

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

by

Terje Monstad

Institute of Marine Research  
P.O. Box 1870 Nordnes  
N-5024 Bergen, Norway

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 occurring 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 (Micromesistius poutassou) 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° 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° 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 environmental 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-coordinated 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 described by Ricker (1975). The calculations 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 depths during the spring and the summer season were used observations made with CTD-sonde from Norwegian research vessels only. The 2<sup>0</sup>-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 distinguish 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

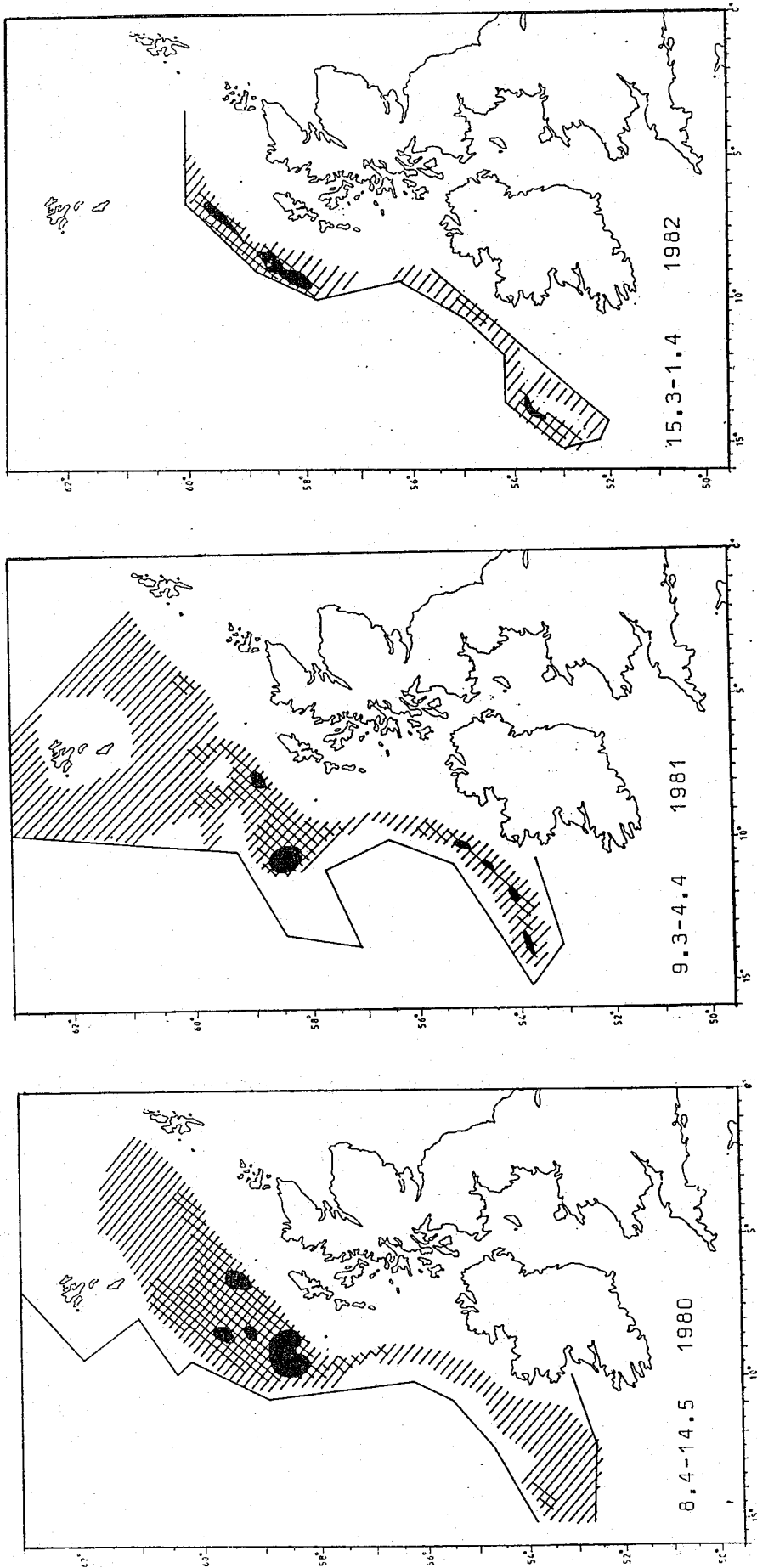


Fig. 1A. Distribution and densities of blue whiting during spring 1980-1982. Single hatch: area with scattered recordings, double hatch: dense recordings, black: very dense recordings. Full line indicates the area surveyed.

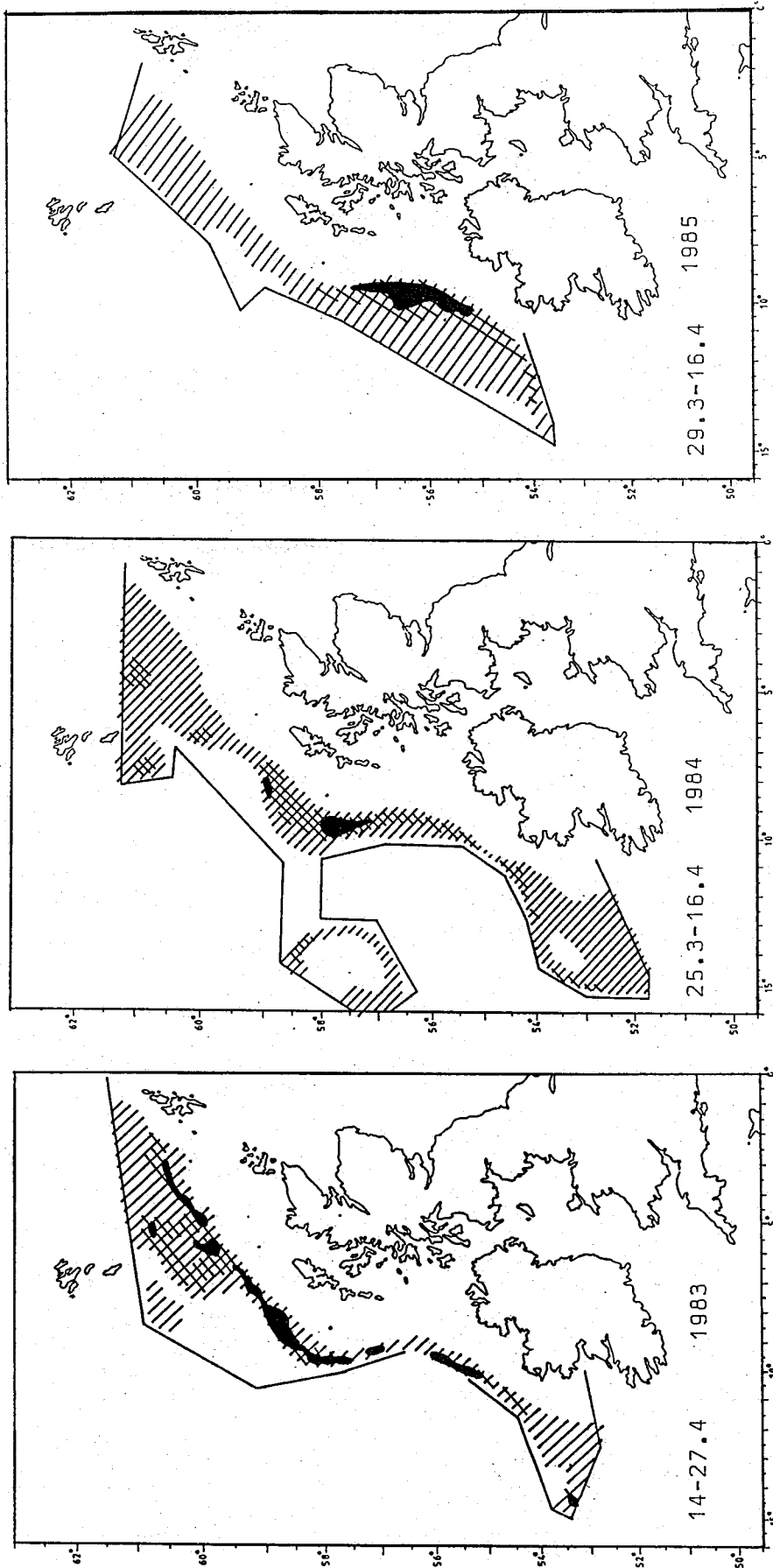


Fig. 1B. Distribution and densities of blue whiting during spring 1983-1985. Symbols as in Fig. 1A.

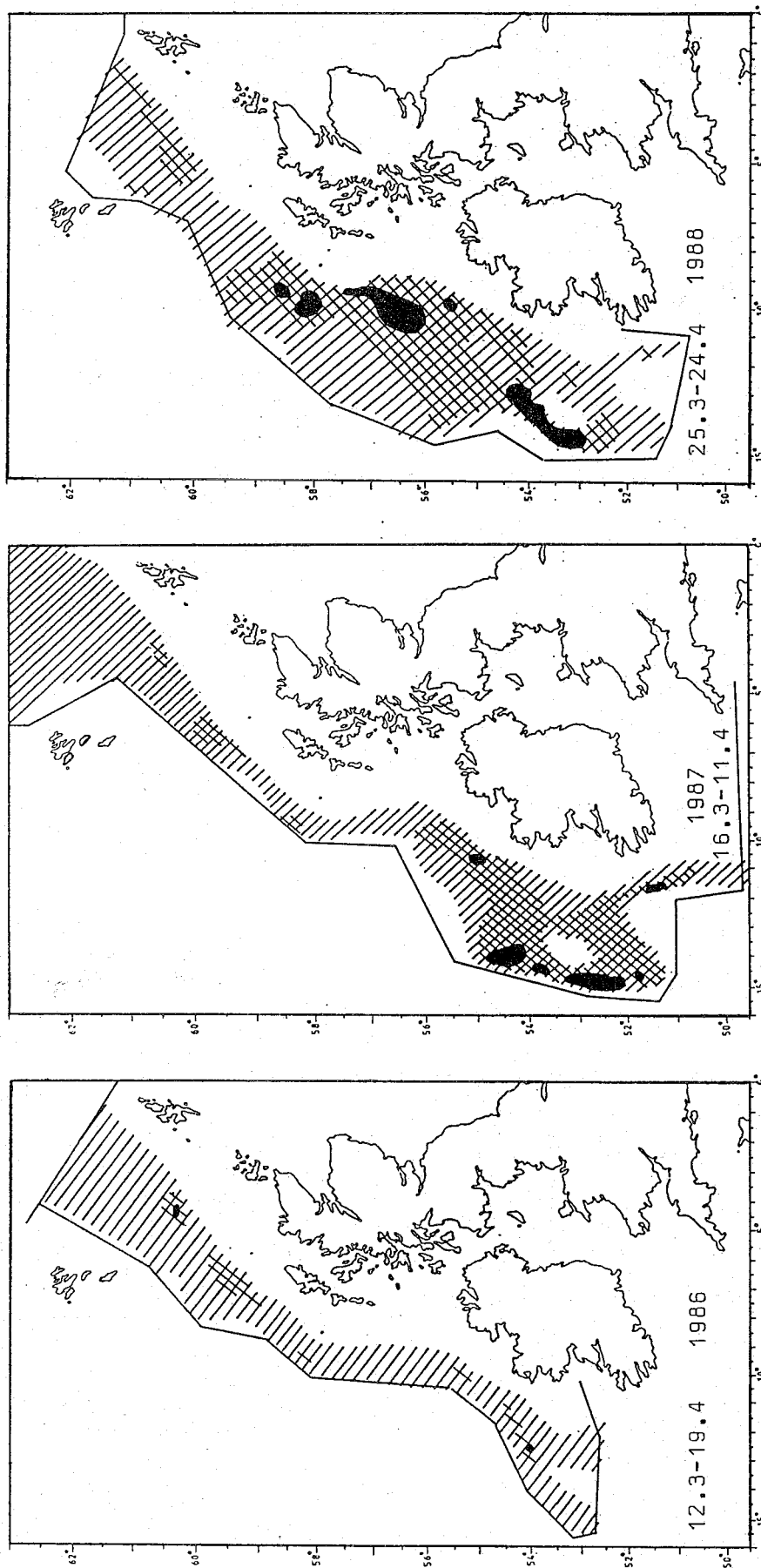


Fig. 1C. Distribution and densities of blue whiting during spring 1986-1988. Symbols as in Fig. 1A.

