

SOME ASPECTS OF MORTALITY, CONDITION FACTORS AND LIVER STATE WITH
ANISAKIS-INFECTION IN BLUE WHITING IN THE NORTH-EAST ATLANTIC

by

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

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 (*Micromesistius poutassou*) 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 uncertainties 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).

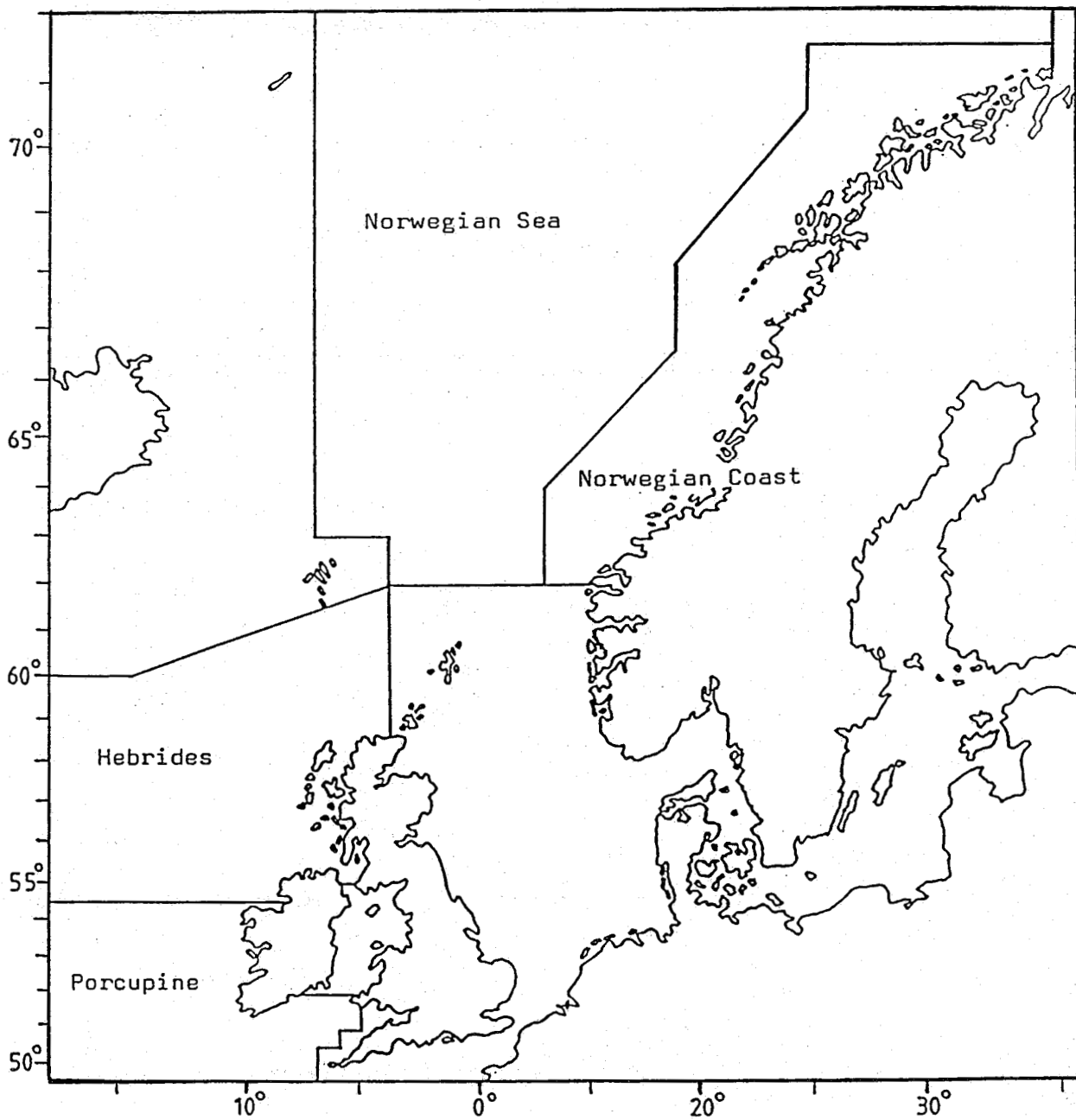


Fig. 1. Borders of areas mentioned in the text.

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

Some aspects of mortality, condition factors and.....

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:

$$C = 1000 \times \text{weight(g)}/\text{length(cm)}^3$$

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.

