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
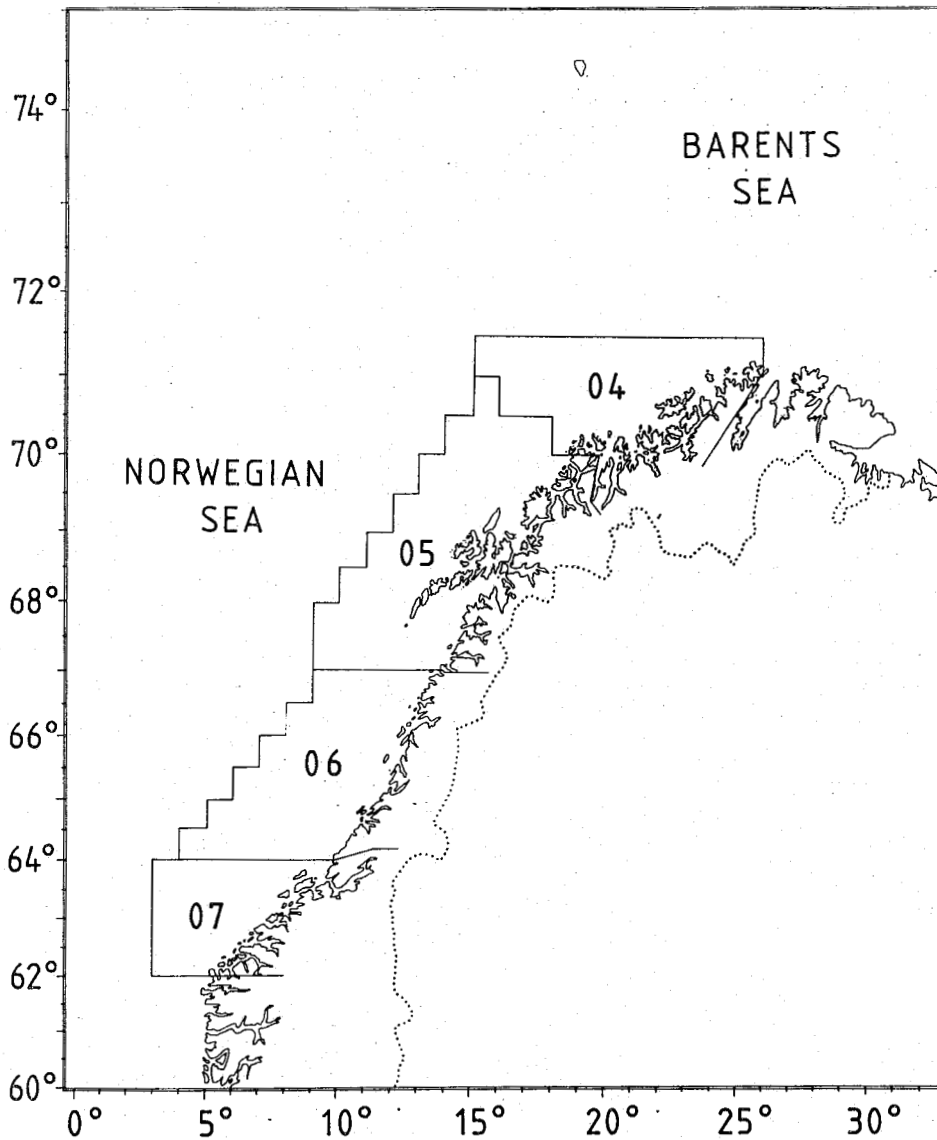change in growth is not necessarily density dependent.

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:

