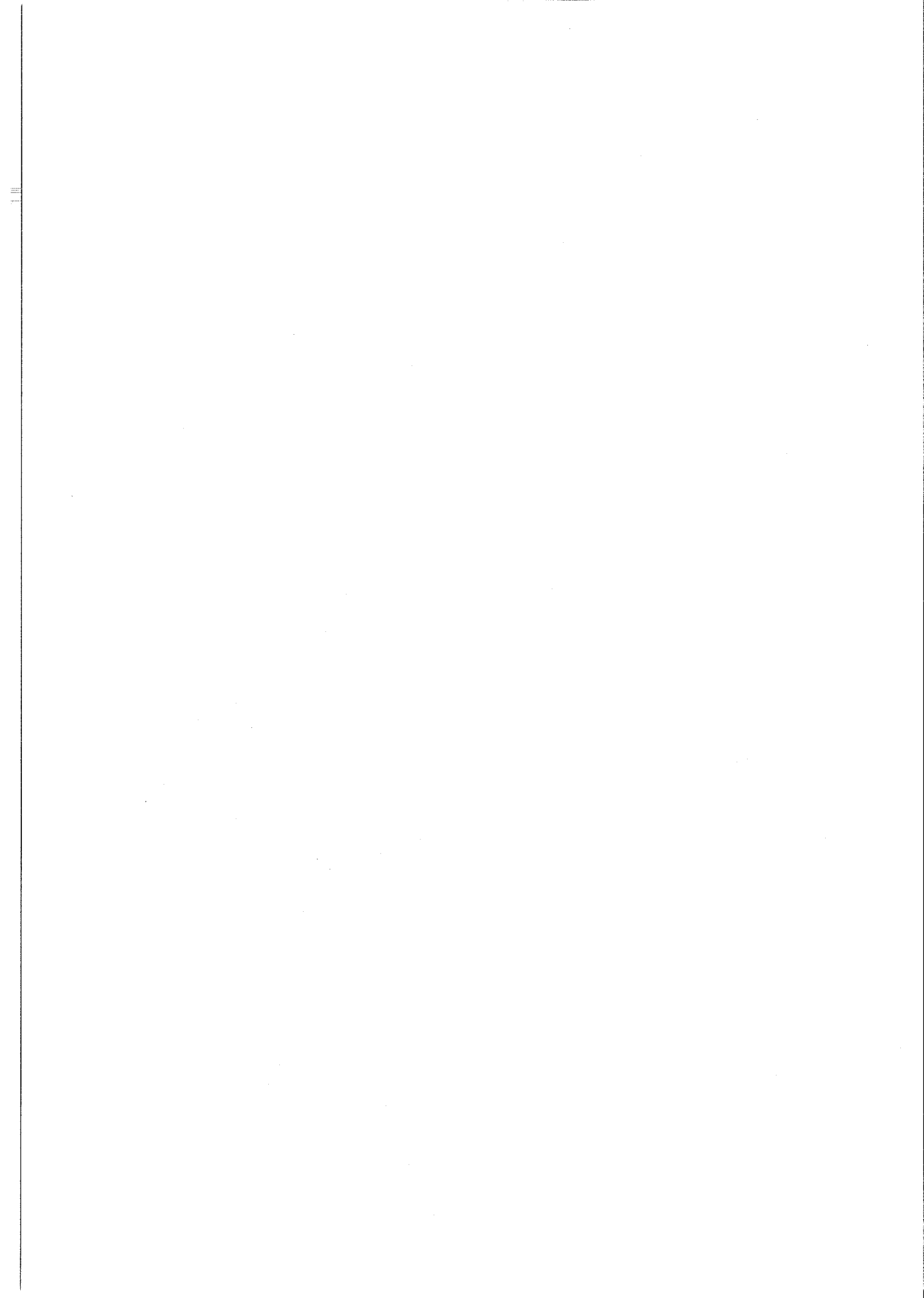
SOME PECULIARITIES OF THE BLUE WHITING MIGRATIONS
IN THE NORTHEAST ATLANTIC IN 1978-1988 IN RELATION
TO STOCK COMPOSITION AND HYDROGRAPHIC CONDITIONS

by

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ABSTRACT

Feeding area and feeding migration pattern of blue whiting in the
Norwegian Sea underwent considerable changes in 1978-1988. In 1978-
1981 feeding migrations covered the entire sea including the northern
and northwestern areas. From 1982 on the feeding area has markedly
contracted and the fish virtually stopped migrating north of 65-66°N.
Orientation of postspawning migrations and times of blue whiting
appearance in the central Norwegian Sea varied considerably as well.
Migrations had an eastward orientation for the major part of the
period in question, excepting 1978 and 1981 when the orientation was
westward. The dates when fish started emerging in the central
Norwegian Sea ranged from 20 May to 6 July.

Variations in feeding migration patterns are mainly caused by large
fluctuations in stock size, transformation of the age-length
composition of the blue whiting population due to fishery and changes
in recruitment, as well as by year-to-year variations in hydrographic
conditions.

INTRODUCTION

The directed blue whiting fishery in the Northeast Atlantic, having developed at a high rate since the mid-1970's, underwent considerable changes within the period under review, both in catch volumes and distribution of fishing effort in various parts of the region. According to ICES statistics (Anon.1986,1989) the total blue whiting catch increased tenfold from 1975 to 1979. Peak annual catch was in 1980, after which an abrupt drop in catches occurred. In 1984 this trend slowed down and the resource base showed signs of improvement. (Table 1).

Table 1. Total catch of blue whiting in the Northeast Atlantic
         by all countries in 1975-1987 (thousand tonnes).

Year	Fishing area			Total
	Spawning grounds	Nursery grounds	Feeding grounds	
1975	62.0	43.3	6.7	112.0
1976	116.4	44.2	3.3	163.9
1977	167.5	44.2	57.0	268.7
1978	263.1	109.4	236.2	608.7
1979	311.7	65.8	741.1	1118.6
1980	280.7	75.1	766.8	1122.6
1981	327.0	61.7	520.8	909.5
1982	392.6	117.6	110.7	620.9
1983	390.3	124.7	53.0	568.0
1984	440.6	116.9	66.0	623.5
1985	507.1	97.8	90.8	635.7
1986	567.3	99.6	160.1	826.9
1987*	478.7	62.7	123.0	664.4

* = Provisional data.

The first years of the fishery more than 50 % of the annual catch was taken on the spawning grounds west of the British Isles. After 1978 the fishing area has been enlarged and the bulk of the total catch (up to 70 %) started coming from the feeding grounds in the Norwegian Sea. Peak variations in catches were recorded there: first, the catch increased about threefold from 1978 to 1980, then in 1983 it dropped to one fifteenth. The subsequent increase in the catches was not as pronounced as the previous drop, especially on the feeding grounds (Table 1).