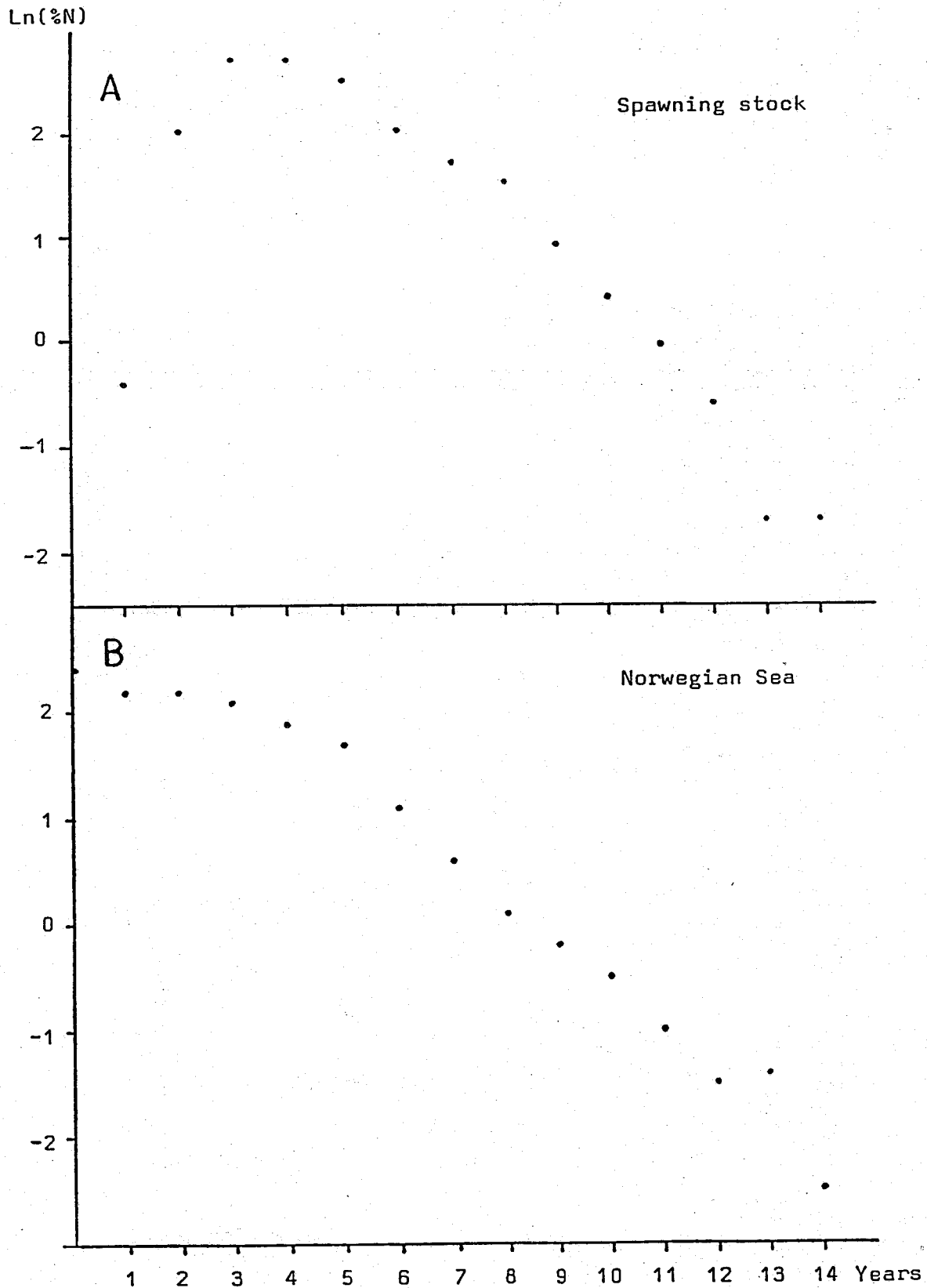


Fig. 2. Mean of natural logarithms of percentage contribution of various age groups against age of blue whiting, 1980-1988. A) In the spawning stock during spring, B) in the stock observed in the Norwegian sea during summer.