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

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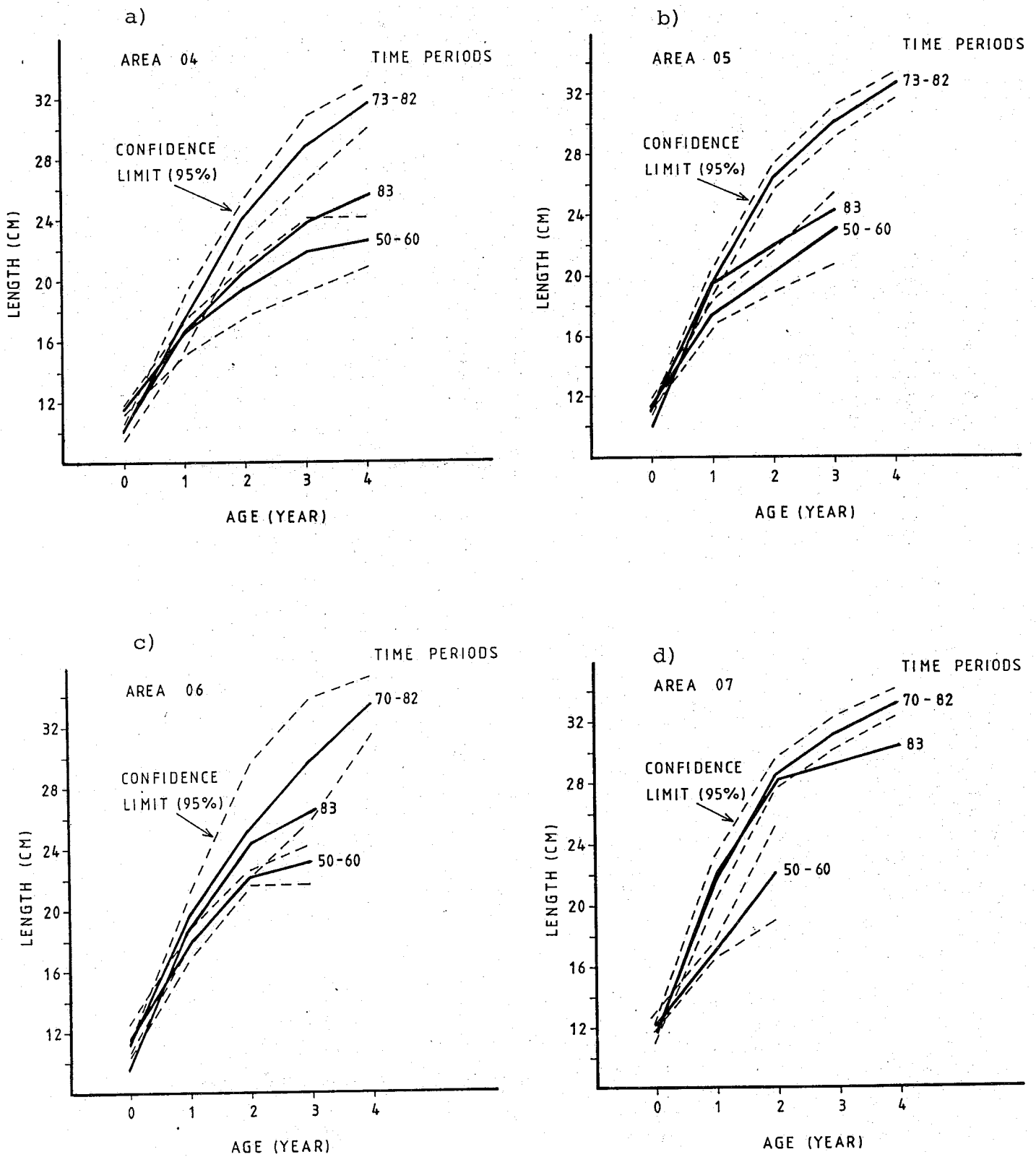
Fig. 2a-d. Plots of length at age in the four regions
in the two periods.