Such considerable variations in catch required, in addition to a regular monitoring of the stock status, an all-round analysis of changes in the age composition of the population and a study of resource base formation peculiarities in relation to environmental factors.

The present paper considers year-to-year variations in the feeding area and in the feeding migration pattern of blue whiting in spring-summer 1978-1988 in relation to age-length composition dynamics, stock status and oceanographic conditions.
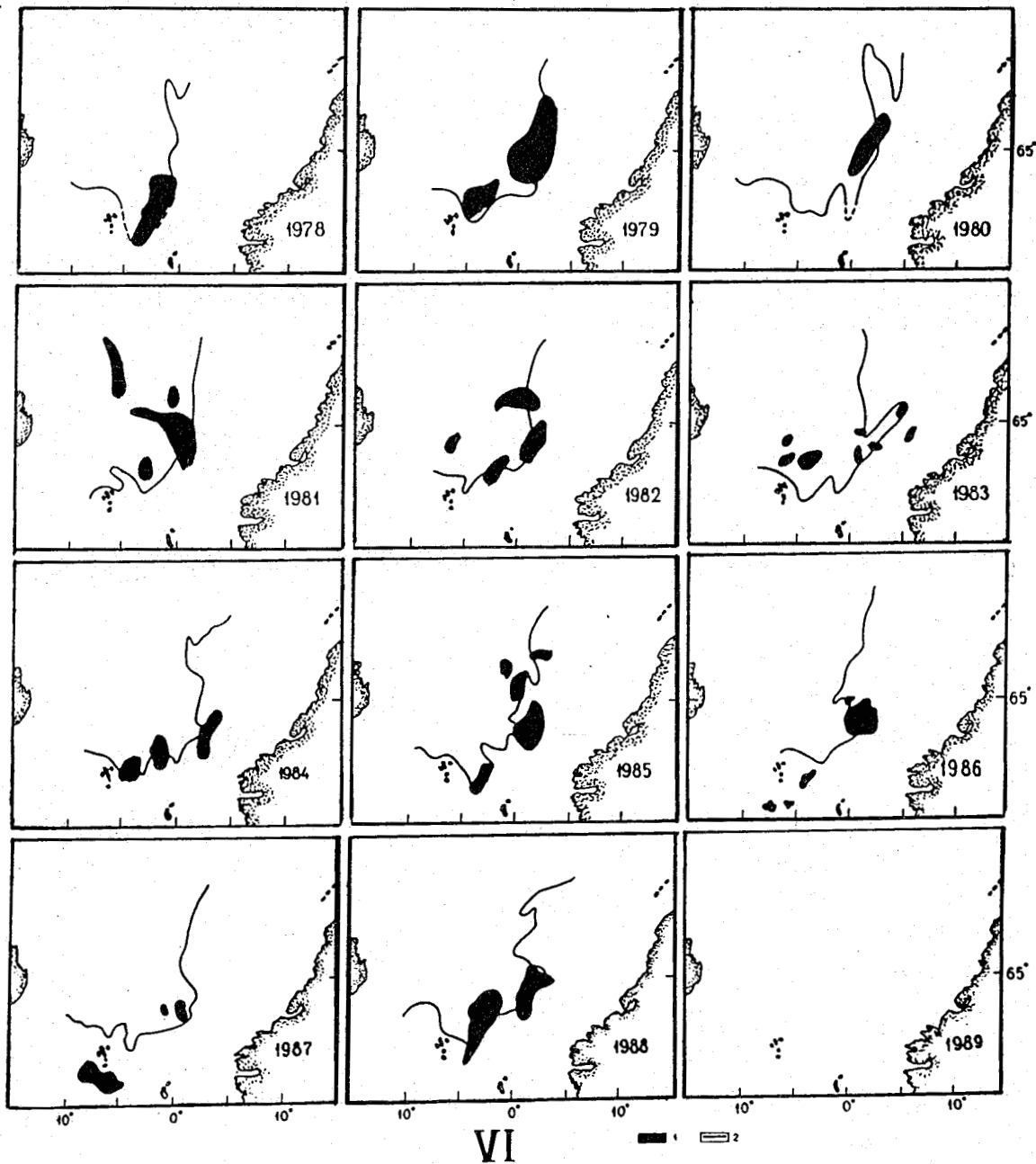
Fig.1. Distribution of commercial blue whiting concentrations (1) and
        position of 5^0C isotherm at 200 m depth (2) in June 1978-1988.

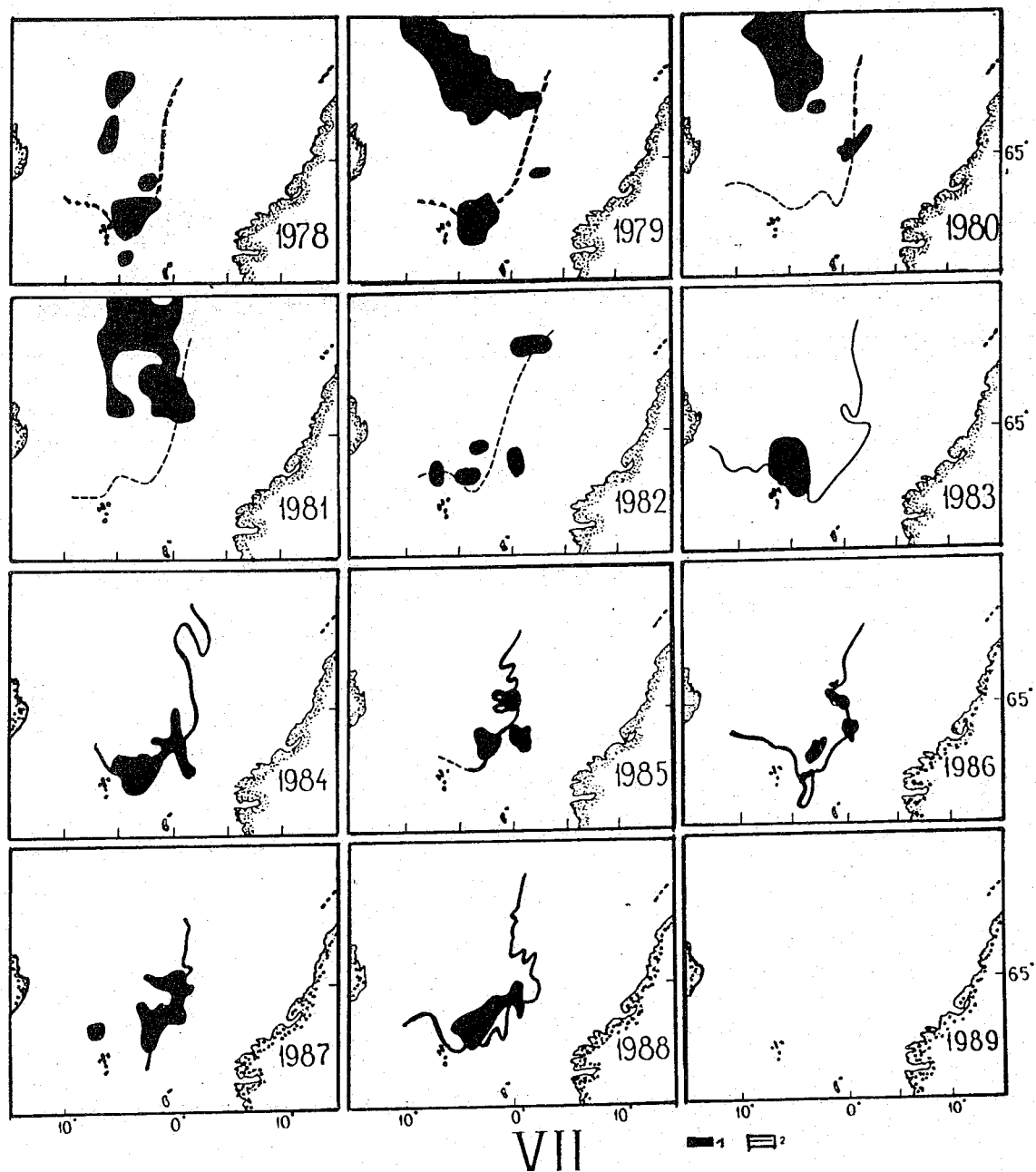Some peculiarities of the blue whiting migrations in the.........