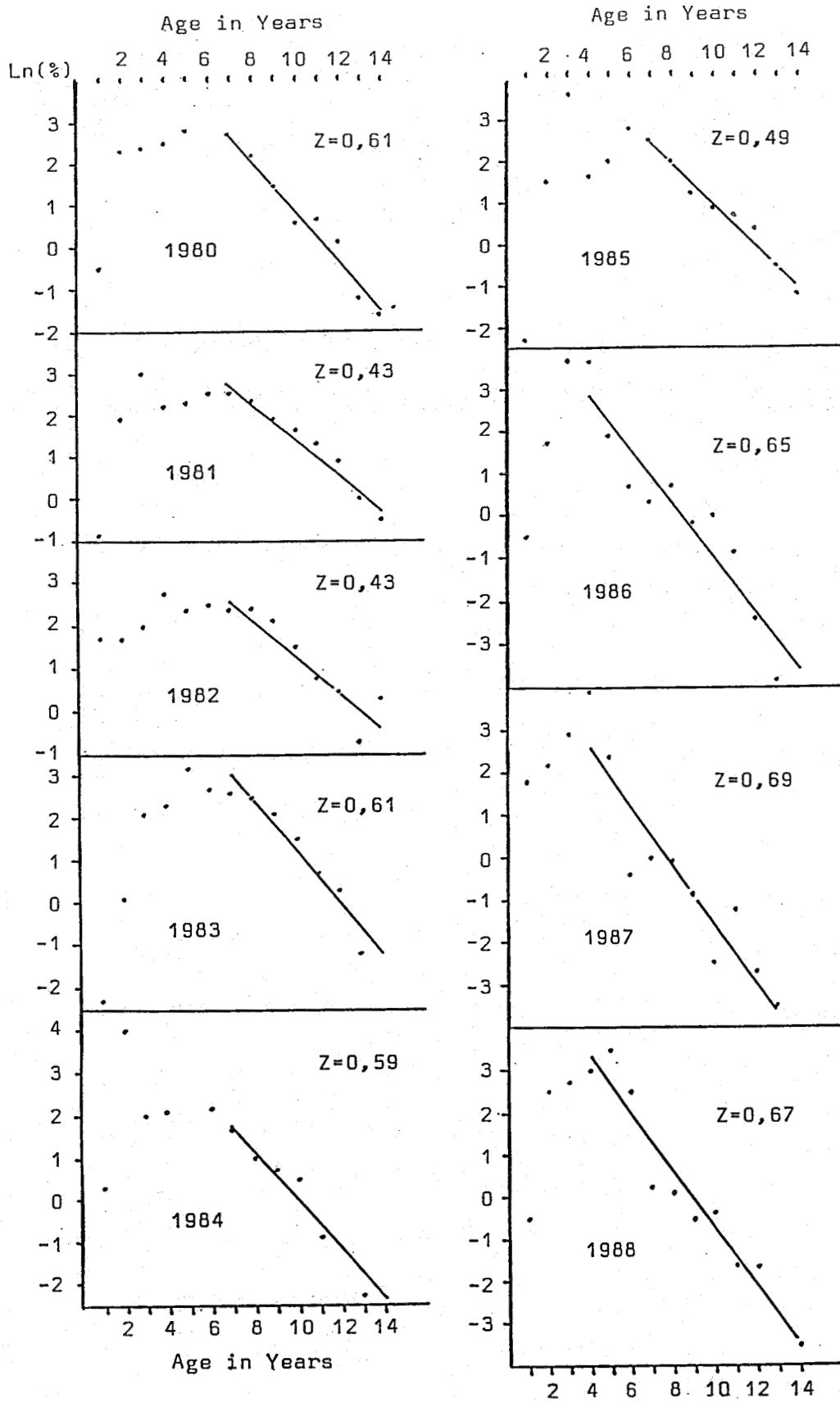


Fig. 3. Natural logarithms of percentage age composition against age in the blue whiting spawning stock during spring 1980-1988, with regression lines fitted to data for ages 7-14 years (1980-85) and ages 4-14 years (1986-88).

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 separate 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 they are even higher than the corresponding Z -values, thus indicating the uncertainties. 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 year. To rely on this method, the population needs to be in an equilibrium 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 equilibrium 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

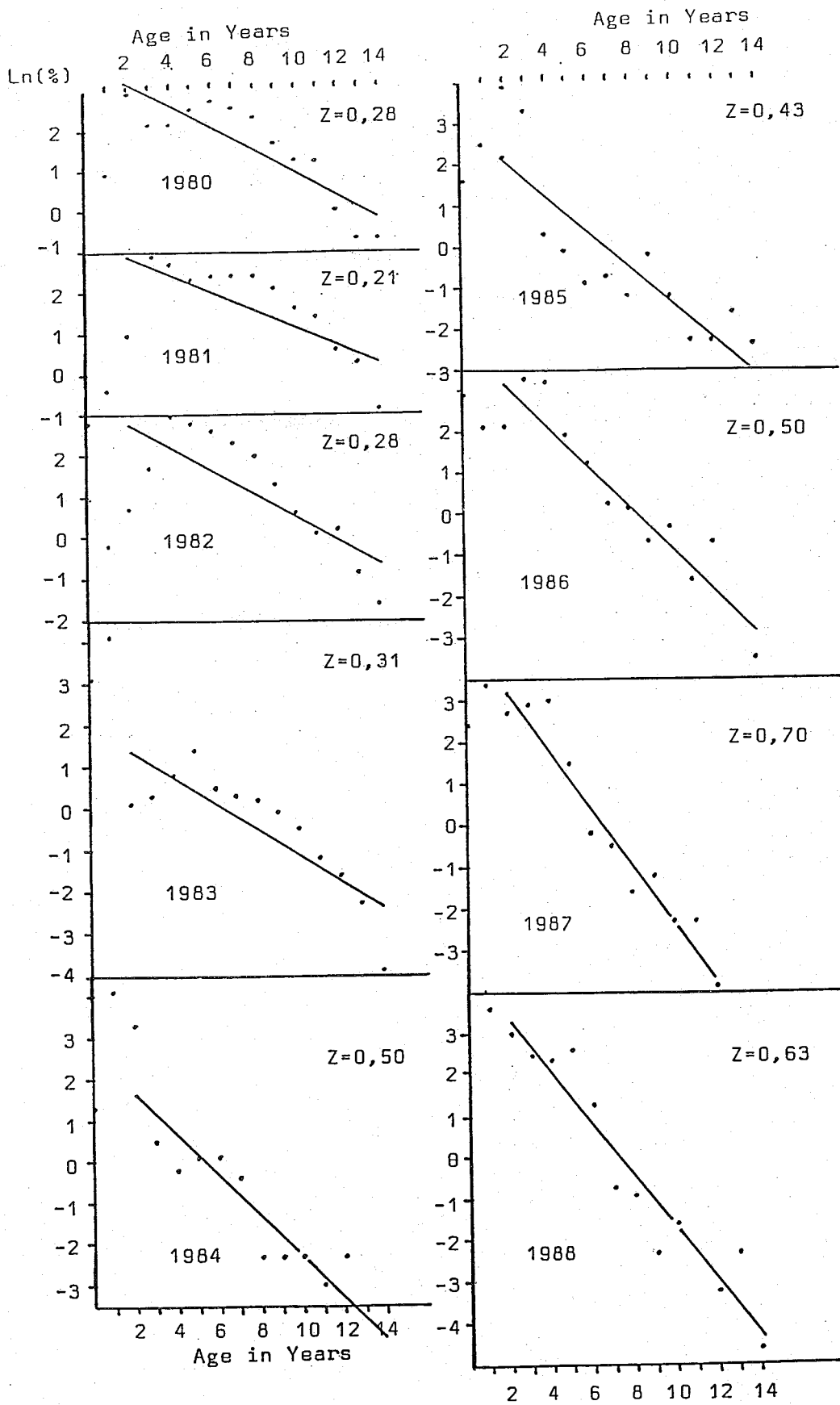


Fig. 4. Natural logarithms of percentage age composition against age in the blue whiting stock observed in the Norwegian Sea during summer 1980-1988, with regression lines fitted to data for ages 2-14 years.