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.

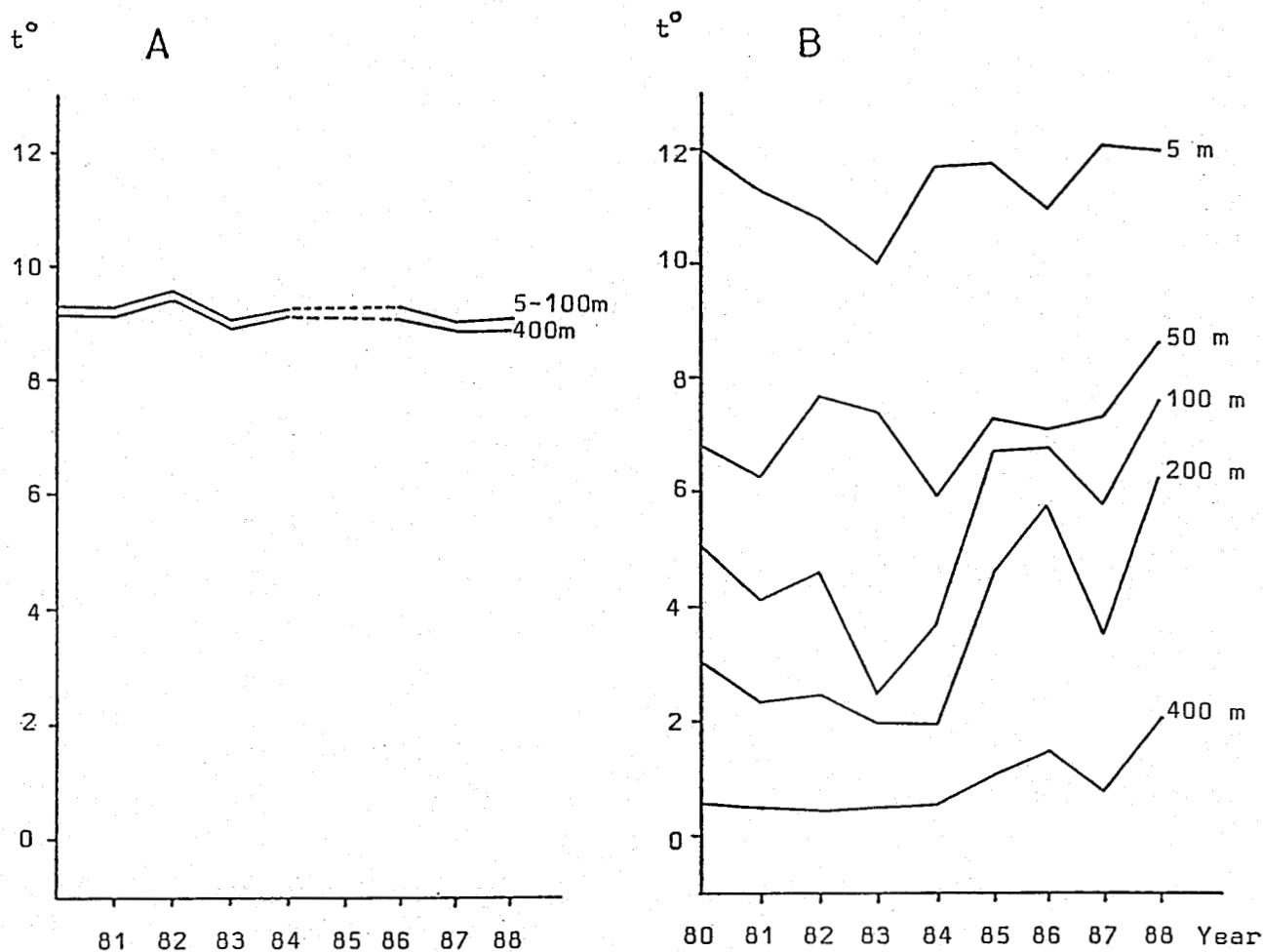


Fig. 2. Temperature trends at 5, 50, 100, 200, and 400 m depth for the period 1980-1988. A) In the spawning area west of the Hebrides in March/April near position: 58°N, 10°W. B) In the Norwegian Sea in August at the outer station of the Svinøy-NW section, position: 64°40'N, 00°00'E/W.



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 concentrations 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 column, with only minor year to year changes, varying slightly around 9° C (Fig.2a).

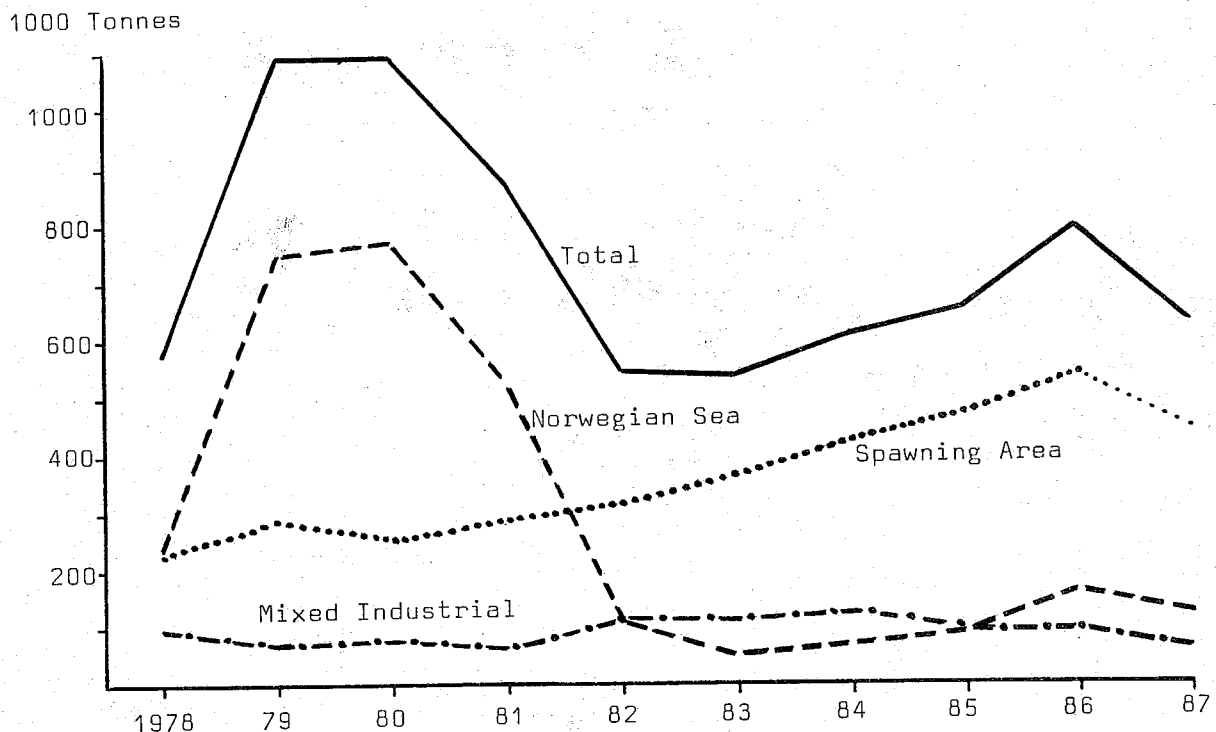


Fig. 3. Annual landings of blue whiting, from the main fisheries and total, of the northern stock, 1978-1987. Source: Working Group Report of 1988.

## 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

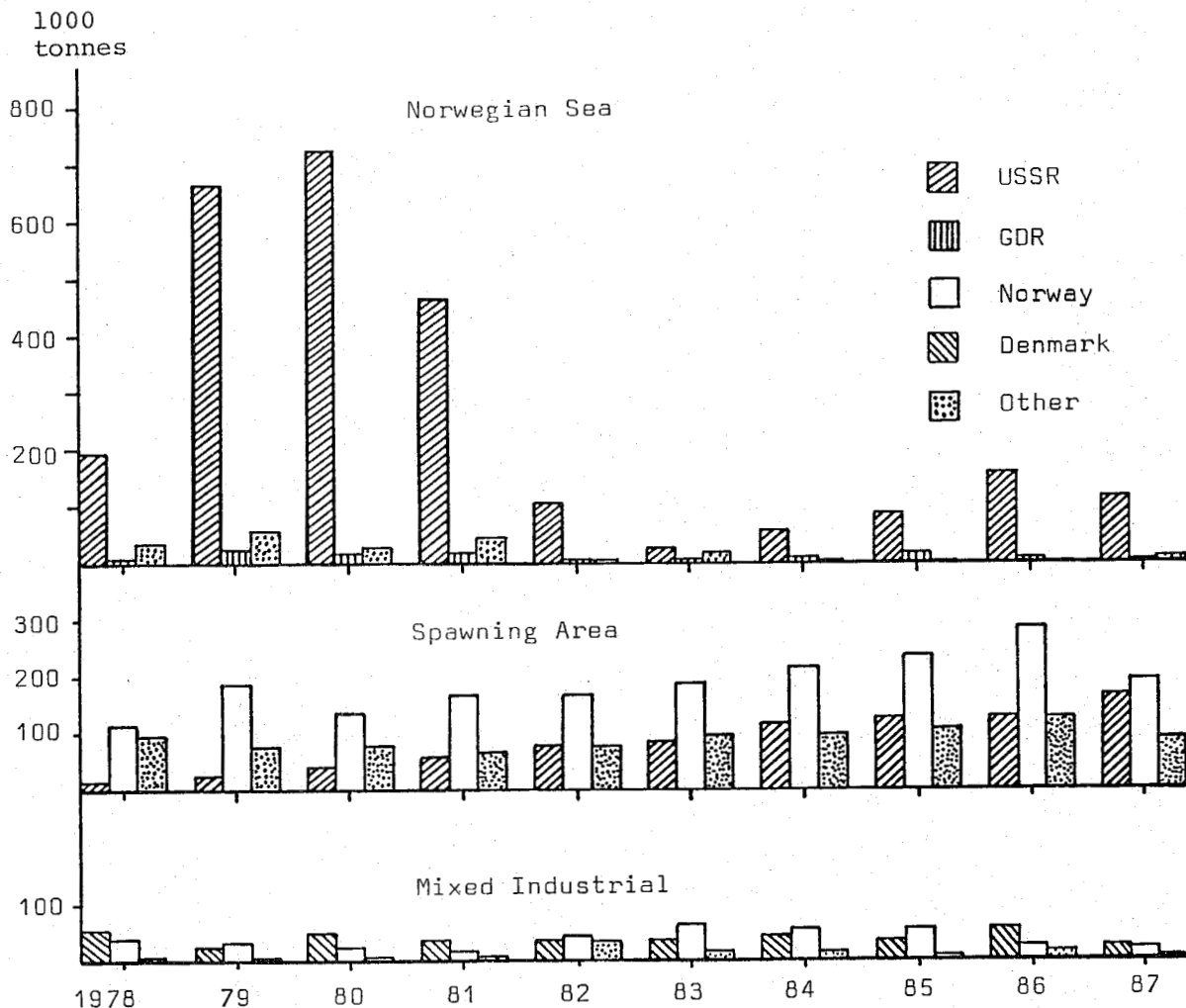


Fig. 4. Annual landings of blue whiting by nations from the main fisheries of the northern stock, 1978-1987. Source: Working Group Report of 1988.