Fig.2. Distribution of commercial blue whiting concentrations (1) and
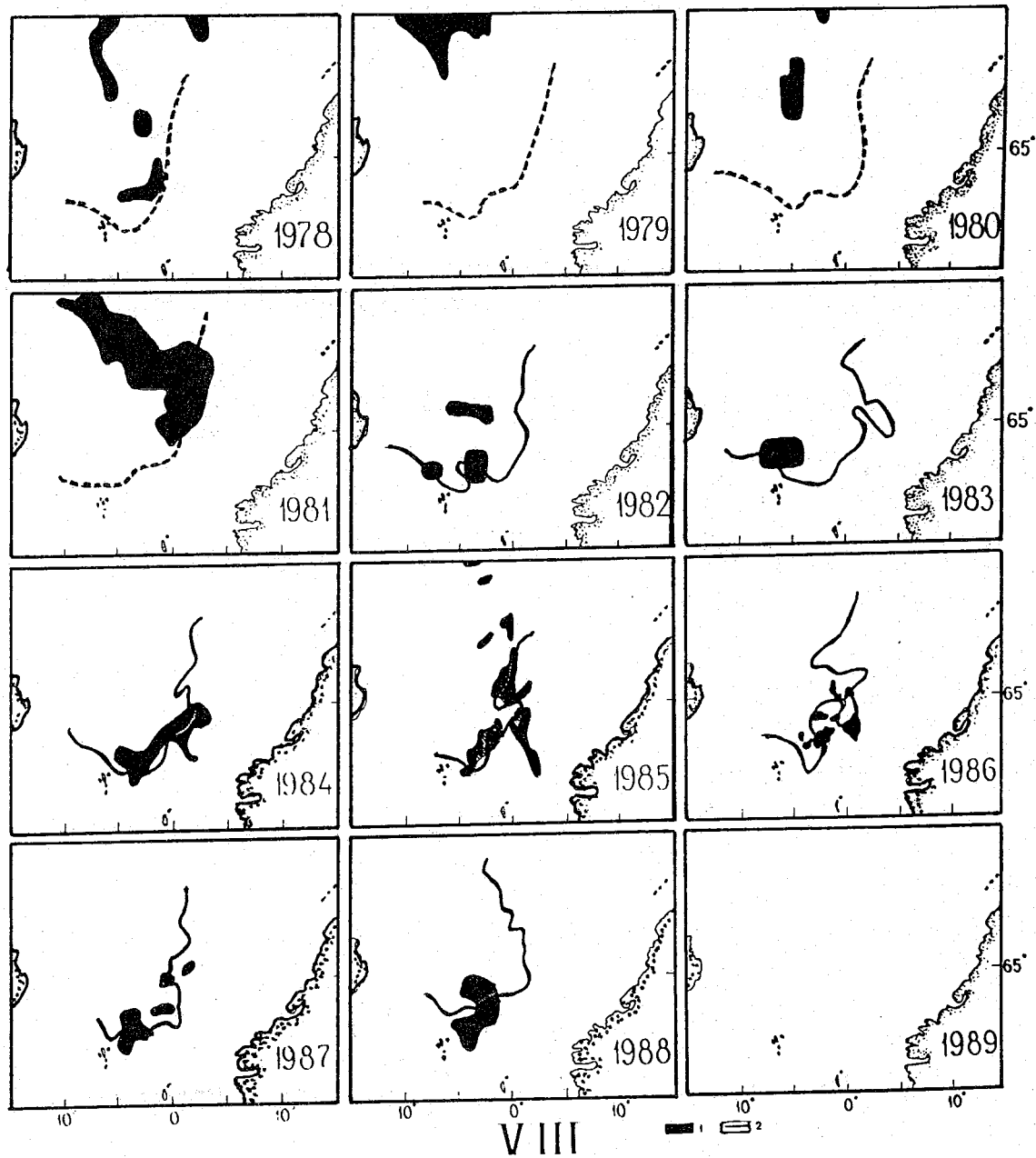position of 5⁰C isotherm at 200 m depth (2) in July 1978-1988.

Fig.3. Distribution of commercial blue whiting concentrations (1) and
        position of 5°C isotherm at 200 m depth (2) in Aug. 1978-1988

MATERIAL AND METHODS

Summarized data from research, scouting and fishing vessels have been
used in the paper. Information on the blue whiting distribution is
presented as monthly maps showing positions of commercial
concentrations (Figs. 1-3). Age-length composition characteristics
were obtained from results of field analyses processed by standard
methods, and estimates of the stock size and recruitment arise from
the data of International Acoustic Surveys and ICES Blue Whiting
Working Groups.

Oceanographic conditions were estimated by using data from standard
hydrographic surveys in the Norwegian Sea, as well as observations
from scouting and fishing vessels. Spatial position of the 5^0C
isoterm at 200 m depth was used to roughly identify the polar front
area.

RESULTS

Data on the blue whiting distribution in summer months (July-August)
show that the feeding area markedly changed in dimensions in 1978-
1988 (Figs.1-3). In 1978-1988 mass feeding migrations had an extended
pattern and covered the entire sea including the northern and
northwestern parts. In those years stable commercial concentrations
remained there for 5-6 months - from July to November and even
December. In 1981 they were observed for three months, and the next
three years the fish did not virtually appear north of 66^0N. In August
1985 the blue whiting were seen to migrate beyond 70^0N, but then the
feeding area contracted once again, with its northern limit shifting
southwards to $64-65^0$N.