Table 3. Abundance ($N \times 10^{-6}$) at various ages of the 1978 - 1985-yearclasses as observed in the Norwegian Sea during summer.

Age	Yearclasses							
	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).

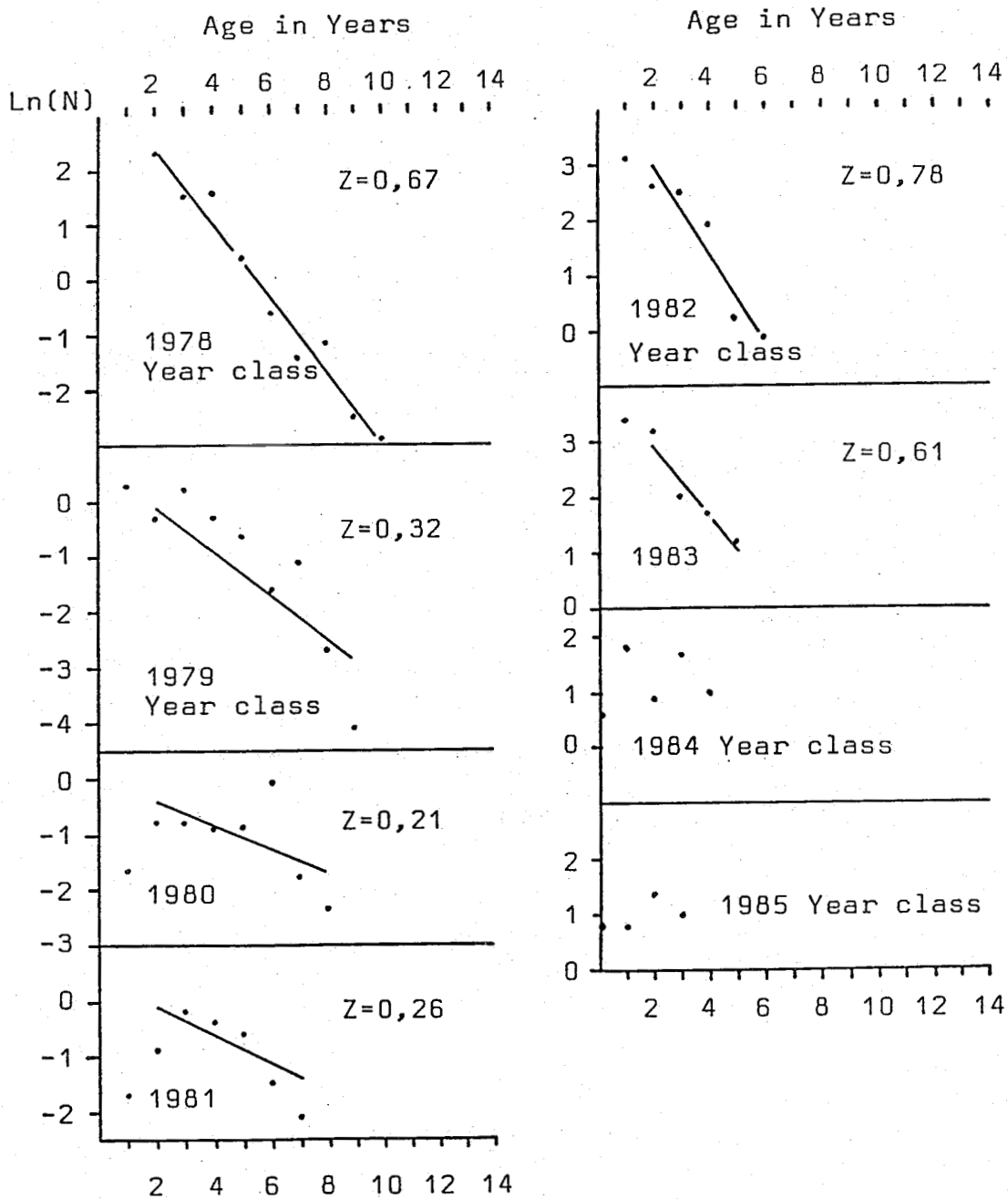


Fig. 5. Natural logarithms of age composition ($N \times 10^{-9}$) against age for the 1978-1985 year classes of blue whiting as observed in the Norwegian Sea during summer. Regression lines fitted to data for 2 years and older age groups for the year classes of 1978-1983.

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 yearclasses. 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.

