Inernational Council for the
Exploration of the Sea

CM 1995/J:12

HERRING STOCK LENGTH-AT- AGE STRUCTURE IN THE EASTERN BALTIC

by

M. Fetter and A.Naglis

Latvian Fisheries Research Institute

6, Daugavgrivas st., Riga, LV-1007, Latvia

Mean length-at-age of herring collected from commercial catches in Subdivision 28 in 1964-1993 was analysed in the aspect of its annual and long-term fluctuations. Annual changes of herring length showed the tendency for decrease of length-at-age from the beginning to the end of the year for all age groups except age group 1. In the most cases the minima of mean length-at-age were observed in the quarters 3 and 4. Relationship between fluctuations of herring length-at-age during the year and the share of gulf herring in the sea was revealed for age groups 3-7. This relationship was especially pronounced in those years when the amount of gulf herring in the sea was quite large. Long-term fluctuations of herring length-at-age were found to be closely connected with stock size of herring in the Gulf of Riga especially in the last years when the intensity of gulf herring migration towards the sea was high due to large stock number and worsening of feeding conditions in the Gulf of Riga.

Introduction

Changes of Baltic herring growth were analysed and generalized in frames of the project Growth Changes of Herring in the Baltic (TemaNord 1994:532) headed by H. Sparholt. In that Report the results of long-term observations concerning changes of herring size-at-age from the end of 1970s till the beginning of 1990s were presented and discussed in detail for all Baltic regions. Different hypotheses dealing with the causes of herring size-at-age changes were discussed in that paper, i.e., migration changes, influence of hydrological conditions, changes in feeding conditions, the effect of herring stock size on its growth, the influence of cod stock and some other factors that could lead to strong changes in herring size-at-age. Summing up the main conclusions of that Project it can be said that the observed decrease in herring size-at-age may be explained most adequately

by the changes in the size selective mortality of herring caused by the reduced cod stock.

Our paper presents a more detailed consideration, than it has been made earlier, of seasonal and long-term fluctuations of herring length-at-age in Subdivision 28 as regards one aspect, i.e., migration of smaller herring from the Gulf of Riga to the open sea. Identification of open sea herring and gulf herring by otoliths is rather difficult since distinctive features of otoliths overlap to a certain extent. However using a large series of observations the general tendencies can be exposed.

The main aim of our report is to demonstrate seasonal and long-term fluctuations in herring length-at-age as well as to reveal the significance of possible influence on them by gulf herring migrations because gulf herring is an inherent component of herring catches in Subdivisions 28.

Material and methods

Data on herring for the period of 1964-1993 were used in this paper. Samples of herring were collected from commercial catches in Subdivision 28. Every month, with few exclusions in some years, 200-400 fishes were taken from commercial catches being then examined by standard methods. Herring age and its populational identification were determined by otoliths. Herring length was measured by Smith. One month was chosen as the minimum of an averaged unit. Data on stock size of herring in the Gulf of Riga were taken from the Report of the Working Group on the Assessment of demersal and pelagic stocks in the Baltic (ICES CM 1995/Assess:18).

Results and discussion

Annual changes of herring length-at-age.

Multi-annual fluctuations of monthly mean values of herring length and the range of its changes for all herring age groups are presented in Fig. 1 and 2. Mean values of length and its minima and maxima are shown in Table 1. Characterizing time-series of herring length fluctuations as a whole (Fig 1, 2) it can be noted that the least minima occurred beginning from 1987 for age groups 3 and older. For age groups 1 and 2 the least minima were observed in the period before 1970. High maxima for practically all age groups were more often recorded during 1978-1985 and 1966-1971.

Yearly length ranges for fish of the same age changed from year to year. It can be noted that high values of yearly length ranges for age groups 3-10 were found more frequently after 1978 than before that year.

Seasonal fluctuations of herring length-at-age are characterized by great variety. Fig. 3 shows yearly distribution of length maxima for age groups 1-9. Natural