Table 2. Spawning stock biomass and recruitment abundance of the blue
         whiting in the Northeast Atlantic in 1979-1987 (Anon. 1988).

Year	Spawning stock (10^6 tonnes)	No of recruits at age 0 (10^9)
1979	5.3	6.6
1980	4.3	4.3
1981	3.5	5.6
1982	2.9	39.4
1983	2.5	40.8
1984	2.6	17.6
1985	3.4	17.2
1986	4.4	6.8
1987	4.2	24.8

The feeding area was changing against the background of considerable
fluctuations in total and spawning stock, and variations in age-length
composition of the population caused mainly by fishery.

The first years of the fishery in the Norwegian Sea (1978-1980)
large fish from older age groups prevailed in the stock. The bulk of
the catch (up to 65-70%) in all fishing areas consisted of fish at age
7-11, 28-33 cm long (Figs. 4-6). From 1981 on, in response to a hard
intensification of the fishery of the preceding three years coinciding

with a series of poor year classes (Table 2), the portion of older age groups began to decrease, and that of younger fish started to increase, so that by 1984 the latter had become predominant in the stock (Figs. 4-6). The spawning stock had partly recovered by 1985 owing to the strong 1982 and 1983 year classes (Table 2). These year classes became the base for fishery from 1984 on (Figs.4-6). Together with a relatively poor recruitment from the 1984-1986 year classes (Table 2) this resulted in a reduction of the total abundance and biomass of the feeding blue whiting.

Parallel with large-scale fluctuations in the range of feeding migrations within the period under consideration, there were also changes in the orientation of the feeding migrations and times when postspawning concentrations started emerging in the offshore Norwegian Sea.

There exist some suggestions that in the Norwegian Sea feeding blue whiting generally migrate northwards, but some years fish may move mainly through the eastern and central or central and western sea, i.e. the feeding migrations may have an eastward or westward orientation (Dragesund and Jakupsstovu, 1971; Hansen et al., 1979). Predominance of the eastward orientation features the 1978-1988 period: the westward ones were only registered in 1978 and 1981 (Figs.4-6).

The dates when postspawning blue whiting started emerging in the offshore sea ranged between 20 May and 6 July (Table 4).

DISCUSSION

Comparing the large-scale variations in feeding area and age-length composition of the population one may suppose a link between them. It is conditioned by distributional generalities of mature and immature fish. As a rule, immature fish keep apart from the rest, though both groups may partly mix seasonally. In winter the spawning part of the population move towards the British and Irish Shelves to breed, and the young fish stay in the southern Norwegian Sea. In spring-summer the postspawning fish migrate north to reach Jan Mayen, going as far as Spitzbergen some years, while the younger age groups, unable to cover long distances, stay in the southern sea up to 65-66°N. Thus a transformation of the population structure involving growth or reduction of individual age groups seems to result in a displacement of the northern limit of the feeding area.

Year-to-year variations in orientation of postspawning migrations and times of mass appearance of fish in the offshore Norwegian Sea are determined, to a great extent, by oceanographic conditions. One of the factors controlling the orientation of migration routes is the position of the southern part of the polar front. Generally, its influence lies in the following: when the frontal zone moves eastwards from its average position, the eastward orientation is observed; with an opposite hydrographic situation we get a westward one. In 1978-1988 the eastward displacement was predominant, except for 1978 and 1981 when the westward movement of the front was recorded. This is illustrated by both spatial positions of the $5°C$ isotherm at 200 m depth (Figs.1.3) and values of the second main component (MC) of water temperature field in June (Table 3) which is, as shown in a number of previous papers (Shevchenko, Isaev, 1984, 1985), a good identifier of position and intensity of the polar front zone. In physical terms this parameter may be treated as follows: its negative values correspond to

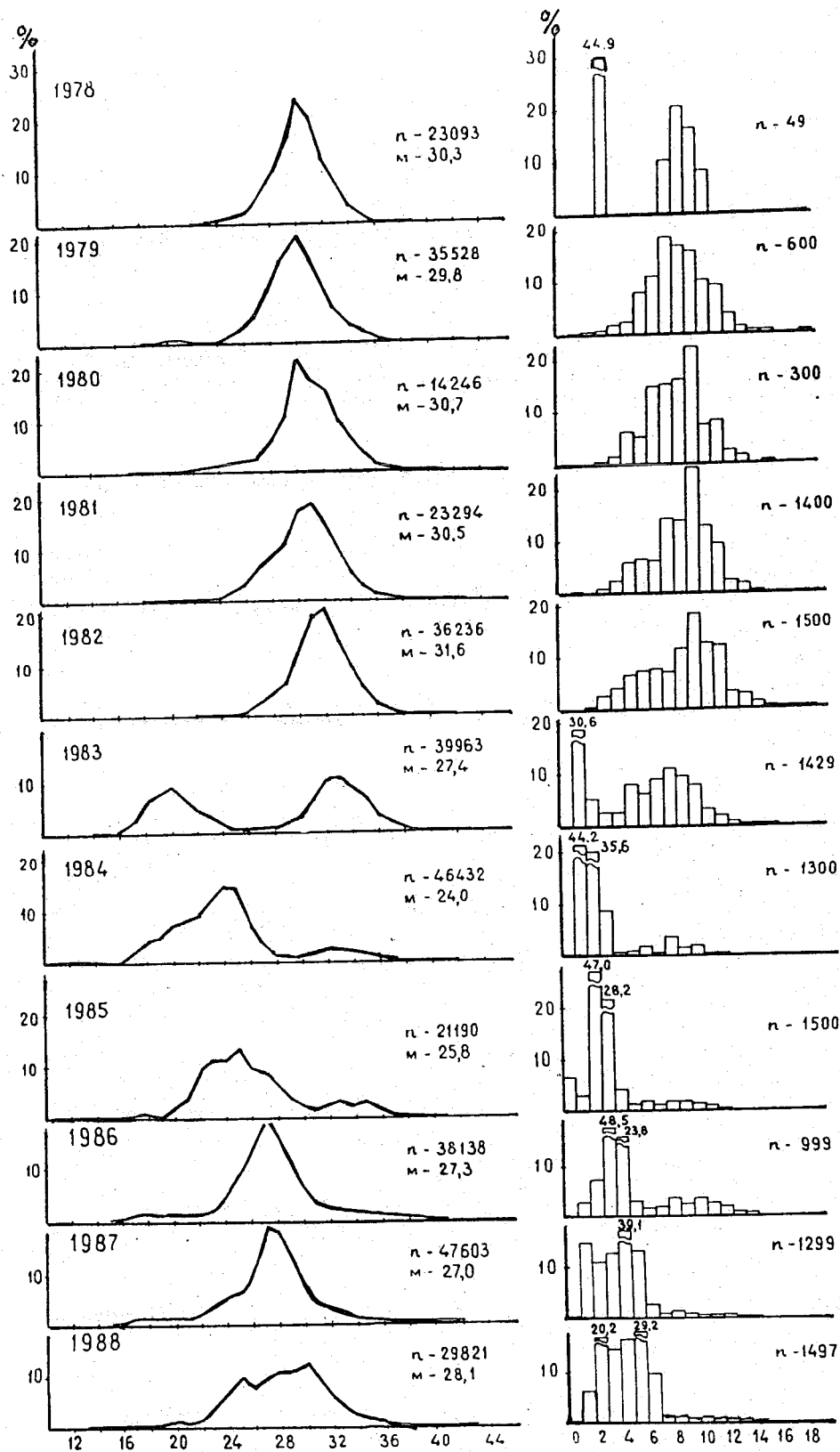Some peculiarities of the blue whiting migrations in the........