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 extent can 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 the 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

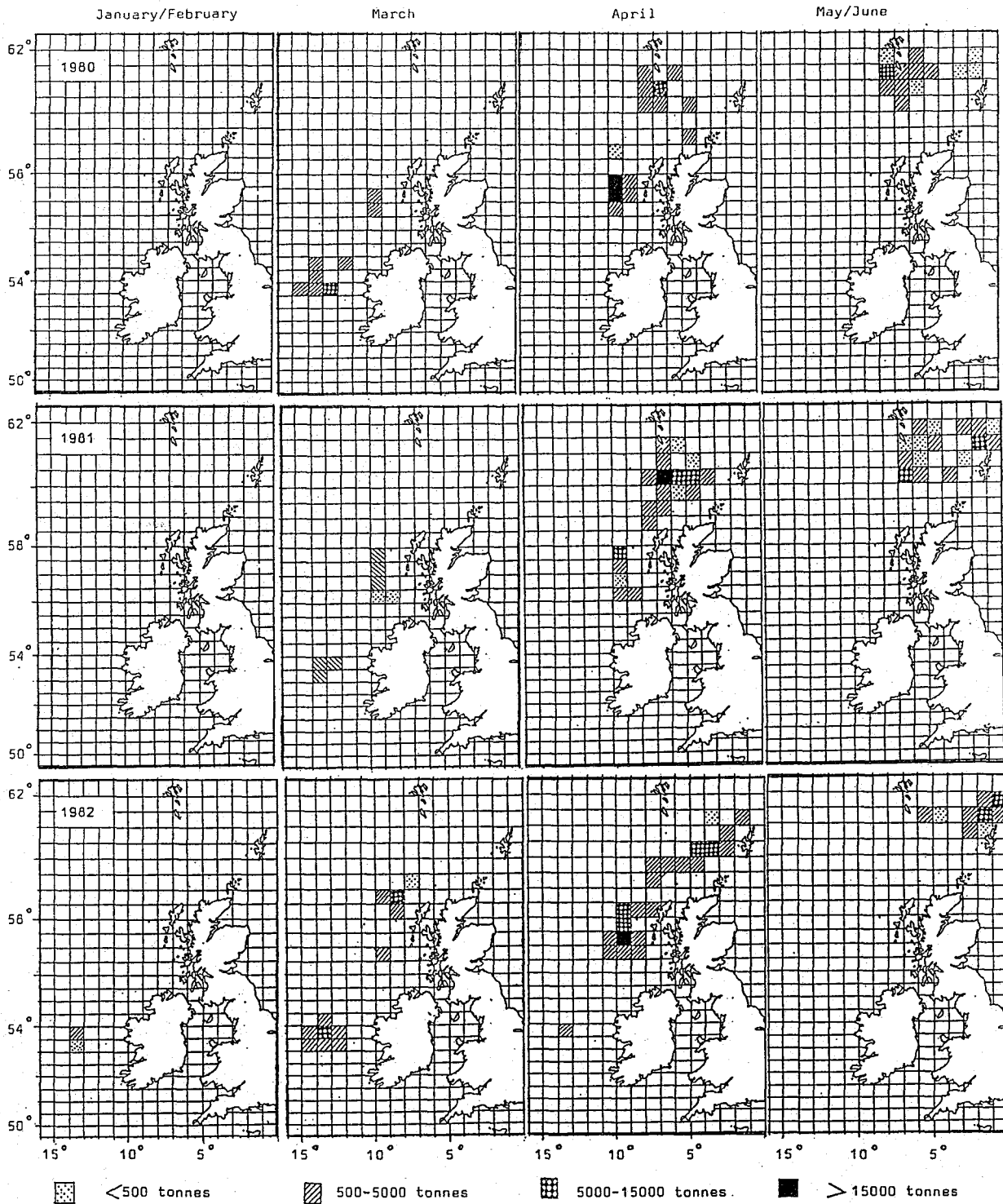


Fig. 5A. Progress of the Norwegian blue whiting fishery in the spawning area, 1980-1982.

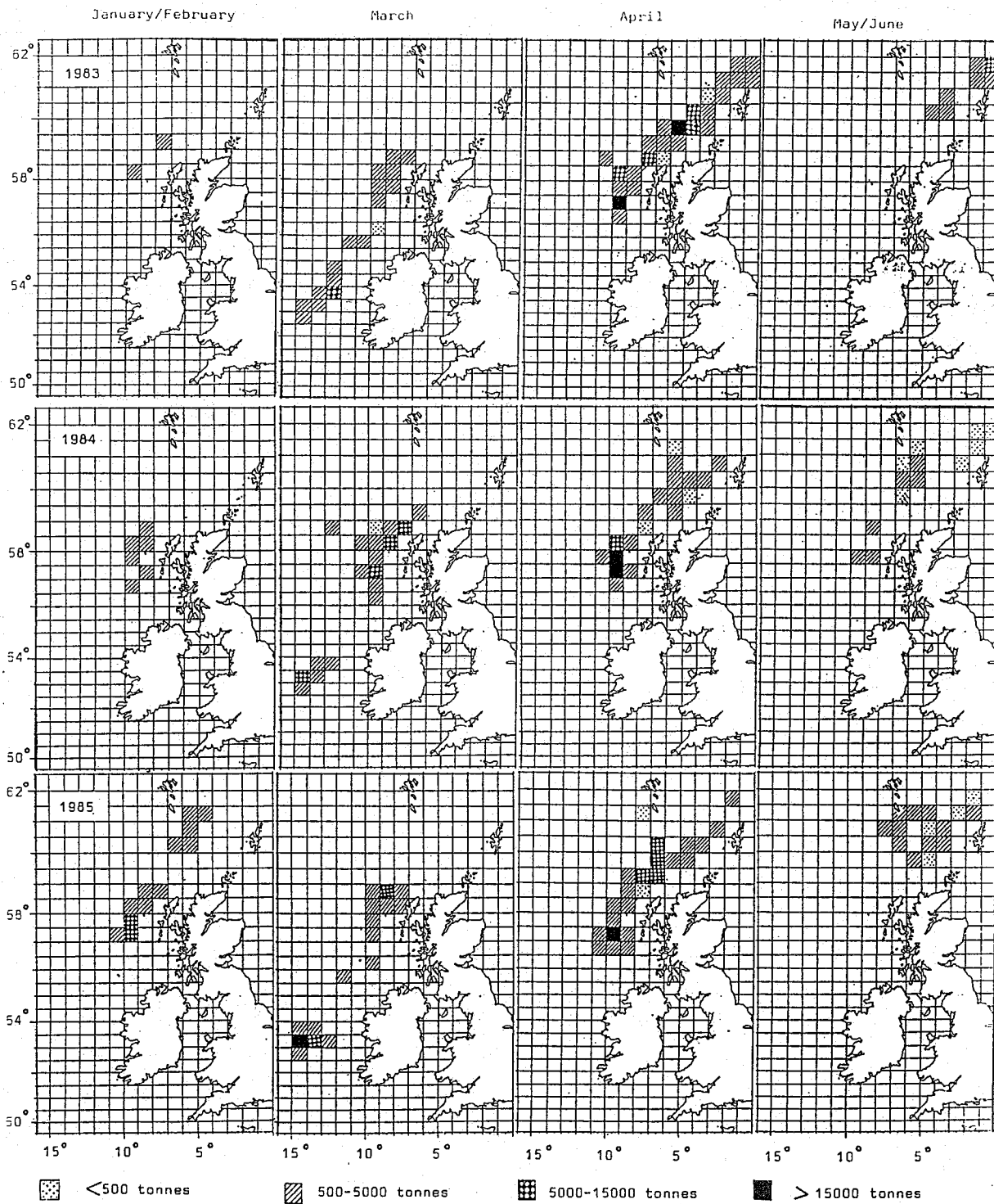


Fig. 5B. Progress of the Norwegian blue whiting fishery in the spawning area, 1983-1985.

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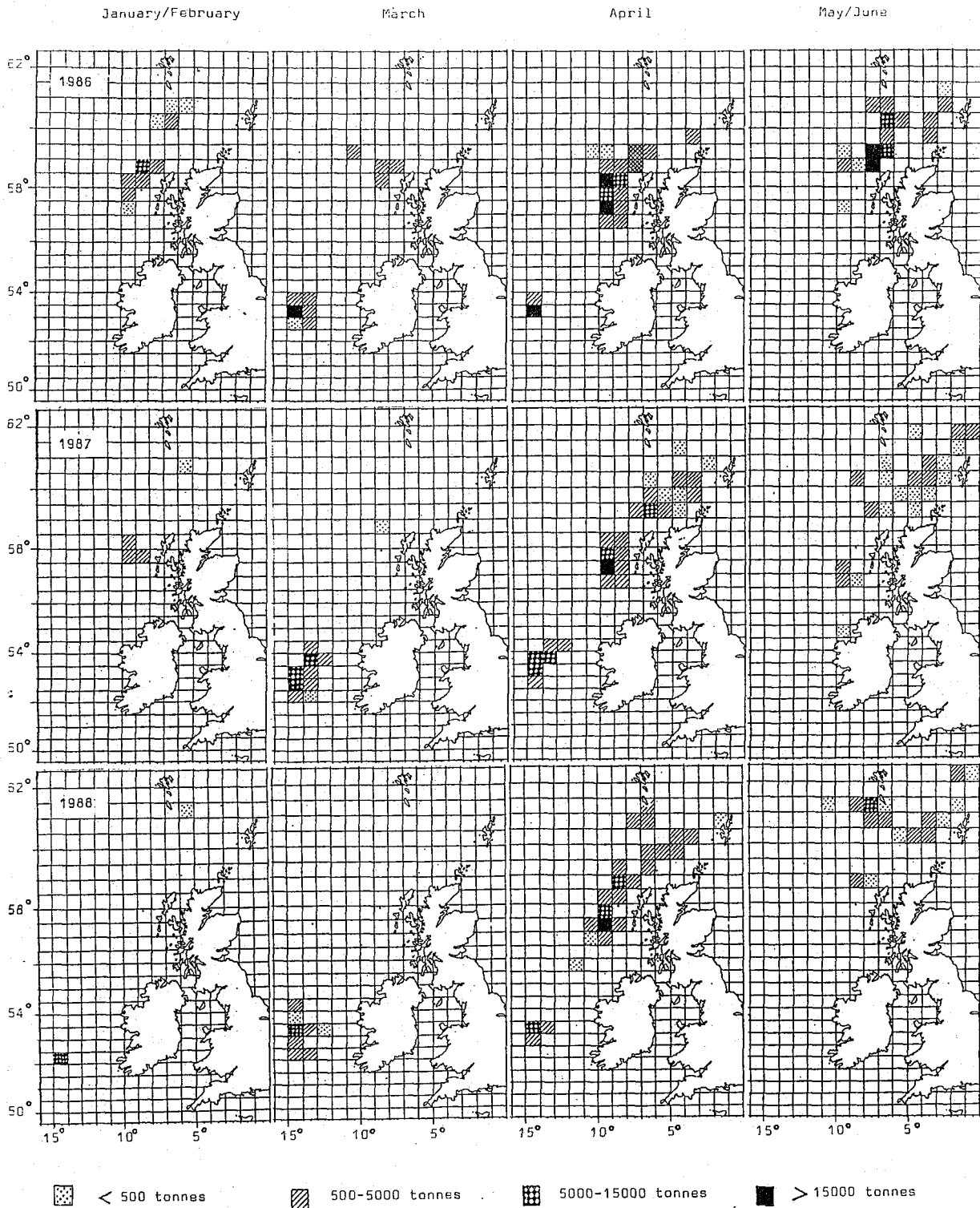


Fig. 5C. Progress of the Norwegian blue whiting fishery in the spawning area, 1986-1988.