scheme of herring growth implies that fish should have its maximum length in the end of the year at least in quarter 4. However, as Fig. 3 demonstrates it is impossible at all to determine any definite month for the length maxima of age group 2. Insignificant concentration of the length maxima for age group1 can be noted by the end of year. Yearly distribution of length maxima for age group 3 still has a weak tendency to grouping in quarters 1 and 2. As regards age groups 4-9 their length maxima were mainly registered in the first half of the year. However, the curves of herring length changes have several peaks during the year (Fig 4, A). Mean length of age group 5 showed its maxima in April and July in 1970 and 1971, unlike 1991 and 1992 when length changes were of a smooth character but maxima were recorded in February - March, and in August (1992). A tendency for yearly decrease in mean length of age groups 2-7 was especially distinctly pronounced when averaged data were considered (Fig 4,B). Natural annual increment of length was observed only for age 1. The rest of age groups demonstrated decrement of their length in quarter 4 as compared with quarters 1 and 2 (Fig. 4, B). As it was shown earlier (Naglis, 1981), during 1972-1977 maximum mean length was observed in February-March, then it decreased in April and was undergoing small changes till December. Mean values of herring length for a whole period of observations (1964-1993) demonstrate that there is a real tendency towards decrease of length from its maximum values in February - April to minimum ones in August-October followed by insignificant increase of length in December (Fig. 5A). Sufficient differences in the pattern of length-at-age annual fluctuations are evidently observed between separate age groups and years. Fig. 5 presents annual fluctuations of length averaged by three-year periods between which there were differences both in annual length ranges, and in mean values of length. Winter or spring maxima of herring mean length-at-age can be explained by the fact that concentrations of fishes are formed according to the degree of their preparation for spawn during pre-spawning period. The biggest individuals are as a rule the first to spawn in each age group. They form concentrations of greater density that are the object of fishery in February - April. The lessening of length-at-age in summer can be explained by the fact that herring starts to feed actively after spawn, and big individuals do not gather in separate shoals but dissipate over feeding areas among the rest of fishes.

However, in Subdivision 28 smaller gulf herring appears in catches beginning from June-July. It leaves the Gulf of Riga after spawn and stays in the open sea sometimes till the end of the year. Summer migration of gulf herring from the Gulf of Riga to the open sea was unfortunately not investigated by tagging. Still our data as regards populational composition of herring in Subdivision 28 testify to the fact that herring with low growth rate and otoliths typical for gulf herring (Ojaveer,1981) was encountered in catches almost permanently though its share changed considerably from year to year and from month to month during one year

(Fig. 7, 8). In the period of 1964-1993 the mean share of gulf herring did not exceed 10 % in catches, during 1976-1978 it was less than 5%, in 1979-1981 its share was negligibly small but during 1991-1993 the share of gulf herring reached 40% (October 1991-1993, Fig 8). In 1981-1986 its share was about 1 % per year (Fig 7). Occurrence of smaller gulf herring in mixed catches obviously affected the mean length-at-age making it less. However, this effect was not revealed equally for different age groups. To describe this fact quantitatively the correlation coefficients were calculated between monthly mean length of different age groups and the share of gulf herring in the open sea for three periods: 1979-1981 characterized by small amount of gulf herring in the sea; 1991-1993 characterized by large amount of gulf herring in the sea, and 1964-1993, i.e. the whole period of observations. Despite quite large values of correlation coefficients (Table 2) between herring mean length and the share of gulf herring we still consider annual length fluctuations to be determined at least by two factors. Concentration of larger fishes in pre-spawning period causes the length maximum in February - April, sometimes in May. By July - August after spawning big fishes do not already form dense concentrations and therefore their mean length decreases in catches even in years when the share of gulf herring in the sea is very small (Fig. 5 and 6, period of 1979-1981). In years of large amount of gulf herring in the sea this lessening of mean length is more pronounced (1987-1989,1991-1993). In the period of small amount of gulf herring in the sea the correlation coefficients are sufficiently lower, especially for age groups 2 and 3. Analogous annual changes in herring length-at-age were described for western part of the Gulf of Finland and neighbouring open sea regions (Ojaveer, 1988).

Hence one of the reasons for periodic annual fluctuations of herring length-at-age in the sea are undoubtedly the migrations of open sea herring to the Gulf of Riga for spawning and oppositely directed migrations of gulf herring in the second half of the year.

Due to the decrease of herring length-at-age by the end of the year annual absolute increments (cm) calculated as the difference between length in quarter 4 and that in quarter 1 of the same year have negative values (Fig. 9A). More or less satisfactory results were obtained when increments were calculated as differences of herring length between quarter 1 of the current year and quarter 1 of the next year, taking into account that the influence of gulf herring was the least in those quarters. But even in this case negative values of length increments were gained for some age groups in several years (Fig. 9B).

Long-term fluctuations of herring length-at-age.