Fig.4. Age-length composition of blue whiting from catches in Faroese waters in 1978-1988.
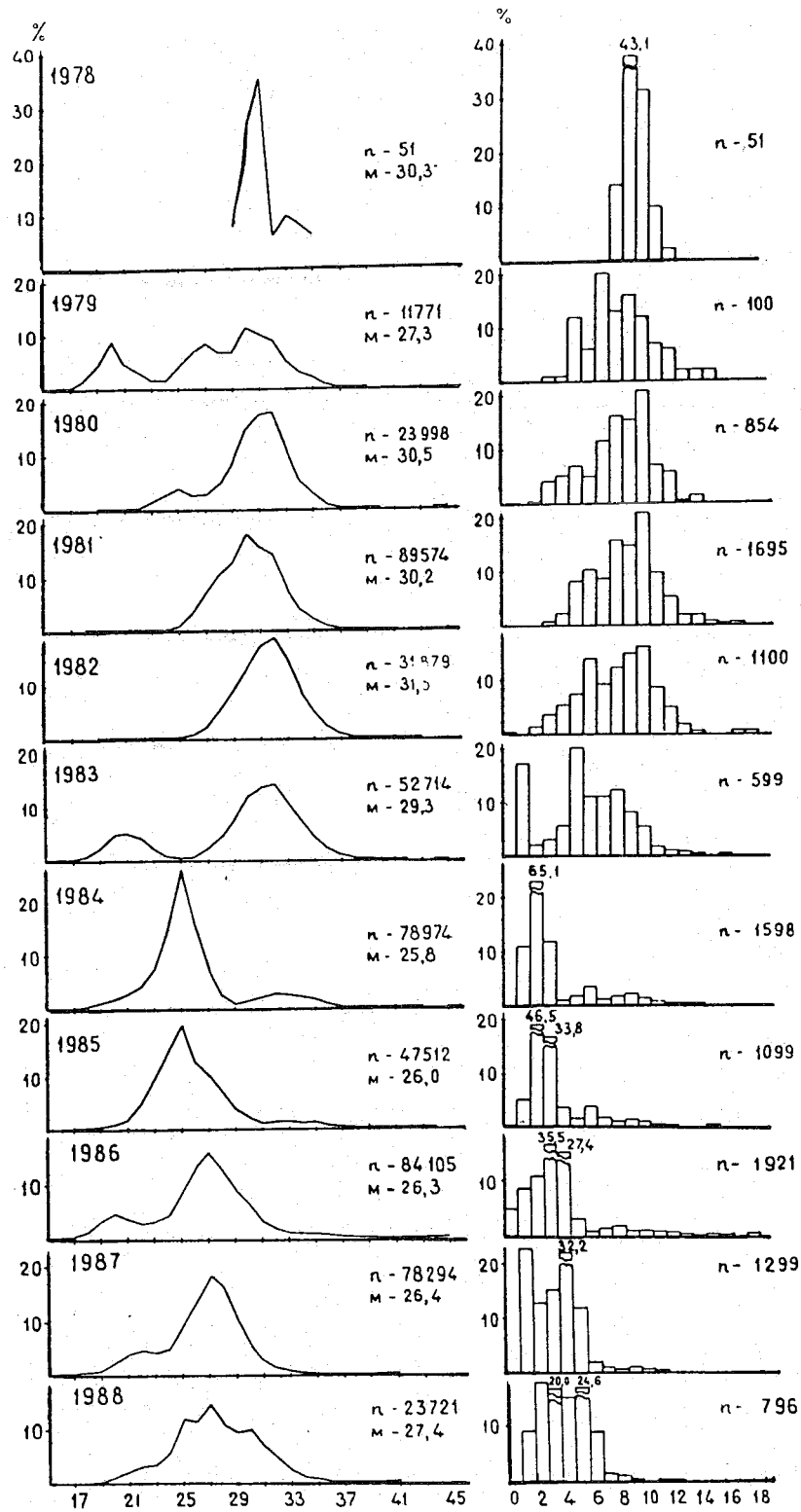
Fig.5. Age-length composition of blue whiting from catches in eastern
        Norwegian Sea in 1978-1988.

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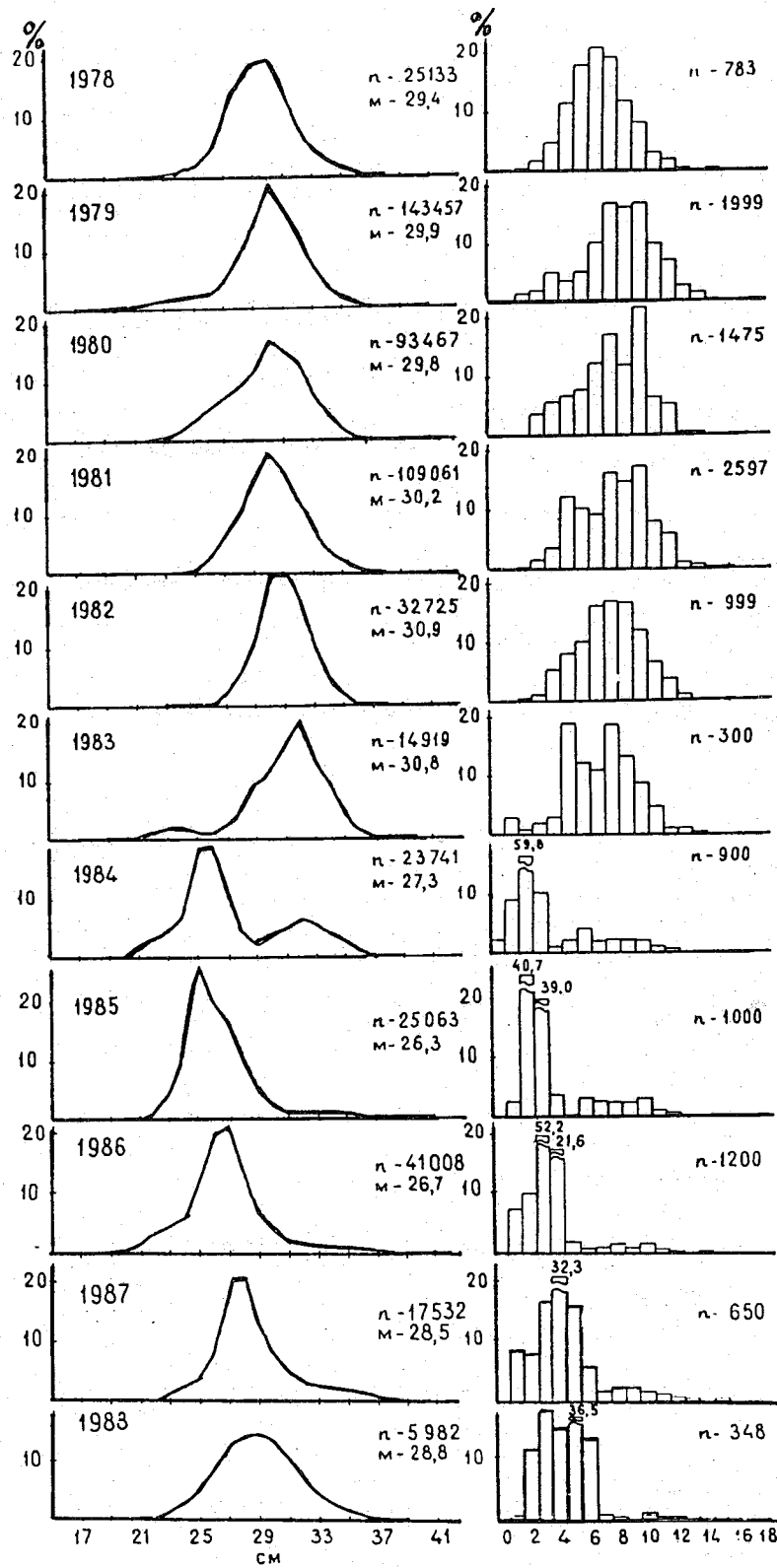