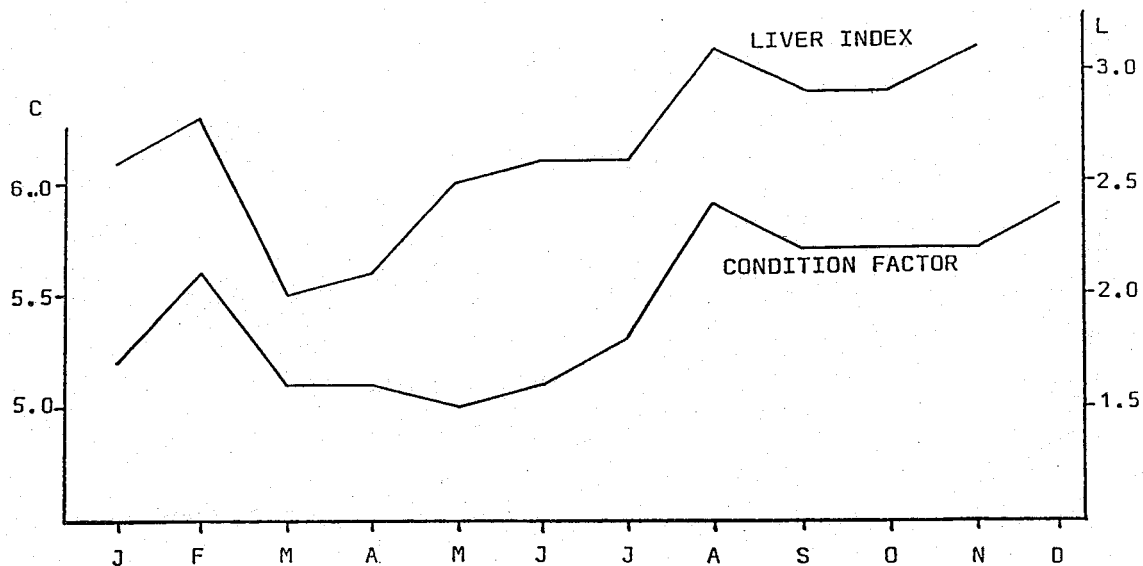


Fig. 6. Monthly mean values of the liver index L and the condition factor C of blue whiting over the period 1982-1988.

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.

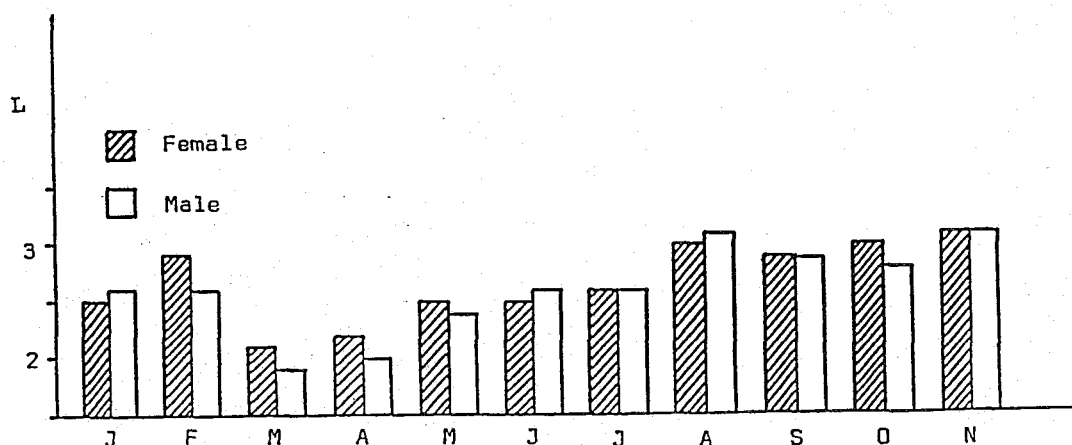


Fig. 7. Monthly mean values of the liver index L by sex of blue whiting over the period 1982-1988.

PARASITES, MORTALITY AND MIGRATION
Some aspects of mortality, condition factors and.....