Long-term fluctuations of herring length-at-age for the period of 1964-1993 are presented in Fig.10 and 11 as deviations from the mean values (1964-1993). A clearly pronounced synchronous character of deviations is noted for age groups

3-7. Table 3 shows the results of couple comparisons of quarterly mean length deviations for age groups 1-7 during the whole period of observations (1964-1993). Commenting on the results of comparisons it should be pointed out that synchronism of length deviations is most pronounced for fishes of two sequent age groups and it weakens with the increase of age difference. Age group 1 and partly age group 2 (quarter 1) are the exclusion. Their length fluctuations correlate very weakly with those of other age groups. Age group 1 is not representative and therefore in this case it is senseless to discuss its size characteristics.

As regards age group 2 fluctuations of its length in quarter 1 evidently reflect the effect of some other factors differing from those for older fishes. As it was above considered the influence of gulf herring on seasonal fluctuations of herring length-at-age in the sea is revealed quite noticeably, especially in the years when its share is growing. Long-term changes in herring length-at-age are also expected to be dependent on the amount of gulf herring migrated to the open sea. Quarter 1 demonstrates the least degree of this influence, but quarters 3 and 4 show the greatest degree (Table 4). In its turn the amount of gulf herring in the open sea during 1970-1993 happened to be closely related with herring stock size in the Gulf of Riga. Correlation coefficients between the share of gulf herring in the sea and its stock size in the Gulf of Riga are **r=0.70** for quarter 1; **r=0.80** for quarter 2; **r=0.88** for quarter 3 and **r=0.89** for quarter 4. It was expected to be evident that herring length-at-age fluctuations in the sea ought to be also strongly connected with stock size in the Gulf of Riga (Table 4). In reality we may speak on strong correlation only for age groups 3-6 considering their length for quarters 2-4 (Table 5). Fig. 12 demonstrates long-term dynamics of herring length-at-age in the sea, the amount of the gulf herring in the sea and its stock number in the Gulf of Riga in the period of 1970-1993. The possible reasons for intensive migration of gulf herring from the gulf to the open sea are the increase of its stock and related with it worsening of food supply for older age groups in the Gulf of Riga during last years (1987-1993). This can be testified by the decrease of its length and weight (Kornilovs;1994) and by quite sharp decrease of Limnocalanus grimaldii abundance that is a very important food item for older age groups of gulf herring in the Gulf of Riga (Kornilovs, 1992; Sidrevics et al. 1993).

Thus basing on our data we assume that herring length fluctuations in Subdivision 28 are determined to a high extent by herring stock size in the Gulf of Riga, food supply in the gulf and connected with this intensity of migration to the open sea. The above said is referred mainly to fishes of older age groups (3-6) in the second half of the year, when their feeding conditions worsen due to consumption.

Summing up the considered facts we may conclude the following:

1. Seasonal and long-term fluctuations of herring length-at-age in Subdivision 28 have a clearly pronounced synchronous character for age groups 3-7. As long as

gulf herring is a permanent component in mixed catches the intensity of its migration from the Gulf of Riga to the open sea affects quite strongly the length-at-age fluctuations of herring in Subdivision 28.

2. The least influence of gulf herring was revealed for quarter 1, the most one occurred for quarters 3 and 4.

3. In resent years (beginning from 1987) the observed intensive migrations of gulf herring to the open sea are evidently caused by the worsening of its feeding conditions in the Gulf of Riga due to its high stock number.

4. Despite certain subjectivity and difficulties of application, the method of herring populational identification using otoliths fits in this case and is quite useful for studies of herring stock structure. Furthermore, by our opinion, it is desirable to develop this method in future.

References

1. Anon. Growth Changes of Herring in the Baltic. Final Report. TemaNord 1994:532.

2. Anon. Report of the Working Group on the Assessment of demersal and pelagic stocks in the Baltic. ICES C.M. 1995/Assess:18.

3. G. Kornilovs, V. Berzinsh, L. Sidrevics. The analysis of mean weight-at-age changes of Baltic Herring in the Gulf of Riga. ICES C.M. 1992/J:24.

4. G. Kornilovs. Yearly length distribution of herring in the Gulf of Riga in relation to populational structure of the stock. ICES C.M. 1994/J:9, Ref.H

5. Naglis A.K. Fishing and biological characteristic of the Baltic herring in Ventspils zone of the Baltic Sea. - In: Rybokhozyaistvennye issledovaniya (BaltNIIRKH). Riga: Avots, 1981, Issue 16, pp.64-70. (in Russ.)

6. Ojaveer, E.,Evtjukhova, B., Rechlin, O., Strzyzewska, K.. Results of investigation of population structure and otoliths of Baltic spring spawning herring. ICES, C.M. 1981/J:19, B.F.C.