Fig.6.   Age-length composition of blue whiting from catches in central
         Norwegian Sea in 1978-1988.

Table 3. Values of the second main component of water temperature
field in June at 0-50 m (T_2, conventional units) and
orientation of the postspawning migrations of blue whiting
(0) in 1978-1988.

Year	T_2	0	Year	T_2	0
1978	-1.4	W	1984	2.0	E
1979	1.2	E	1985	1.0	E
1980	0.8	E	1986	1.1	E
1981	-1.0	W	1987	0.3	E
1982	-0.2	Es	1988	0.2	E
1983	1.9	E			

E = eastward orientation; W = westward orientation;
Es = scattered distribution tending to the eastern one.

the westward shift of the front, positive ones are associated with the
eastward shift, and absolute values characterize the intensity of the
frontal zone. When the second MC values are close to 0, the
observations reveal a weakening of the front and formation of a low-
gradient temperature field. As seen in Table 3, considerable negative
values of this index were recorded but in 1978 and 1981. These two
years, as mentioned above, the postspawning migrations of blue whiting
had a westward orientation.

Changes in orientation of the feeding migrations are most pronounced
in years with a high abundance and a relatively large proportion of
mature fish in the population. In such cases large numbers of post-
spawners in summer undertake long feeding migrations to the northern
part of the sea and the distribution may be closely linked to
oceanographic conditions. When young fish prevail, the major part of
the stock is distributed in the southern part of the sea predominantly
in Faroese waters. Though mature blue whiting at that time undertake
the usual feeding migrations, as a rule they do not form any
commercial concentrations. Besides, when such a structure of the stock
occurs under extreme oceanographic conditions, the postspawners may
not form any commercial concentrations at all. Such a situation
occurred, for example, in the summer months 1983-1984.

Fishing conditions occur in the central Norwegian Sea when post-
spawning concentrations appear there. The moment of fish appearance in
this part of the sea vary considerably by years (Table 4) and are to a
certain extent connected with a meridional gradient of water
temperature. Table 4 shows that this connection is not strictly
conclusive. It is most pronounced in years with a high abundance of
fish and a predominance of large mature individuals, when mass
appearance of postspawners in the offshore sea occurs under a well-
pronounced eastward orientation (1979, 1980) as well as a westward one
(1978, 1981). In these cases, a spatial structure of the temperature
field characterized by a meridional gradient has a decisive effect
upon the moment of formation of commercial concentrations in the
offshore sea.

Table 4. Meridional gradients of June water temperature at 0-50 m
         in the Western Branch of the Norwegian Current between
         67°30'N and 65°45'N (ΔT_w,°C) and start dates of mass
         appearance of blue whiting in the central Norwegian Sea
         (D) in 1978-1988.

Year	ΔT_w	D
1978	-1.1	4 July
1979	0.5	20 May
1980	0.4	27 May
1981	-0.6	25 June
1982	-0.3	16 June
1983	-0.3	*
1984	1.2	*
1985	0.2	7 June
1986	-0.7	6 July
1987	-0.4	5 July
1988	-0.3	2 July

* No fish were observed

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Section VII: Management

PROBLEMS OF INVESTIGATIONS AND
INTERNATIONAL MONITORING OF THE BLUE WHITING
FISHERY IN THE NORTHEAST ATLANTIC

by

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The blue whiting, a small but valuable commercial fish from the Gadidae family, is one of the most numerous species in the North Atlantic ichthyofauna. The area of its distribution extends from the Pyrenean peninsula to Greenland and Spitsbergen. The blue whiting is an active oceanic migrant. At various stages of its life history its habitat covers practically all the economic and fishing zones of the coastal and island states of Europe, including the Faroes and Iceland, and also open waters outside 200 miles zones - in the Northeast Atlantic, Norwegian, Greenland and Barents seas. The commercial fishery for blue whiting began its active development in the mid-1970's and until now this species has been on one of the leading places in the Northeast Atlantic by volume of yields. In the mid-1980's a directed fishery for blue whiting was carried out by more than 15 countries, whose annual catches are presented in Table 1.

Table 1. Catch in thousand tonnes by various nationes, 1980-1986.

Country	Year						
	1980	1981	1982	1983	1984	1985	1986
Denmark	69.2	46.4	58.1	67.0	75.5	47.6	68.7
GDR	14.4	29.2	10.8	8.8	9.4	8.5	6.3
Ireland	-	2.7	-	-	-	0.7	16.4
Spain	23.7	30.7	27.5	26.3	25.9	35.8	25.0
Netherlands	-	0.8	0.4	0.1	1.1	1.9	10.0
Norway	56.6	185.0	217.6	253.3	270.5	288.7	310.1
Portugal	6.0	7.4	3.9	4.7	5.2	7.0	8.1
USSR	766.9	522.9	176.9	109.8	171.1	215.7	284.0
Faroes	39.4	37.4	66.2	80.2	72.0	75.9	86.2
Sweden	4.2	1.9	1.2	3.8	5.4	3.6	8.5

A large-scale exploitation of blue whiting requires an expansion of stock investigations (Zilanov 1981), including scientifically founded measurements of the regulations on an international basis. The inter-state cooperation on these problems is being conducted within the ICES framework.