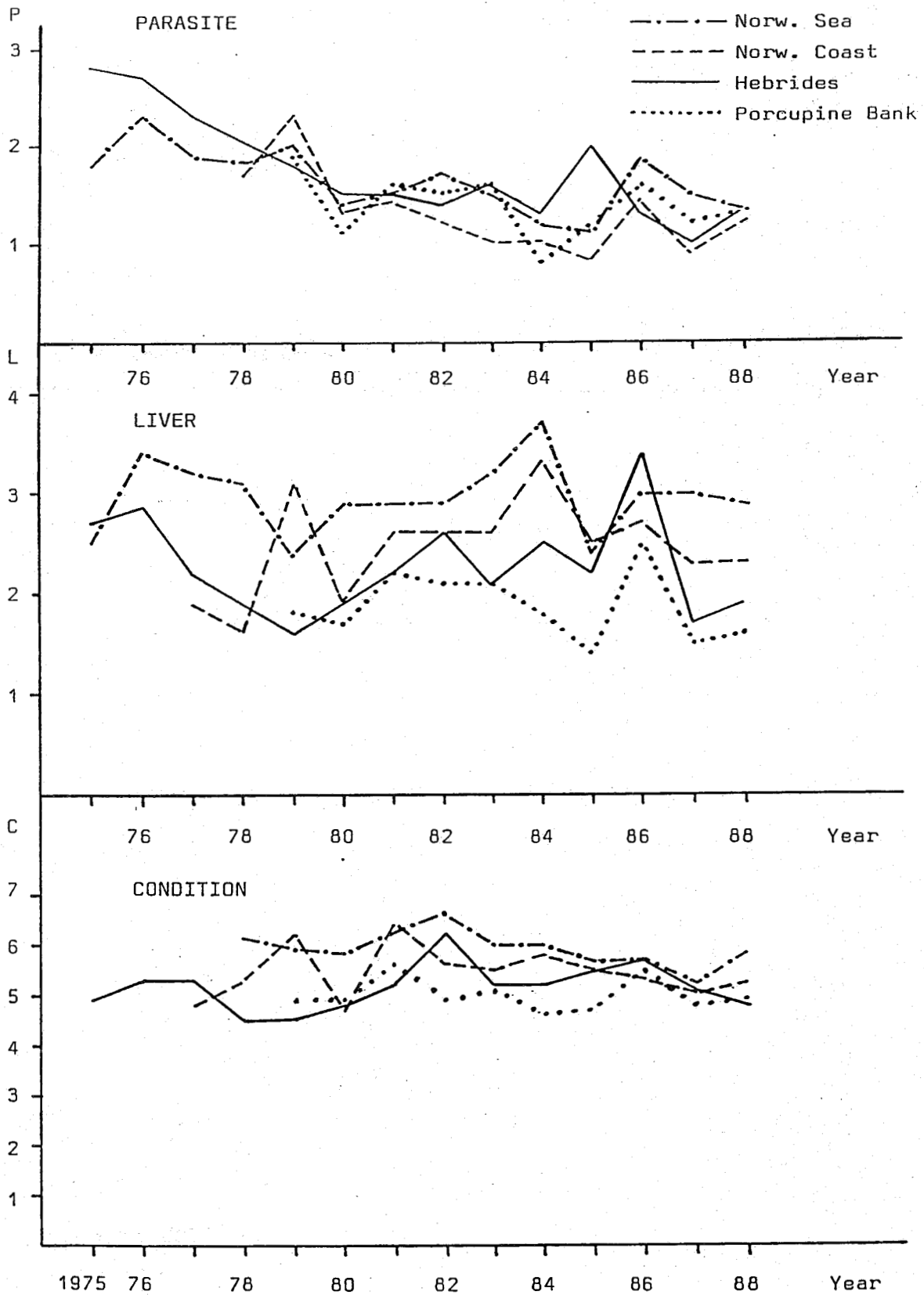


Fig. 8. Annual mean values of the parasite index P (larval Anisakis on liver surface), the liver index L and condition factor C of blue whiting in various areas (Fig. 1) 1975-1988.

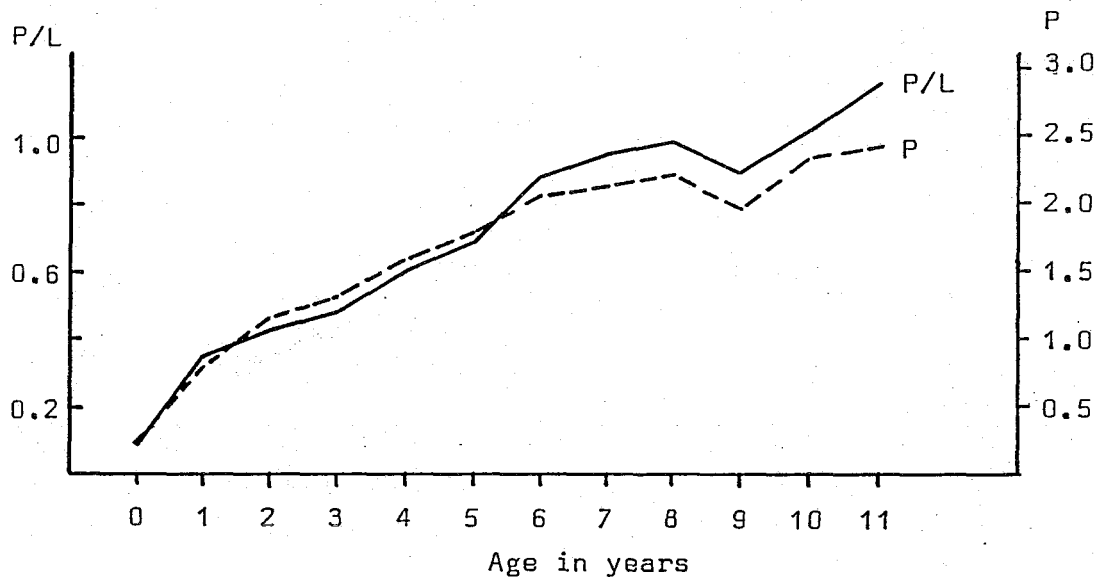


Fig. 9. Mean values of the parasite index P and the ratio between the parasite and liver indices P/L by age of blue whiting.

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.