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° 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 decrease 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 estimates 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 concentrations 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 concentrations to a great extent confined to the north in an area between Jan Mayen and Bear Island (Fig.6a). In the succeeding years the

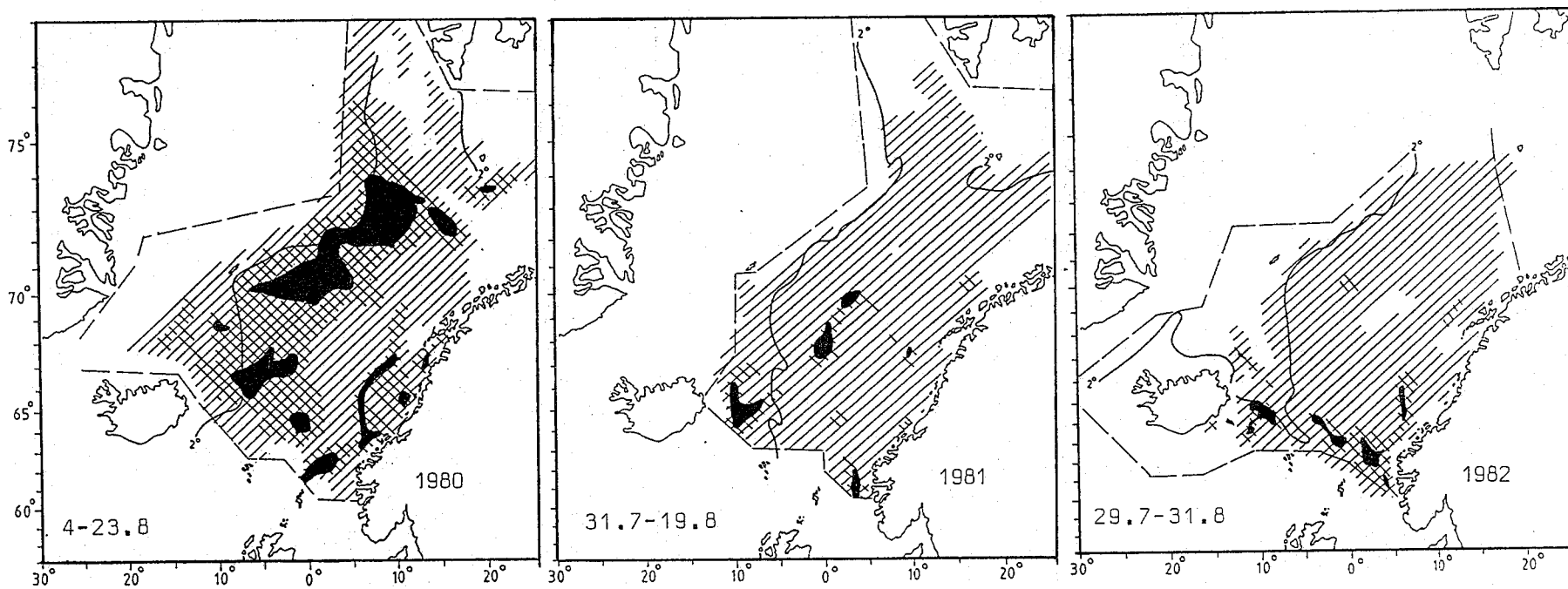


Fig. 6A. Distribution and densities of blue whiting with  $20^{\circ}\text{C}$  isoline at 200 m depth, during summer 1980-1982. Single hatch: area with scattered recordings, double hatch: dense recordings, black: very dense recordings. Stippled line indicates the area surveyed.



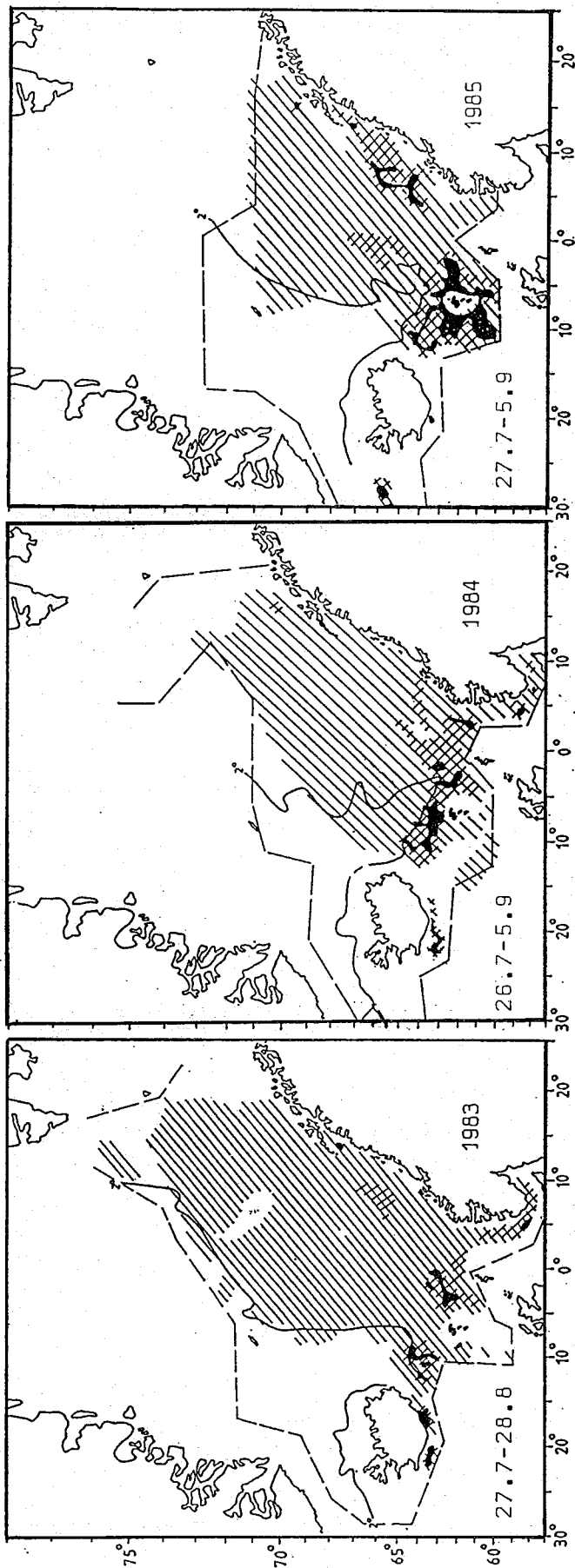


Fig. 6B. Distribution and densities of blue whiting with 2°C isoline at 200 m depth, during summer 1983-1985. Symbols as in Fig. 6A.

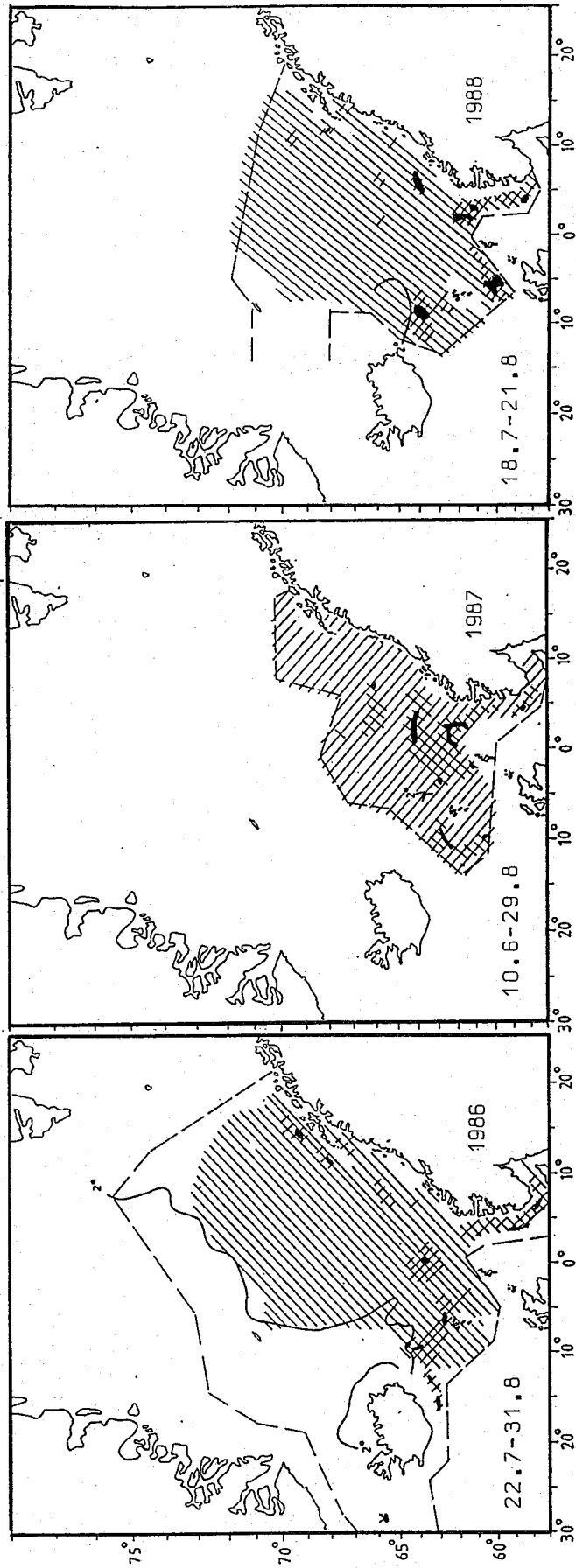


Fig. 6C. Distribution and densities of blue whiting with 20°C isoline at 200 m depth, during summer 1984-1988. Symbols as in Fig. 6A.

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  $2^{\circ}$  -isoline at 200 m depth, especially in the northwestern part in 1981 - 1986. In 1987 and 1988 water of temperature around  $2^{\circ}$  C at 200 m was only observed within a narrow area 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  $64^{\circ}40'$  N  $00^{\circ}00'$  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 column with warmer water from south.

The August temperature in the surface layer varied between  $10^{\circ}$  and  $12^{\circ}$  during the period, while at 400 m it varied from  $0.5^{\circ}$  in 1980 to  $2^{\circ}$  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  $1.9^{\circ}$  in 1983 to  $5.8^{\circ}$  in 1986, dropped to  $3.5^{\circ}$  the next year and then increased radically to  $6.2^{\circ}$  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  $0.5^{\circ}$  -  $2^{\circ}$  higher temperature level.

The distribution pattern in the feeding area to a great extent is influenced by the availability 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 Arctic water with temperature below  $3^{\circ}$  C the Arctic 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

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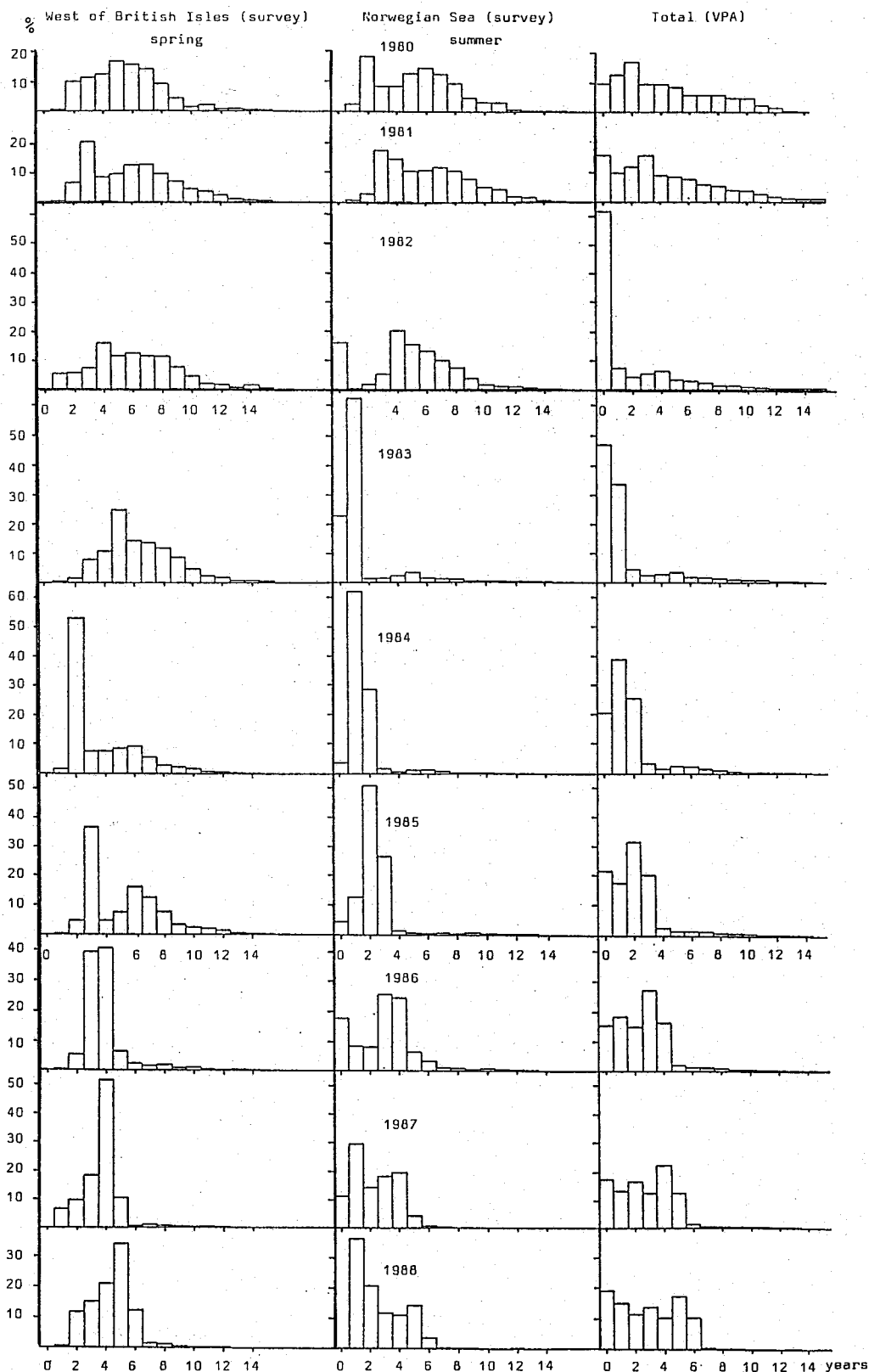


Fig. 7. Age composition (N%) of blue whiting in the period 1980-1988 in the spawning stock west of the British Isles during spring, in the stock recorded in the Norwegian Sea during summer and in the total stock as calculated by VPA.