One can easily observe the positive experience of this organization's activities; its experience allows, to our mind, to assess the actual state of the stock at a contemporary level of knowledge and to work out recommendations for a rational exploitation of the stock. At the same time there are some problems, the tackling of which would

contribute to a more comprehensive knowledge of the role of this
species in the Northeast Atlantic ecosystem and also promote choosing
the optimum conditions for the stock exploitation (Tables 1. and 2.).

The intraspecies structure of the blue whiting is still poorly
studied. In the material of the Blue Whiting Working Group, two stocks
- the northern (Hebrido-Norwegian) stock and southern (Biscay) stock
are distinguished. This corresponds to the earlier hypothesis
(Zilanov 1966) about the existence of two genetically isolated
populations in the North and East Atlantic. Neither can it be excluded
that their areas of distribution, especially those south and southwest
of Ireland, concide in certain periods (Zilanov 1984). Morphometric
and biochemical analyses of blue whiting indicate a possible existence
of local populations in the waters west of Great Britain and Ireland
(Lysenko and Malkov 1984). But this theory is not supported by other
scientists (Giedz 1983) and is still under discussion (Anon. 1986 a,
1987). Therefore it seems expedient (as is repeatedly emphasized in
the Working Group reports) to intensify studies of the blue whiting
population structure, as this will be valuable both theoretically and
practically.

One of the sources of information for the blue whiting stock state
assessment are the results of annual spring hydroacoustic surveys on
spawning grounds west of Great Britain and Ireland, and summer surveys
on the feeding grounds in the Norwegian Sea (Zilanov, 1981). Usually
2-4 research vessels take part in the spring surveys, and up to 9
vessels from various countries partake in summer surveys. Various
estimates of the blue whiting stock size from the material of
hydroacoustic surveys in the period 1982-1987 (Anon. 1987) are
presented in Table 2.

Table 2. Estimation of the blue whiting stock size based on acoustic
         surveys on the spawning grounds (west of Great Britain and
         Ireland) and in the feeding area (Norwegian Sea).

Area	Total biomass in mill. tonnes					
	1982	1983	1984	1985	1986	1987
Spawning grounds:						
1st survey	2.5	4.7(4.4)	2.7(2.4)	6.4(1.7)	6.4(5.6)	5.4(5.1)
2nd survey		3.6(3.6)	3.4(2.7)	2.8(2.7)	2.6(2.0)	7.4(6.9)
3rd survey			2.8(2.1)			4.8(4.5)
Norwegian Sea:	4.6(4.1)	2.8(1.1)	3.8(0.4)	4.9(0.5)	3.0(0.9)	

Note: In brackets are the data on the immature stock.

Considerable variations in the stock estimates from the spawning areas
are conditioned, on one hand, by the fact that data from these surveys
are usually presented by each vessel separately, whereas the results
of summer surveys in the Norwegian Sea are discussed and summarized
before the presentation (Anon., 1986 b). On the other hand,
these variations are conditioned by a series of reasons of
methodological and organizational origin.

Due to this, hydroacoustic surveys, though being the most important
tool for stock investigations can not serve as the only criterion for
a qualitative estimate of blue whiting biomass and abundance. Their
methodological and organizational fundament requires a serious
consideration and discussion. In particular, due to the lack of a
reliable technique for hydroacoustic coefficients' recalculations and
also because of dispersed distribution of fish during feeding periods,
the results of summer hydroacoustic surveys on the mature stock are,
as a rule, considered insufficiently representative. It would be
expedient to change these surveys for assessment of juveniles with
corresponding changes in technique and areas investigated. This would
promote a better knowledge of the dynamics of the commercial stock
recruitment and, correspondingly, improve the prediction of the stock
status and possible or expected yield.

Experience shows that the organizing of international hydroacoustic
surveys in 200 miles zones requires proper decisions from the ICES
concerning areas, terms and time of each nation's investigations. At
present, planning of such research is difficult, due to the lack of
preliminary information at an international level, and results, for
instance, in the fact that in 1987 and 1988 there were no
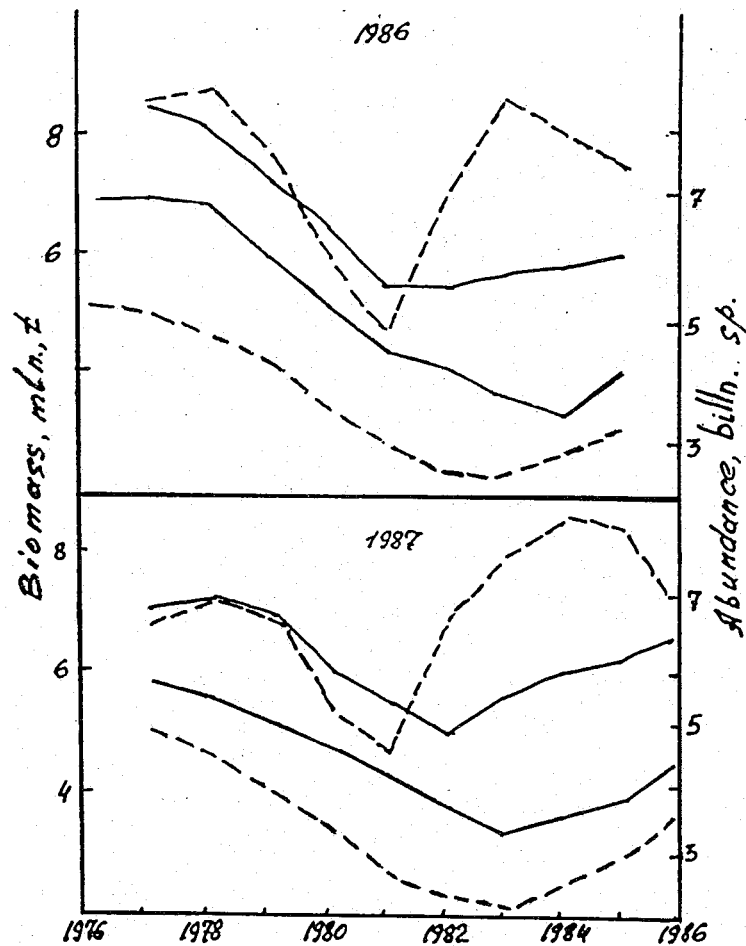international surveys in the Norwegian Sea.

Fig.1. Results of the northern (Hebrido-Norwegian) blue whiting stock
       biomass and abundance calculations by VPA method:
       (1) - total biomass, (2) - total abundance,(3) - spawning stock
       biomass, (4) - spawning stock abundance.