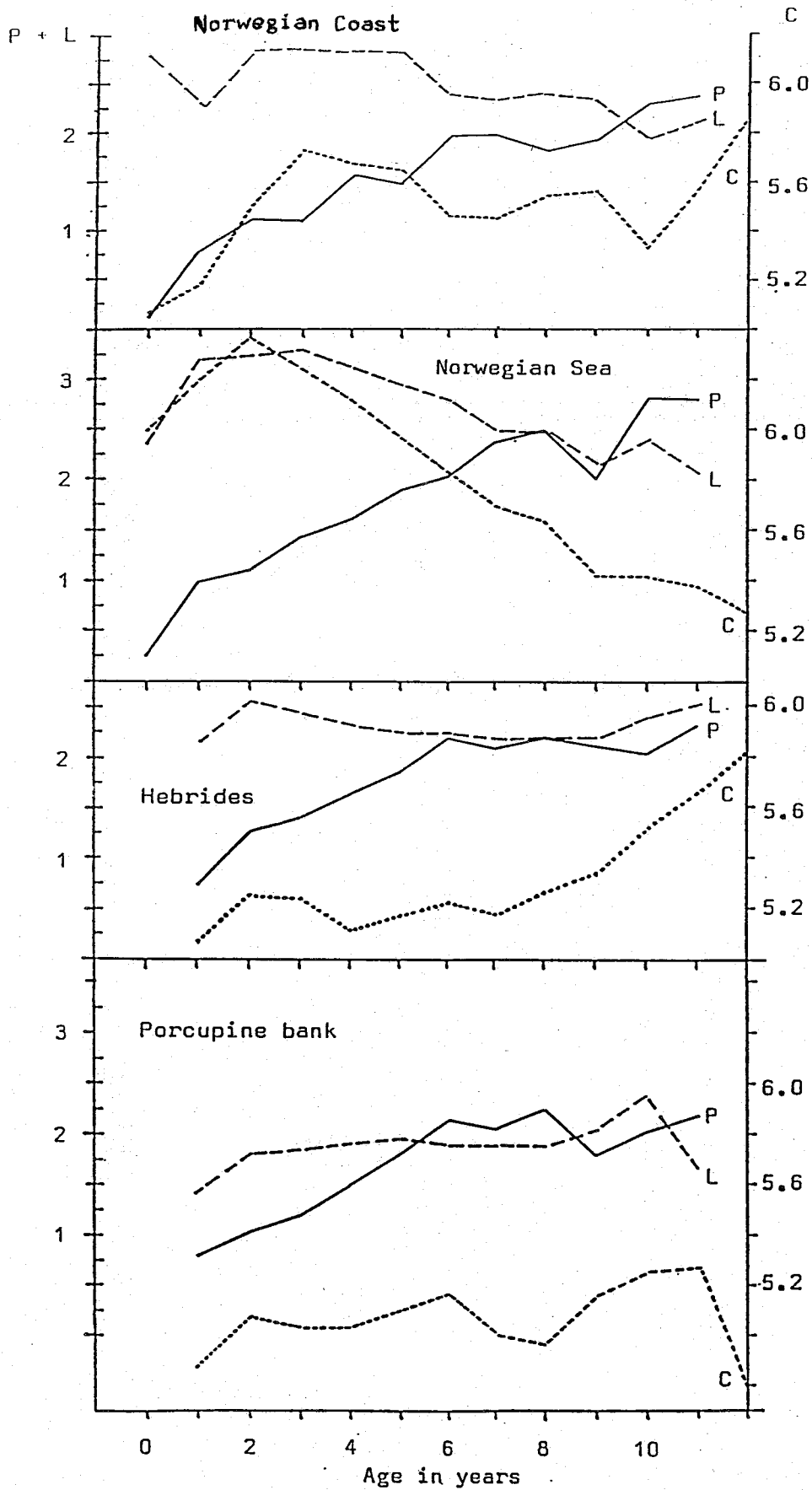


Fig. 10. Parasite index P, liver index L and condition factor C by age of blue whiting in various areas 1970-1987.