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 congregations 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.

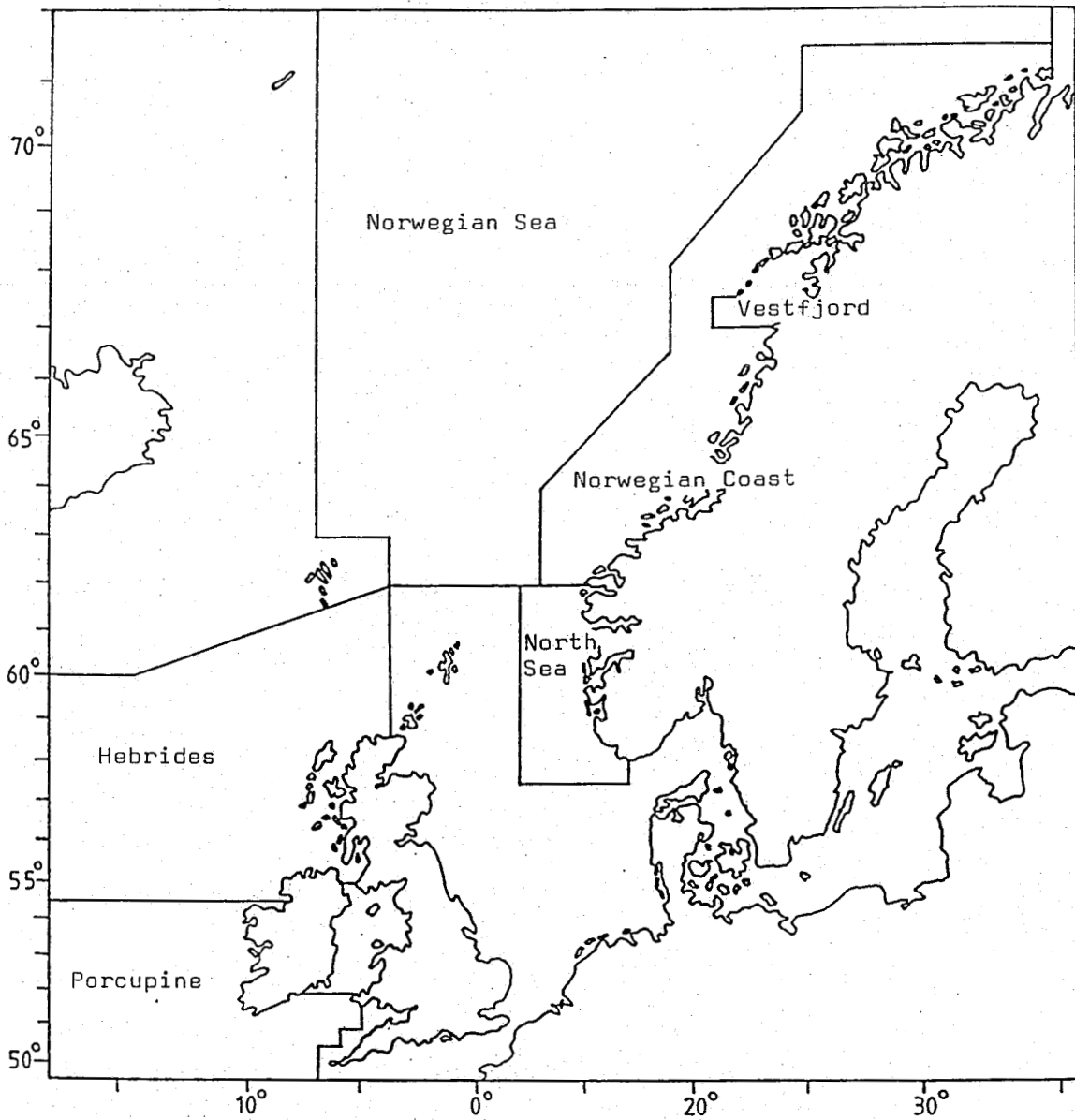


Fig. 8. Borders of the six different areas mentioned in the text.

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 to be very similar in the various areas. After 5 years the growth diversified 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 British 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

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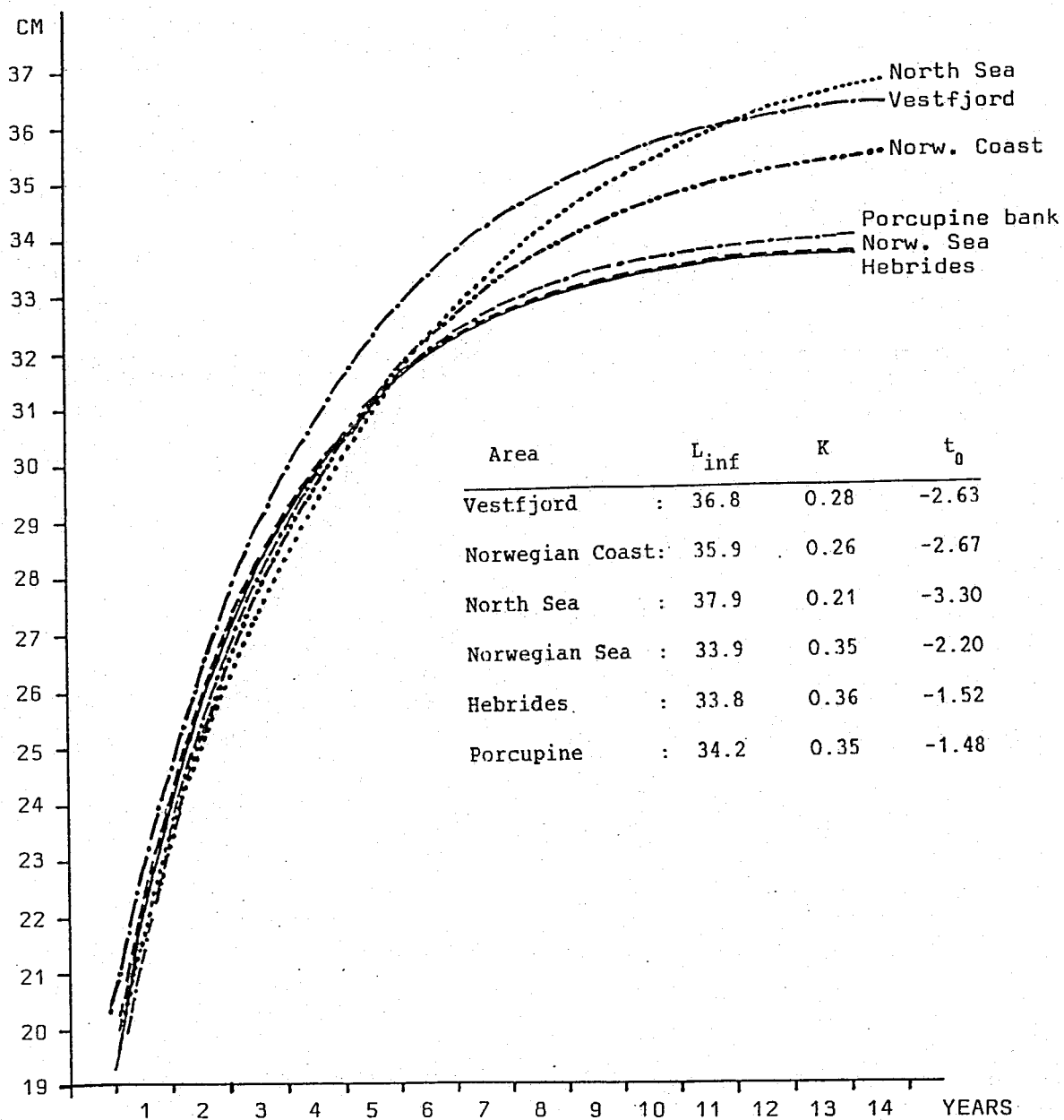


Fig. 9. von Bertalanffy's growth curves and parameters of blue whiting, combined sexes, from six different areas in the North-east Atlantic.



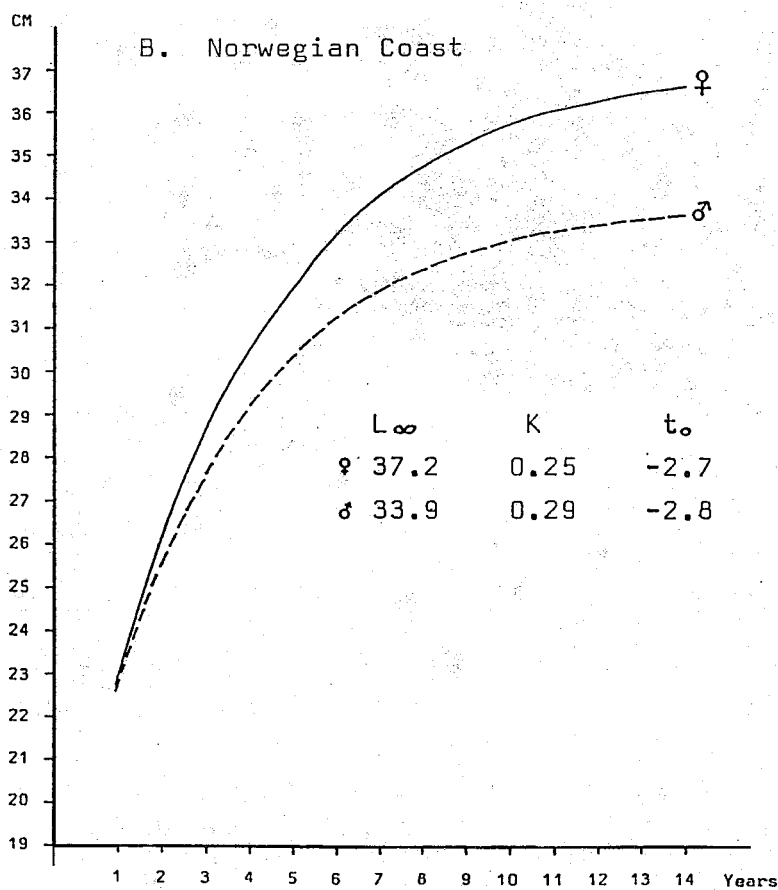
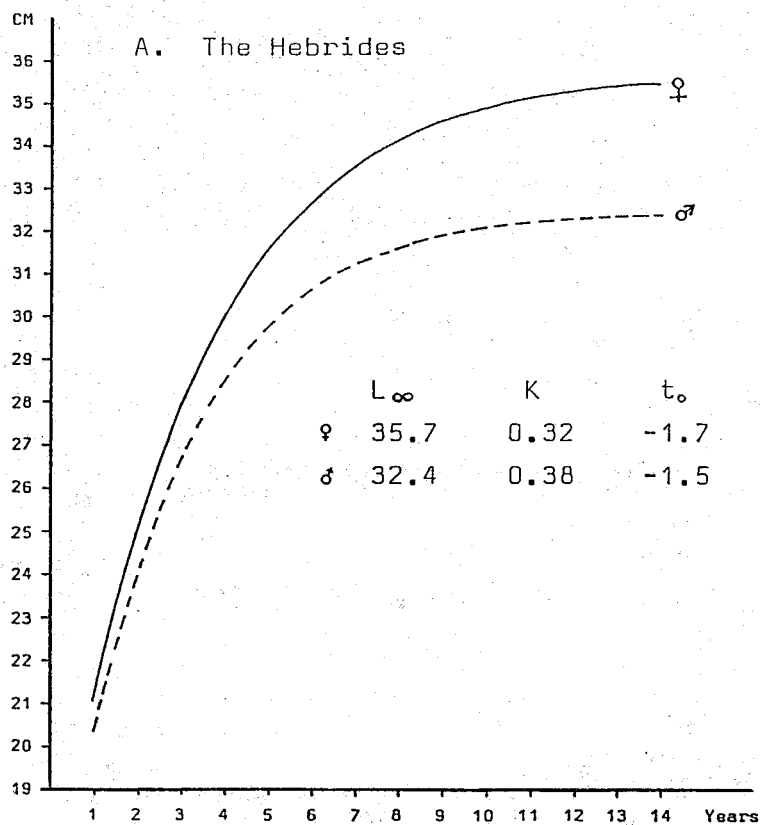


Fig. 10. von Bertalanffy's growth curves and parameters of blue whiting, male and female from A) the Hebrides and B) the Norwegian Coast.