A mathematical model for the blue whiting northern stock dynamics is
being worked out using the VPA method. The same natural mortality
coefficient is taken for all age groups, and this is certainly one of
the disadvantages of the model. At the same time, annual corrections
obtained by the results of hydroacoustic surveys and biological data
allow, to a great extent, to verify the main parameters and input
data.

Two options for estimating the northern blue whiting stock abundance
and biomass presented by the Working Group in 1986 and 1987 are shown
in Fig. 1. The difference in the output data is caused by correction
of the model in accordance with biological data as well as by the
introduction of fishing mortality coefficients for each age group
using the 1987 option. For the rich 1982-1983 year-classes (the 1986
option) these coefficients were taken at the level of 0.19, which
corresponds to the level of their overexploitation. That is why at
increasing exploitation of the total and spawning stocks biomass
(since 1983) already in 1984-1985 there appeared signs of a reduction
of the total abundance. This has not affected the spawning stock
biomass, but will nevertheless cause a stock decrease in 1989 and
1990, with a poor or even average fecundity of the 1984-1985
yearclasses.

Analysing the results of calculations by VPA one should keep in mind
that the algorythms of the model imply an even distribution of fishing
effort over all areas of commercial stock distribution. Actually, a
considerable part of blue whiting concentrations in the 200 miles
zones, and especially off the western and southern coasts of Ireland
is underexploited, whereas the greater part of the whole stock can be
distributed in the areas mentioned. That is why it is expedient to
expand investigations of blue whiting in those areas.

Table 3. Catch, in thousand tonnes, in various areas 1979-1986.

Fishing area	1979	1980	1981	1982	1983	1984	1985	1986
Norwegian Sea (feeding and wintering)	741.0	766.8	520.7	110.7	53.0	65.9	90.7	160.1
West of Great Britain and Ireland (spawning)	284.5	250.7	288.3	361.6	361.5	415.9	456.4	497.7
North Sea (breeding)	63.3	75.1	61.7	117.6	117.7	122.8	97.8	99.6

The structure of the commercial fishery for the northern blue whiting
stock can scarcely be recognized as the optimal one. The maximum yield
in 1979-1981 based mainly on older age-groups was taken in the feeding
and wintering areas in the Norwegian and Greenland seas. Even at a
high level of catches the reproductive potential of the species
remained at a sufficiently high level (Seliverstov et al. 1987). This
is confirmed by the appearence of the rich 1982 and 1983 yearclasses.
In catches since 1982 and onwards fish of an age up to 3 year were
permanently predominant. This may be explained both by an
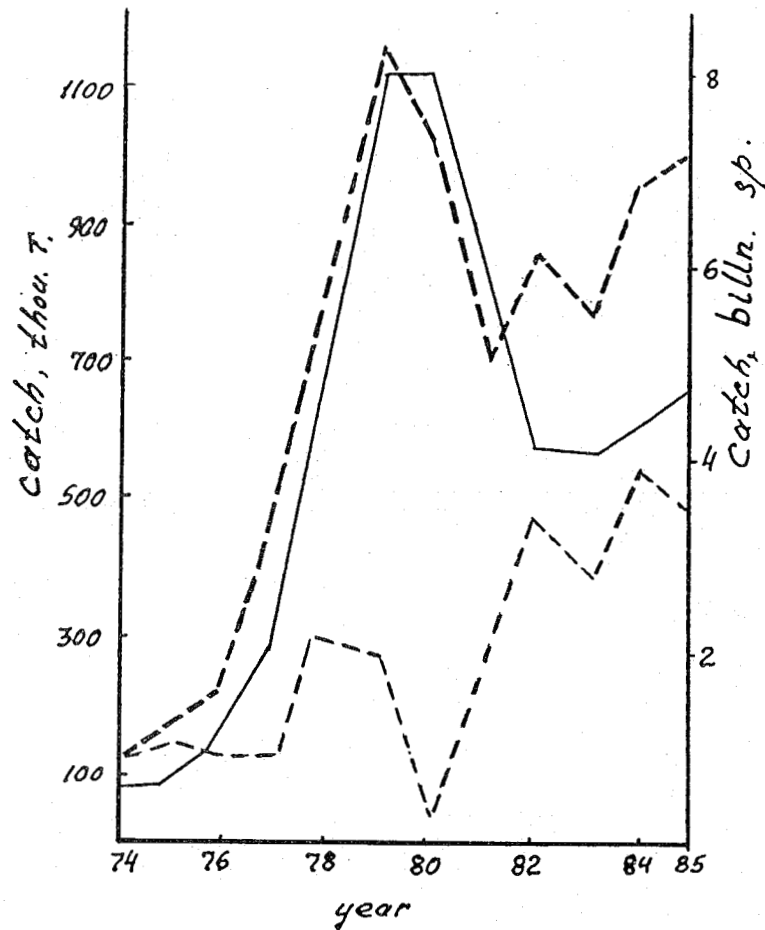intensification of the fishery in areas of young fish concentrations

Fig.2. Catch of the northern blue whiting stock:
      (1) - Total in thousand tonnnes,
      (2) - total individuals (x 10^9),
      (3) - individuals at age up to 3 years old.

in the North Sea and the appearence of the rich 1982-1983 year-classes
which significantly contributed to the catches in the British and
Irish zones. In recent years, the fishery has shifted particularly to
these areas and parallel to the increase of the fishery for
prespawning and spawning blue whiting (Table 3) the number of immature
fish has also increased in catches. For instance, the total catch of
northern blue whiting was 652.4 $\times 10^3$ tons, compared with 1092.6 x 10^3
tons in 1980. At the same time there were practically no change in the
amount of fish taken (7052.3 and 7051.8 x 10^9 individuals,
respectively), and the number of fish of an age up to 3 years has
increased by more than 3.5 times (Fig. 2).

Considering all the above mentioned we think that the following
problems should be solved:
1. The catch of small immature fish should be limited. In 1986 NEAFK
   proposed to use a mesh size not less than 35 mm in the directed
   fishery for blue whiting. But this proposal did not apply to areas
   of "mixed industrial fishery" where the largest amount of immature
   fish was taken.

2. The intensity of fishery in the northern stock areas of
   reproduction should be reduced, and the effort released should be
   transferred to the feeding and wintering areas (north of 62⁰ N)
   which are underexploited by the fishery. The solution of this
   problem is of special importance due to appearence of abundant year
   classes of herring whose ecological niche in the Norwegian and
   Greenland seas is to a certain extent filled with blue whiting
   (Zilanov 1984).
3. These problems may be overcome only by way of intensified
   investigations and strengthened international cooperation with
   consideration of all rights and duties according the Maritime Law
   Convention of 1982.

All the practical problems including creation of the optimal regime of
the blue whiting stock exploitation and measures on the fishery
regulation and improvement of investigations should be discussed
during meetings of such international organizations as NEAFC and ICES
and also on a bilateral basis between the countries utmostly
interested in a rational exploitation of blue whiting in the Northeast
Atlantic.

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