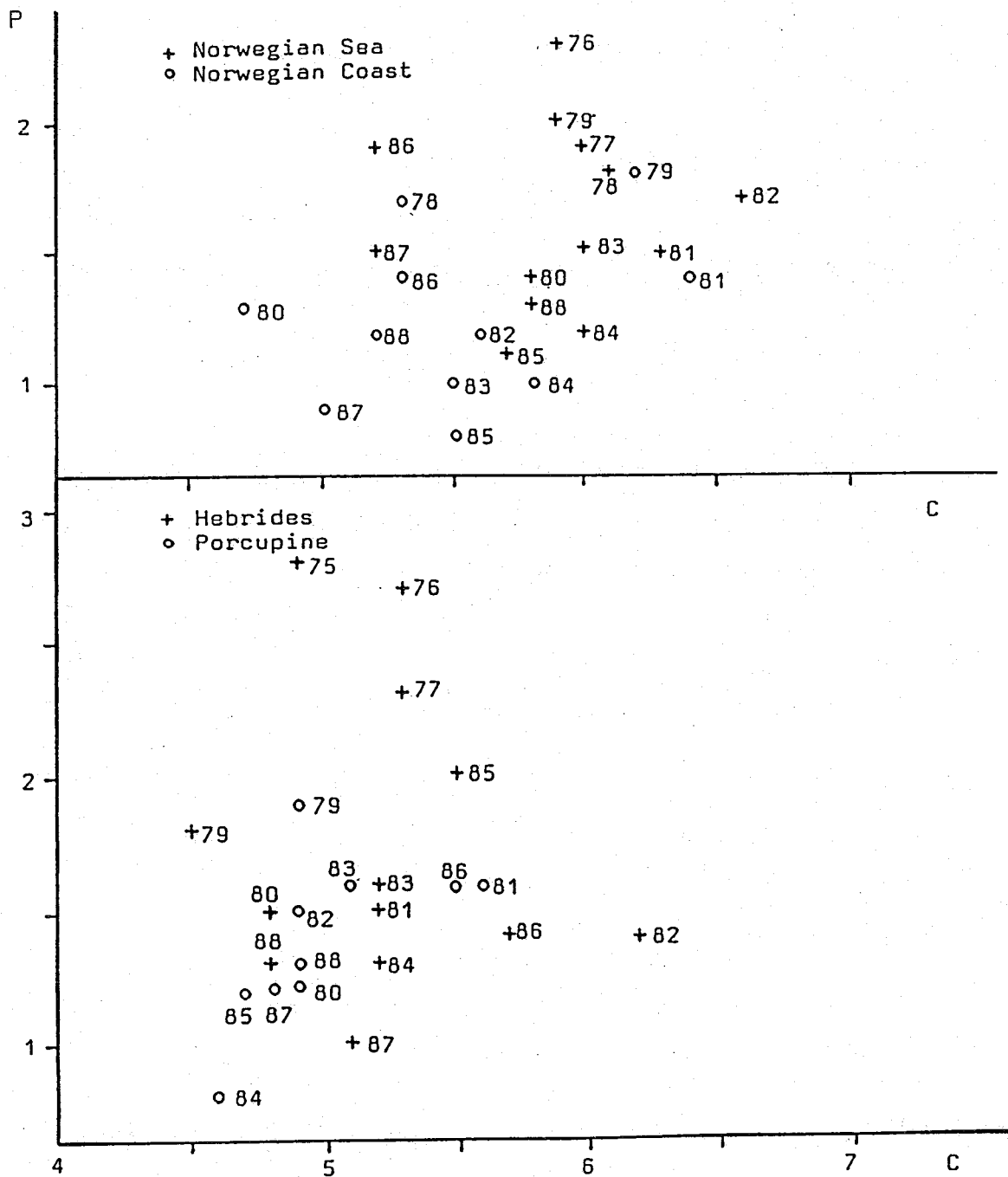


Fig. 11. Annual mean values of the parasite index P against condition factor C of the blue whiting in the Norwegian Sea and the Norwegian Coast areas (upper), and the Hebrides and the Porcupine areas (lower).

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 neglectable 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 believe 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 appearance 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 yearclasses are given in Table 4 together with corresponding parasite and liver size indices.

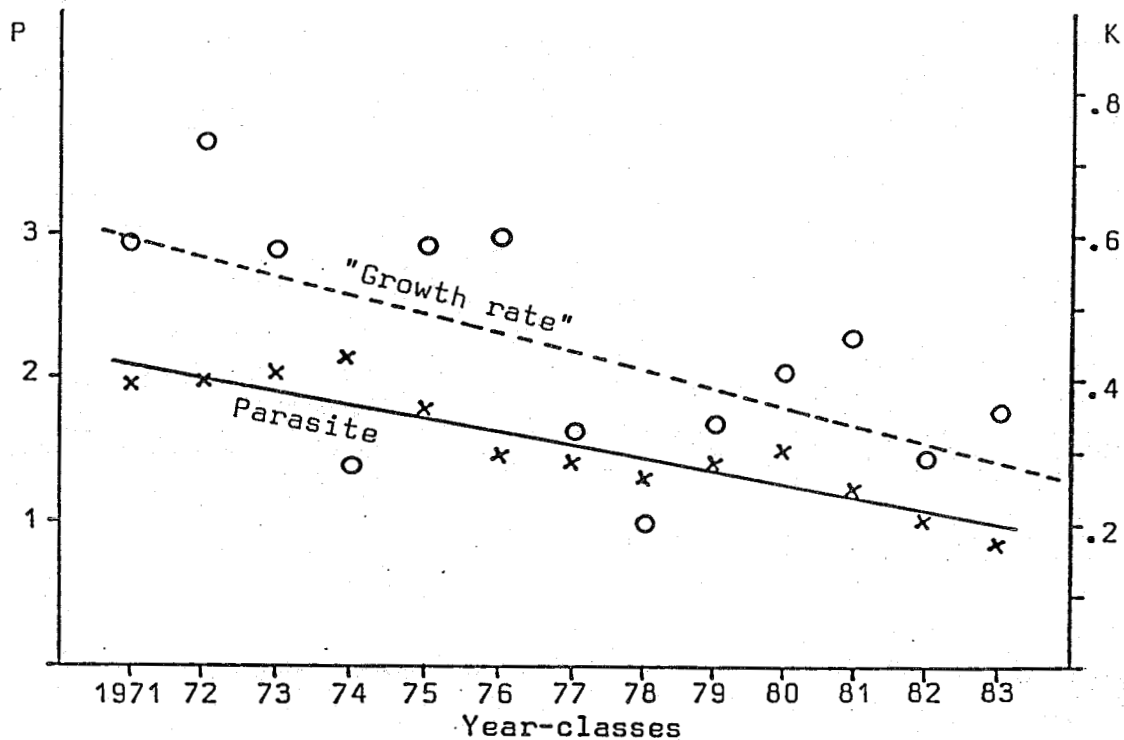


Fig. 12. Regression of growth parameter K (von Bertalanffy), circle and stippled line, and of parasite index P, cross and full line, against year classes of blue whiting in the Hebrides area during spring, based on values for the six first years of life.

The regressions illustrated in Fig. 12 were calculated to:

$$y_K = -0.03 \cdot x_{\text{yearclass}} + 0.6 \quad \text{for the growth, and}$$

$$y_P = -0.10 \cdot x_{\text{yearclass}} + 2.2 \quad \text{for the parasite index.}$$

The lines were almost parallel with decreasing values with increasing yearclasses.

Although there is variation in the yearclass' K-values, this analysis gives no reason to believe that the burden of larval *Anisakis* parasites on the liver surface affects the blue whiting host, regarding the length growth in the first six years of life.

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