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 growth 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 from 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 presumably 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 approximately 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 diversified, 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 fit to the von Bertalanffy'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.

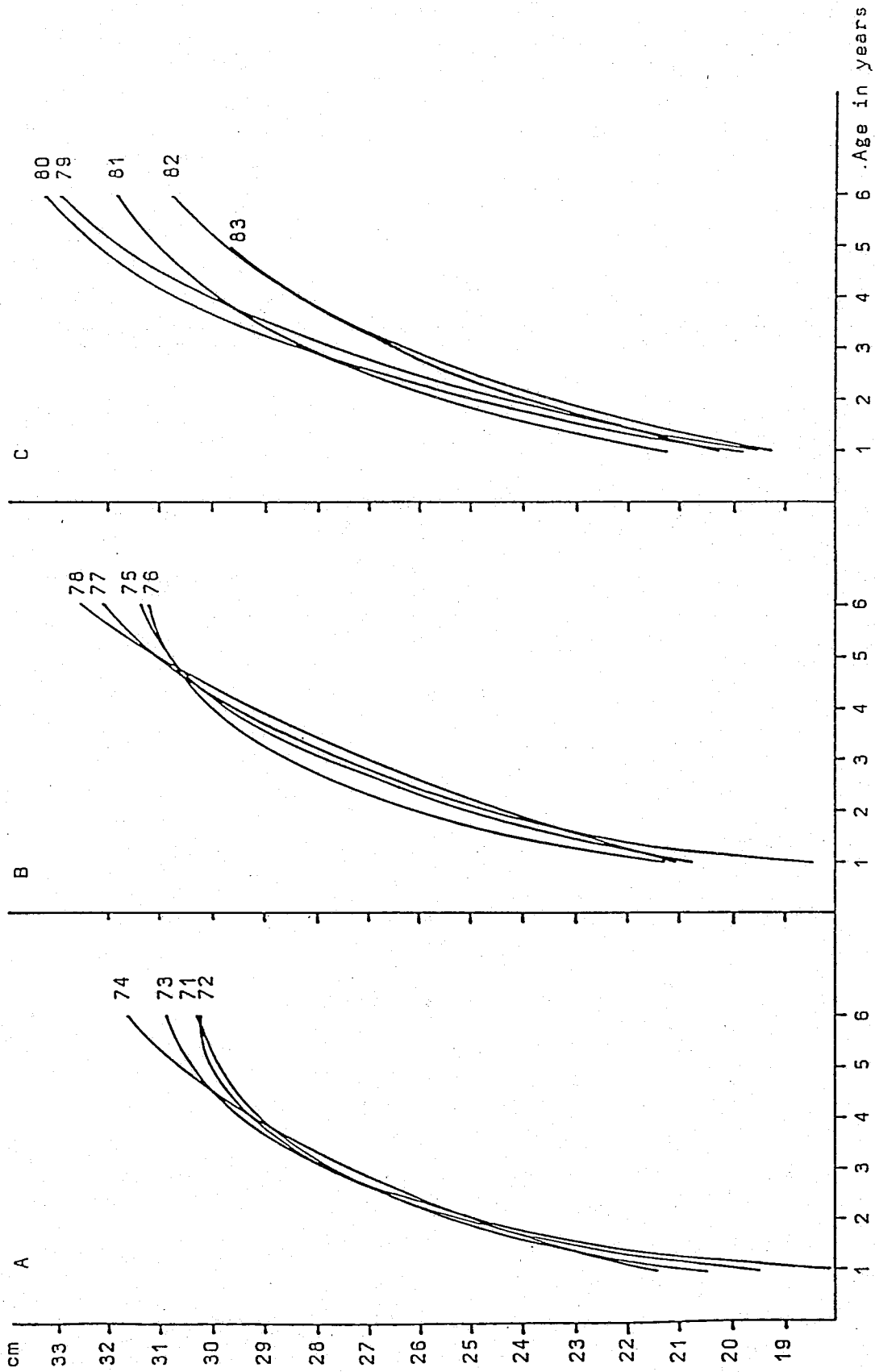


Fig. 11. von Bertalanffy's growth curves of blue whiting, combined sexes, for the six first years of life as appearing in the Hebrides area for A) the 1971-1974, B) the 1975-1978, and C) the 1979-1983 year classes.

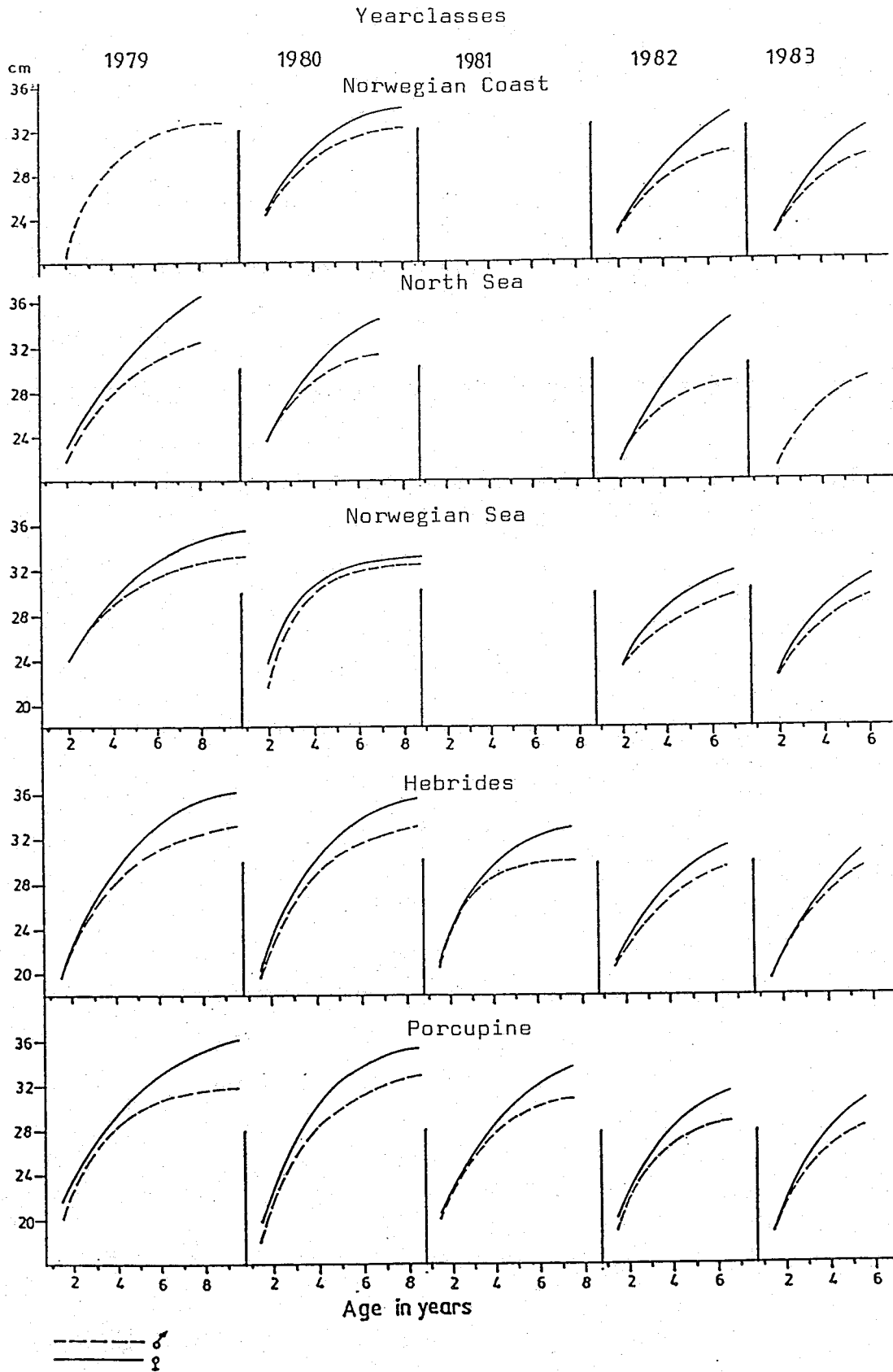


Fig. 12. von Bertalanffy's growth curves of the 1979-1983 year classes of blue whiting, males and females, as appearing five different areas during the last decade.

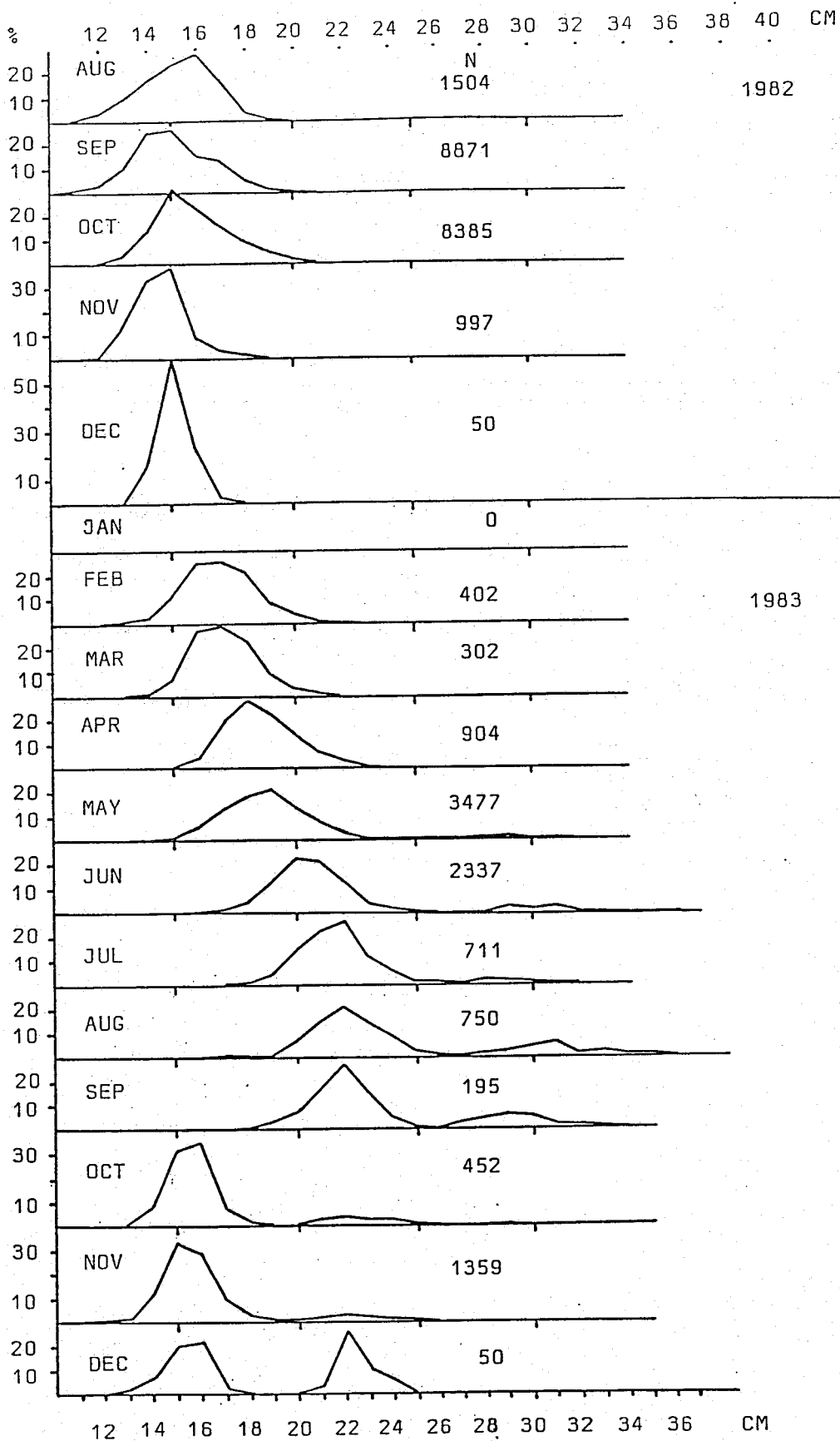


Fig. 13A. Length distribution (N%) by month of blue whiting in samples from the mixed industrial fishery in the North Sea, 1982 and 1983.