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 x 10^6 individuals in the fifties, while in the seventies
this number was reduced to 436 x 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
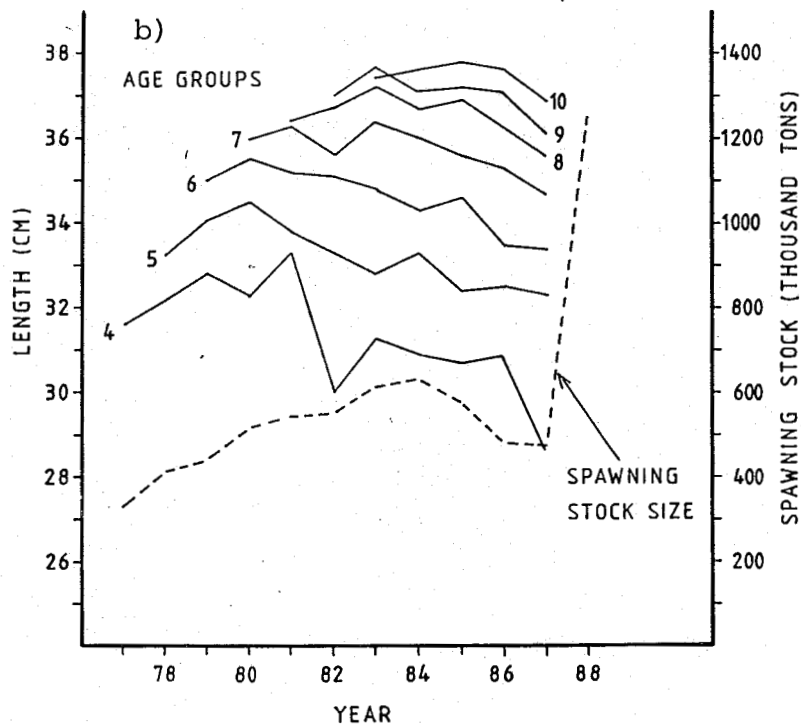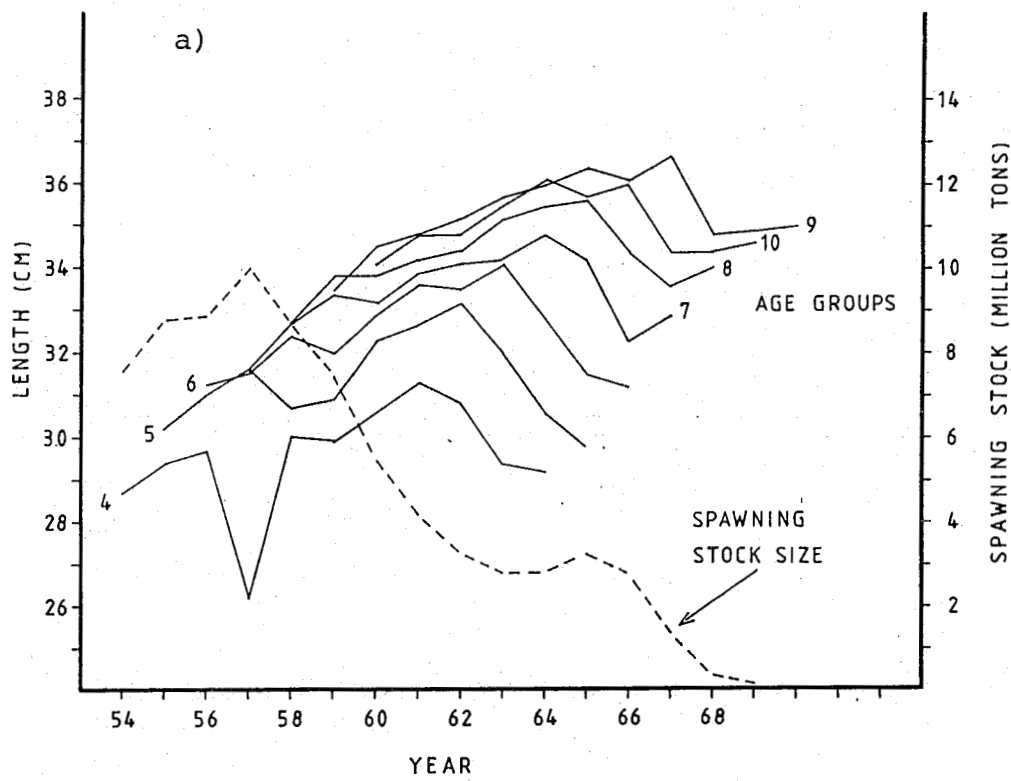the slow growing ones.

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
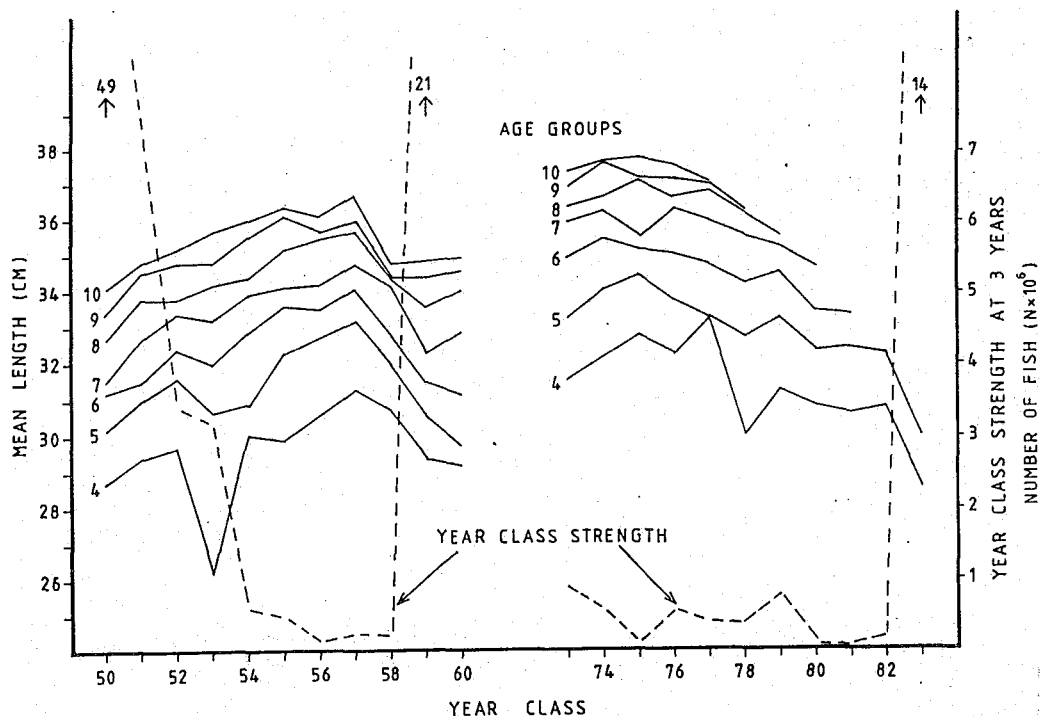stock abundance.