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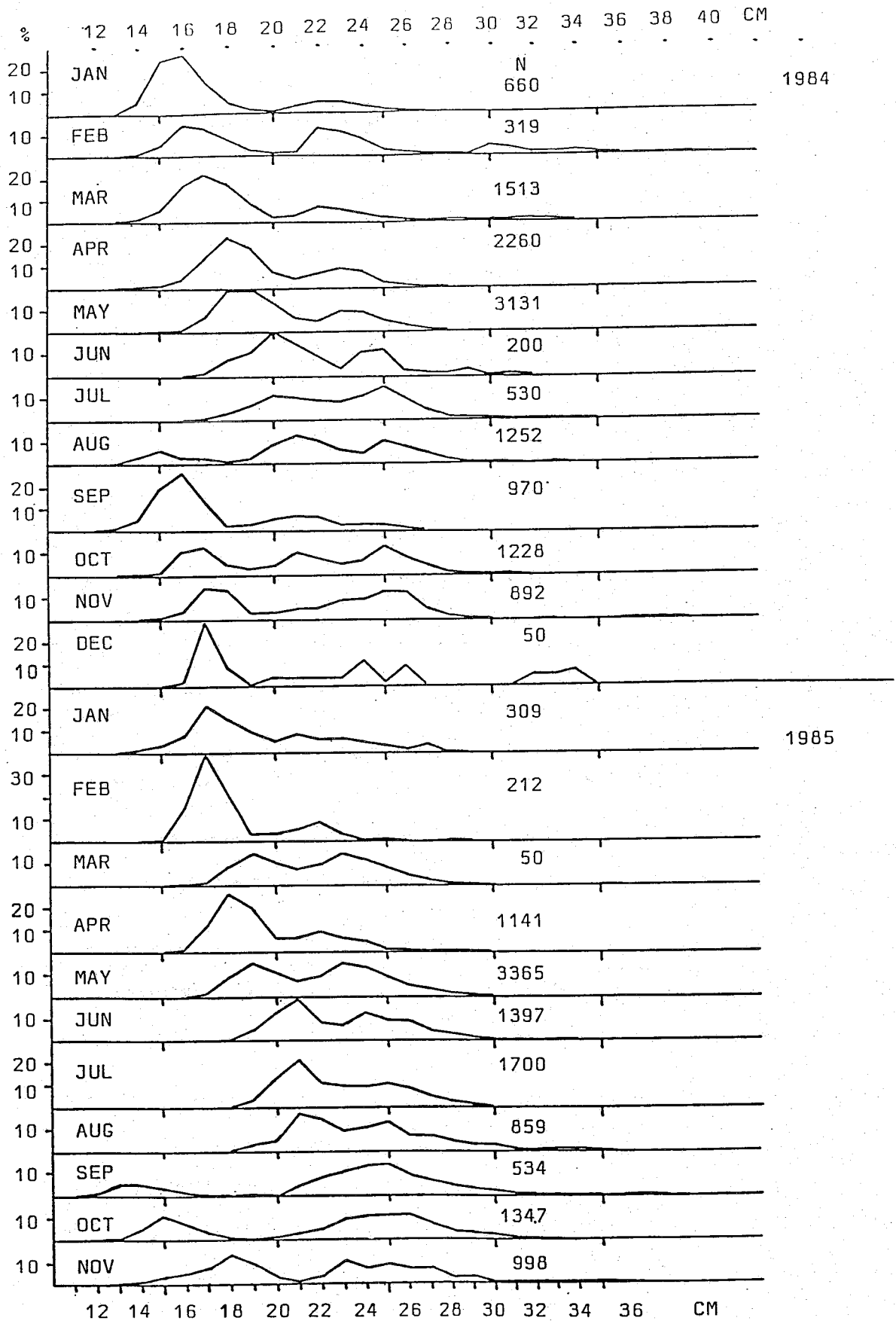


Fig. 13B. Length distribution (N%) by month of blue whiting in samples from the mixed industrial fishery in the North Sea, 1984 and 1985.

2) For juveniles in the North Sea.

Blue whiting recruits to the fishery already in its first year of life, in general as 0-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 0-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	

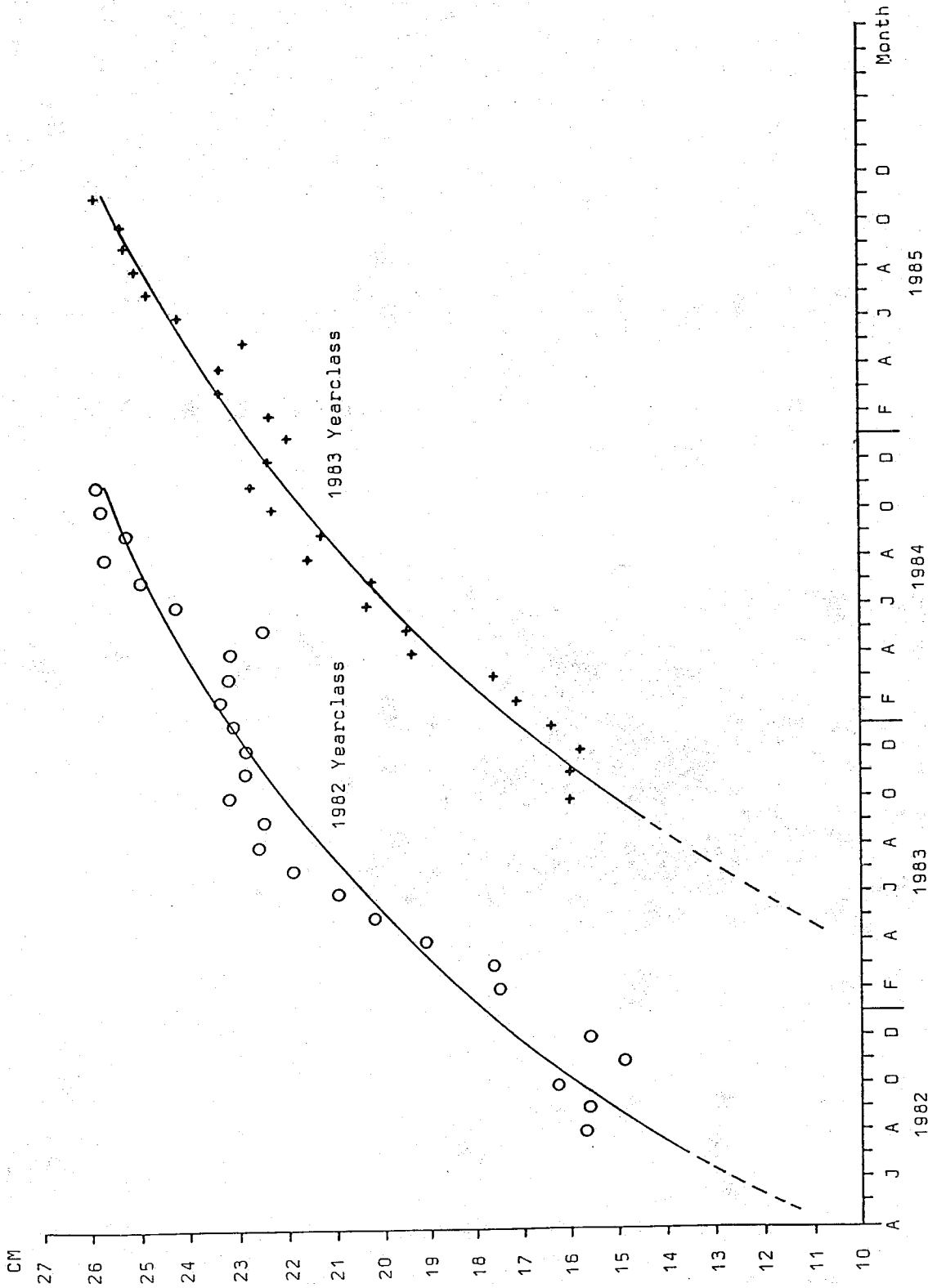


Fig. 14. von Bertalanffy's growth curves for the first three years of life of the 1982 and 1983 year classes, based on samples from the mixed industrial fishery in the North Sea.



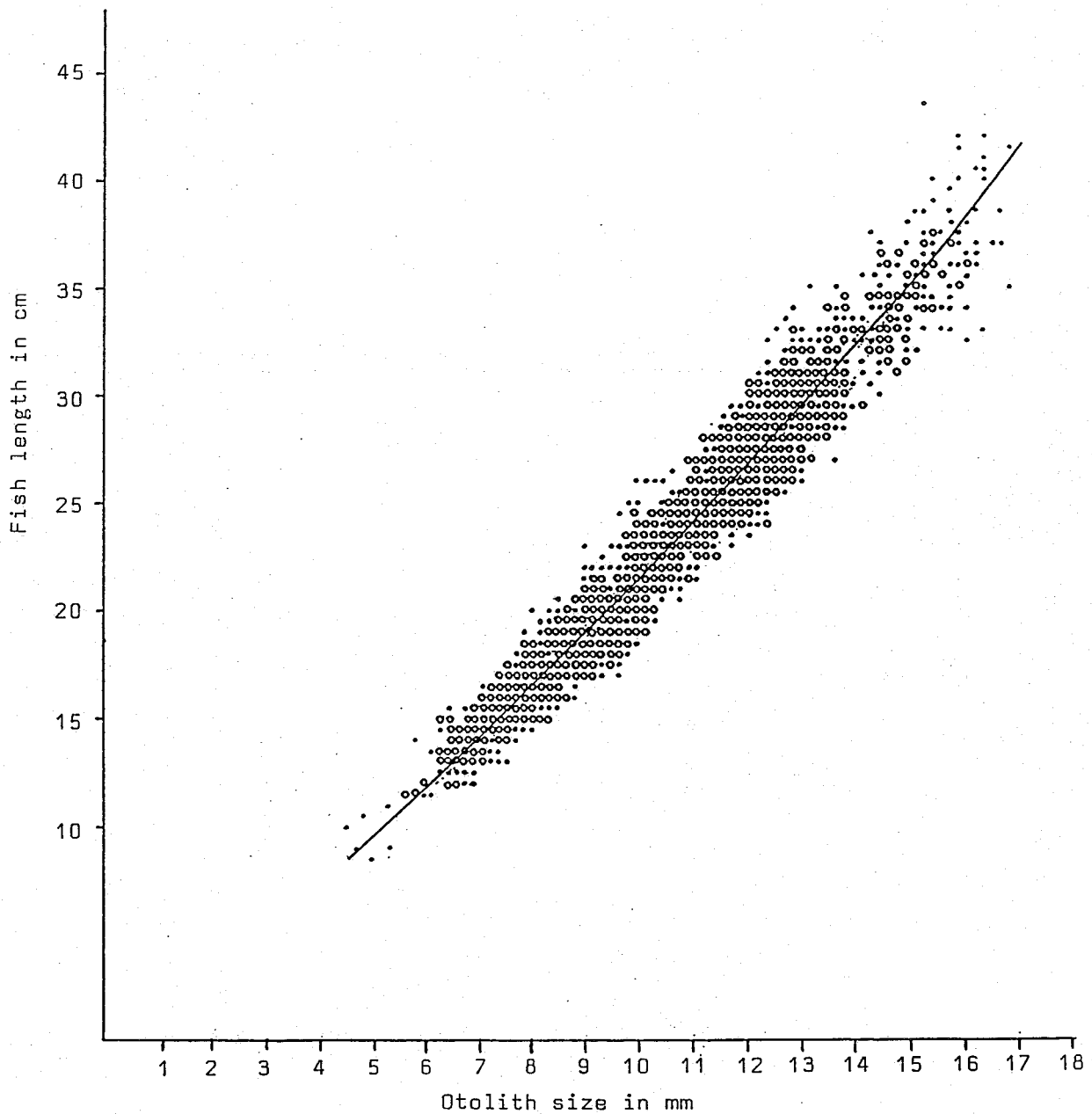


Fig. 15. Fish length-otolith size relationship of blue whiting, based on approximately 1000 specimen. The curve is drawn by hand and used for "backcalculation". Dot represents one and circle more than one specimen.

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 monthly basis (Fig. 14). The data, which is not separated by sex, gave the following equations:

1982-yearclass:

$$l_t = 29.8 (1 - e^{-0.05(t+9.3)})$$

1983-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 "backcalculated" 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 almost 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.

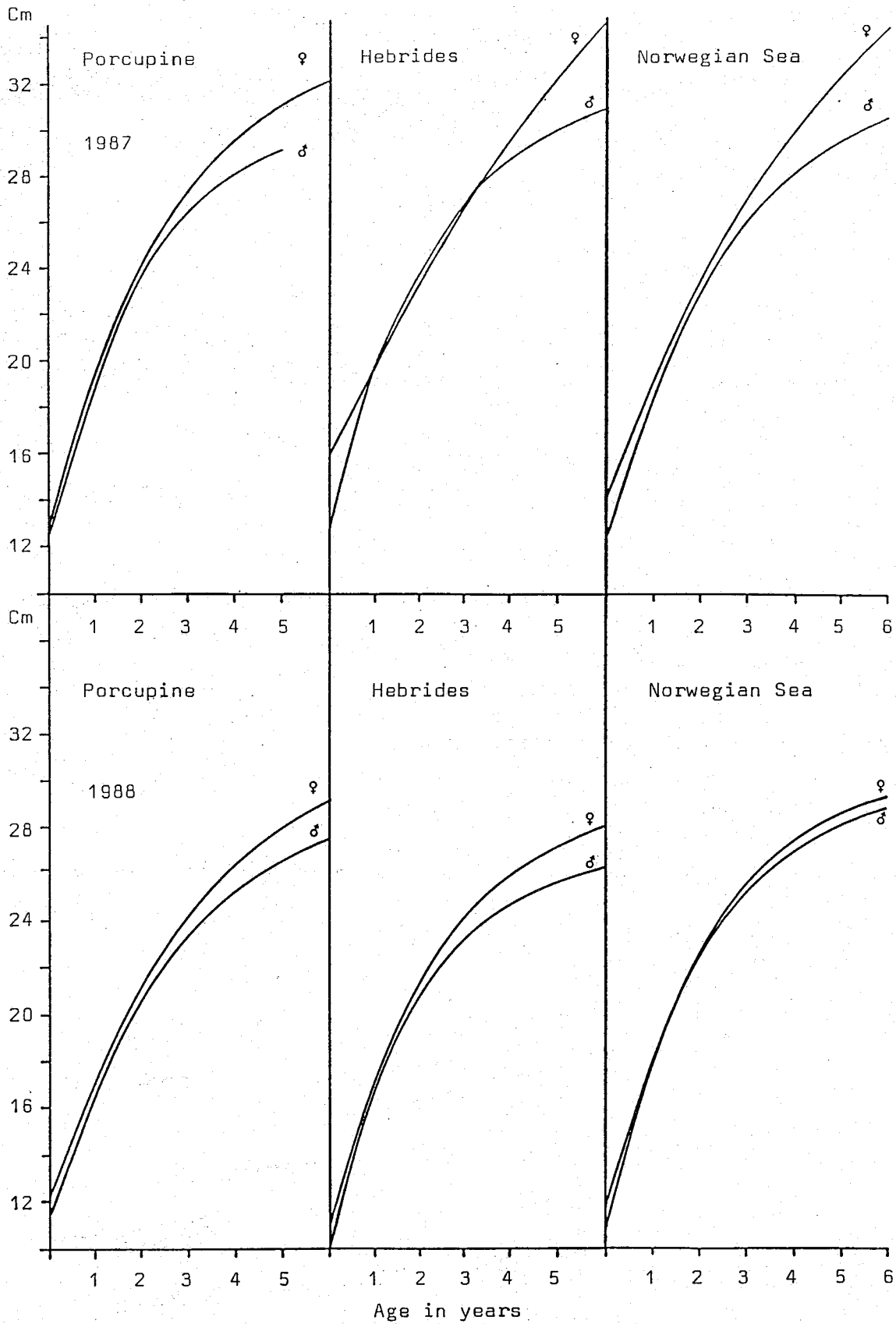


Fig. 16. von Bertalanffy's growth curves based on backcalculated lengths of blue whiting for the first six years of life, males and females, as appearing in three different areas in 1987 (upper half), and in 1988 (lower half).

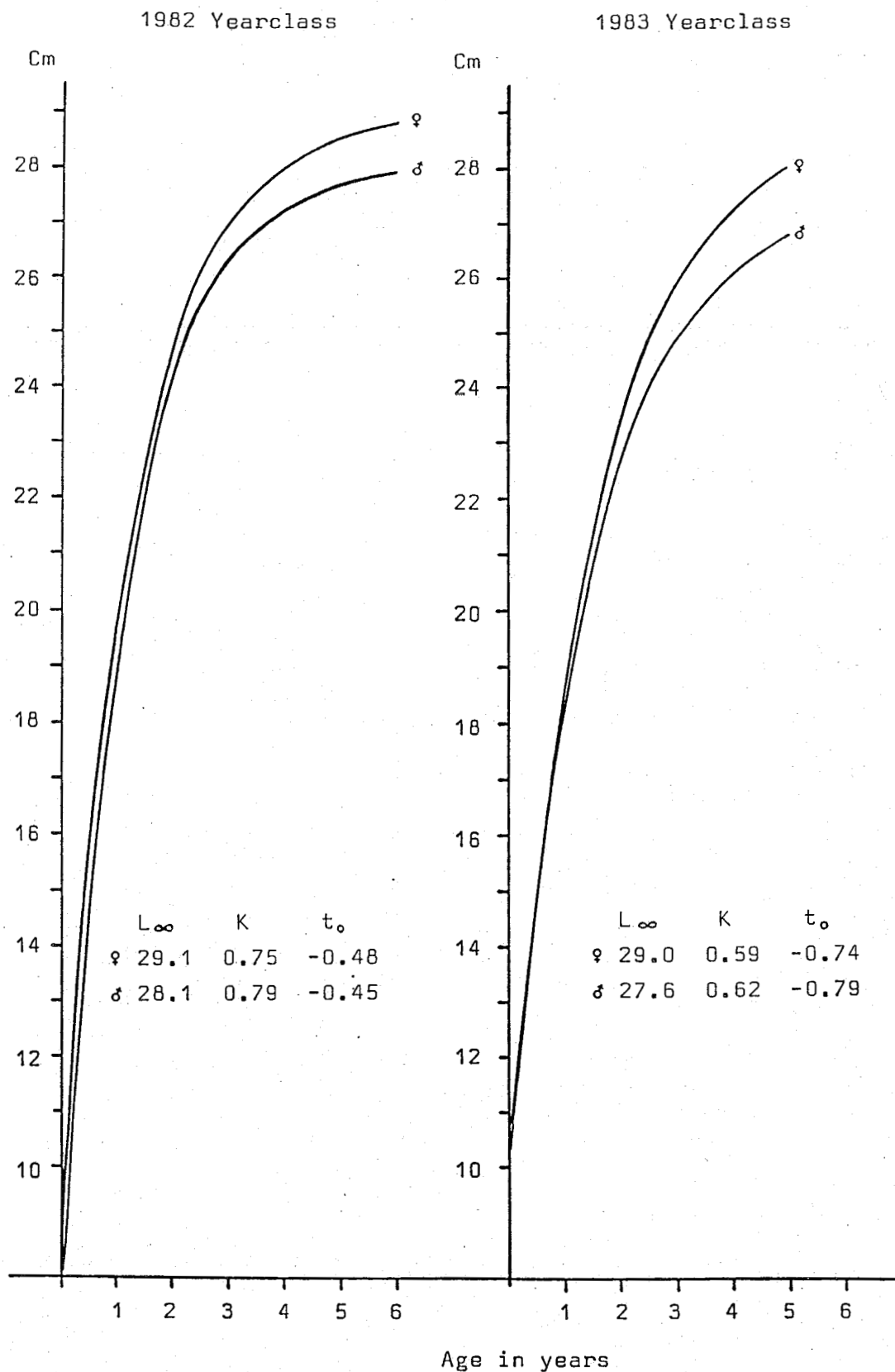


Fig. 17. von Bertalanffy's growth curves and parameters based on backcalculated lengths of the 1982 and 1983 year classes in their 6 and 5 first years of life respectively as appearing in the Hebrides area.

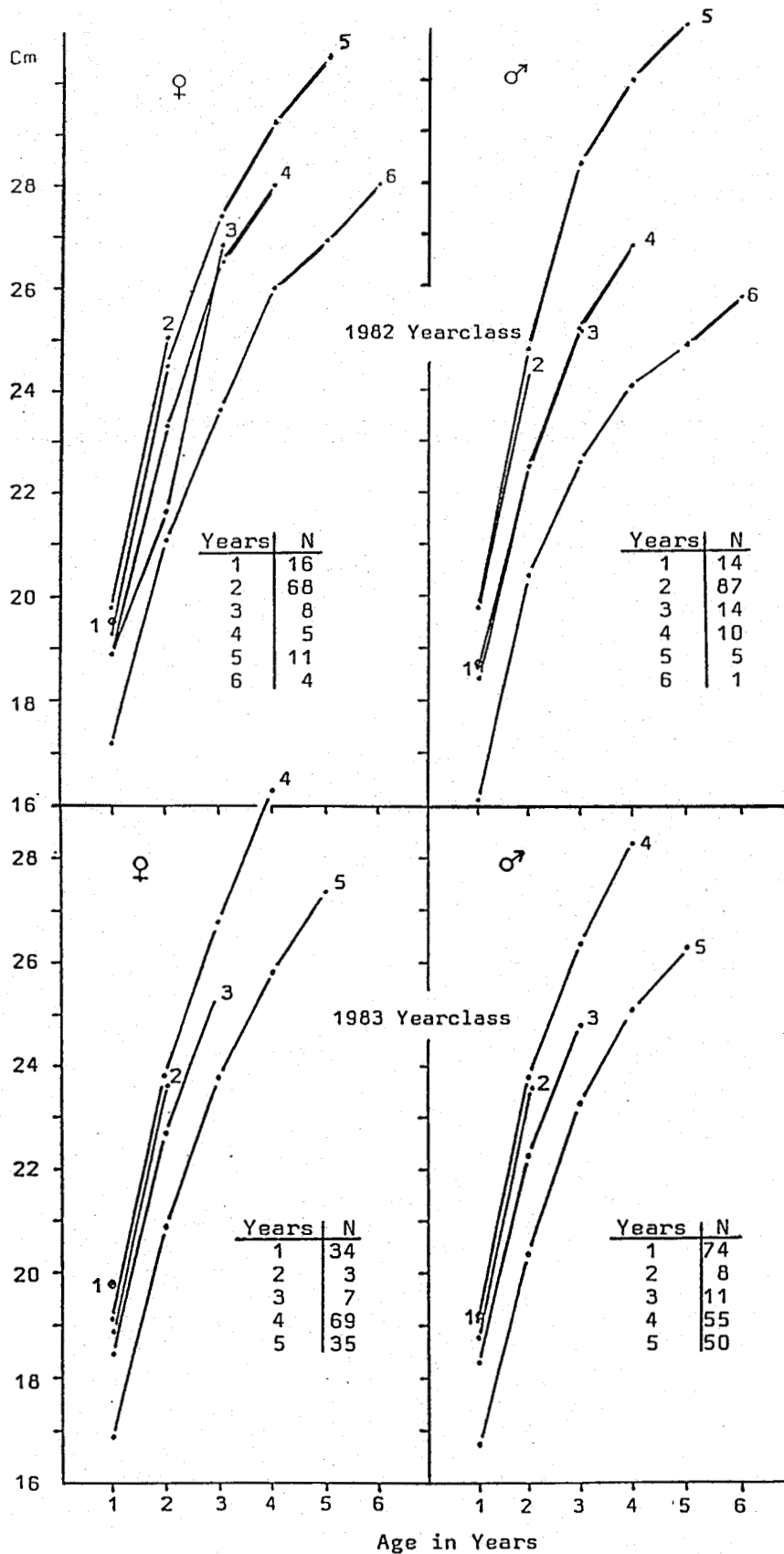


Fig. 18. Backcalculated fish lengths of blue whiting, males and females in the Hebrides area, separate for the 1-6 years age groups of the 1982 year class (upper half) and the 1-5 years age groups of the 1983 year class (lower half).

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 insignificant 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 distribution due to poor number of individuals measured. However, the difference 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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