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
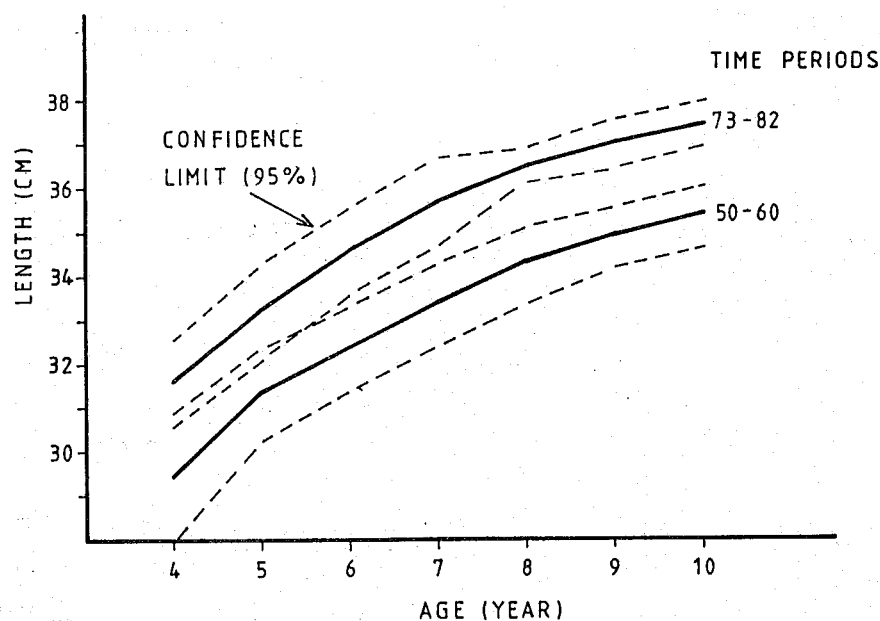growth in length is initiated early in life, before maturation.

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.

REFERENCES

Dragesund, O. 1970. Distribution, abundance and mortality of young and
          adolescent Norwegian spring spawning herring (Clupea
          harengus L.) in relation to subsequent year-class strength.
          Fisk. Dir. Skr. Ser. Havunders., 15(4): 451 - 556.

Dragesund, O., Hamre, J. and Ulltang, Ø. 1979. Biology and population
          dynamics of the Norwegian spring spawning herring. ICES
          Symposium on the biological basis of pelagic fish stock
          management, 3: 80 pp. (mimeo).

Jakobsson, J. and Halldorsson, O. 1984. Changes in biological para-
          meters in the Icelandic summer spawning herring. ICES
          CM 1984/H:43, 12 pp. (mimeo).

Jørgensen, K. O. 1979. Norsk vårgytende sild (Clupea harengus L.)
          Endringer i biologiske parametre i perioden 1950 - 1978.
          Thesis, University of Bergen, 75 pp. (In Norwegian)
          (mimeo).

Toresen, R. 1986. Length and age at maturity of Norwegian spring-
          spawning herring for the year-classes 1959-61 and 1973-78.
          ICES CM 1986/H:42, 4 pp. (mimeo).

Watkin, E.E. 1927. Investigations on Cardigan Bay Herring. Part V.
          Rep. Mar. and Fresh Water Inv. Dept. Zool. Univ. Coll.
          Wales, 2.

Østvedt, O.J. 1958. Some considerations concerning the homogeneity of
          the Atlanto-scandian herring. Rapp. P.-v. Reun. Cons. int.
          Explor. Mer, 143: 53-57.

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Long term changes of growth and maturation....

Table 1 a. Mean length at age.

AREA 04

			Age		
Year	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

Year	\	\	Age	\	\
	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

	Age				
Year	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

LIFE HISTORY - herring
Long term changes of growth and maturation....

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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