7. Ojaveer, E.. Baltic Herring (biology and fishery). Moskva VO "Agropromizdat",1988.(in Russ.)

8. L. Sidrevics, R. Line, V. Berzinsh and G. Kornilovs. Long-term changes of zooplankton abundance in the Gulf of Riga. ICES C.M. 1993/L:15, Biological Oceanography Committee.

Table 1

Minima, maxima and mean values,of herring length-at-age in Subdivision 28 for period 1964-1993 by quarters

Quarter		Age groups						
		1	2	3	4	5	6	7
1	Min	10.6	12.9	15.4	16.2	16.7	17.0	17.9
	Max	14.4	16.7	18.7	20.2	21.3	22.1	22.7
	Mean	13.0	15.4	17.1	18.1	18.7	19.5	20.0
2	Min	11.4	14.0	14.7	15.5	15.9	16.9	17.4
	Max	14.7	17.3	17.9	19.6	20.6	22.0	23.0
	Mean	13.2	15.2	16.5	17.6	18.4	19.5	20.0
3	Min	12.3	13.7	14.5	15.2	15.8	16.5	17.7
	Max	14.6	16.4	17.5	19.3	20.2	20.6	22.2
	Mean	13.4	15.1	16.3	17.2	17.9	18.6	19.4
4	Min	13.1	13.8	14.2	15.1	15.4	15.6	17.4
	Max	15.8	16.8	18.1	18.9	20.1	21.7	21.2
	Mean	14.0	15.5	16.6	17.5	18.1	18.7	19.2

Table 2

Correlation coefficients between monthly mean values of herring length and the share of gulf herring

Age group	Period		
	1979-1981*	1991-1993**	1964-1993
2	-0.27	-0.89	-0.72
3	-0.58	-0.82	-0.80
4	-0.69	-0.90	-0.90
5	-0.70	-0.81	-0.94
6	-0.75	-0.65	-0.85

* - the share of gulf herring was small, ** - the share of gulf herring was large.

Table 3

Correlation coefficients between mean length deviations of different age groups within one quarter for period 1964-1993

Quarter	Age group	Age group					
		1	2	3	4	5	6
1	2	0.34					
	3	-0.18	0.50				
	4	0.11	0.55	0.84			
	5	0.13	0.42	0.73	0.93		
	6	0.14	0.46	0.64	0.85	0.86	
	7	0.16	0.34	0.51	0.72	0.79	0.92
2	2	0.25					
	3	0.23	0.82				
	4	0.22	0.76	0.93			
	5	0.22	0.62	0.85	0.92		
	6	0.30	0.59	0.72	0.78	0.83	
	7	-0.04	0.45	0.60	0.67	0.66	0.71
3	2	-0.14					
	3	-0.02	0.80				
	4	0.08	0.76	0.89			
	5	0.24	0.71	0.84	0.91		
	6	0.27	0.58	0.75	0.83	0.86	
	7	0.23	0.33	0.59	0.71	0.70	0.78
4	2	0.45					
	3	0.19	0.76				
	4	0.15	0.63	0.89			
	5	0.03	0.54	0.86	0.94		
	6	0.19	0.45	0.70	0.81	0.86	
	7	0.29	0.46	0.59	0.68	0.68	0.77

for $r > 0.47$ $p=0.01$

Table 4

Correlation coefficients between herring mean length-at-age and the share of gulf herring (for period 1964-1993) and stock size of the gulf herring in the Gulf of Riga (for period 1970-1993) by quarters

Age	The share of gulf herring in the sea				Stock size in the Gulf of Riga			
group	q 1	q 2	q 3	q 4	q 1	q 2	q 3	q 4
1	0.30	-0.30	-0.08	-0.04	-0.64	-0.06	-0.22	-0.04
2	-0.36	-0.53	-0.64	-0.49	-0.50	-0.62	-0.60	-0.55
3	-0.64	-0.76	-0.78	-0.70	-0.53	-0.73	-0.75	-0.72
4	-0.61	-0.75	-0.80	-0.84	-0.65	-0.80	-0.83	-0.80
5	-0.59	-0.70	-0.79	-0.85	-0.58	-0.79	-0.78	-0.84
6	-0.63	-0.65	-0.78	-0.82	-0.63	-0.72	-0.69	-0.74
7	-0.53	-0.50	-0.57	-0.71	-0.59	-0.62	-0.57	-0.54
8	-0.49	-0.65	-0.32	-0.54	-0.51	-0.60	-0.63	-0.39
9	-0.65	-0.70	-0.22	-0.58	-0.52	-0.50	-0.17	-0.55

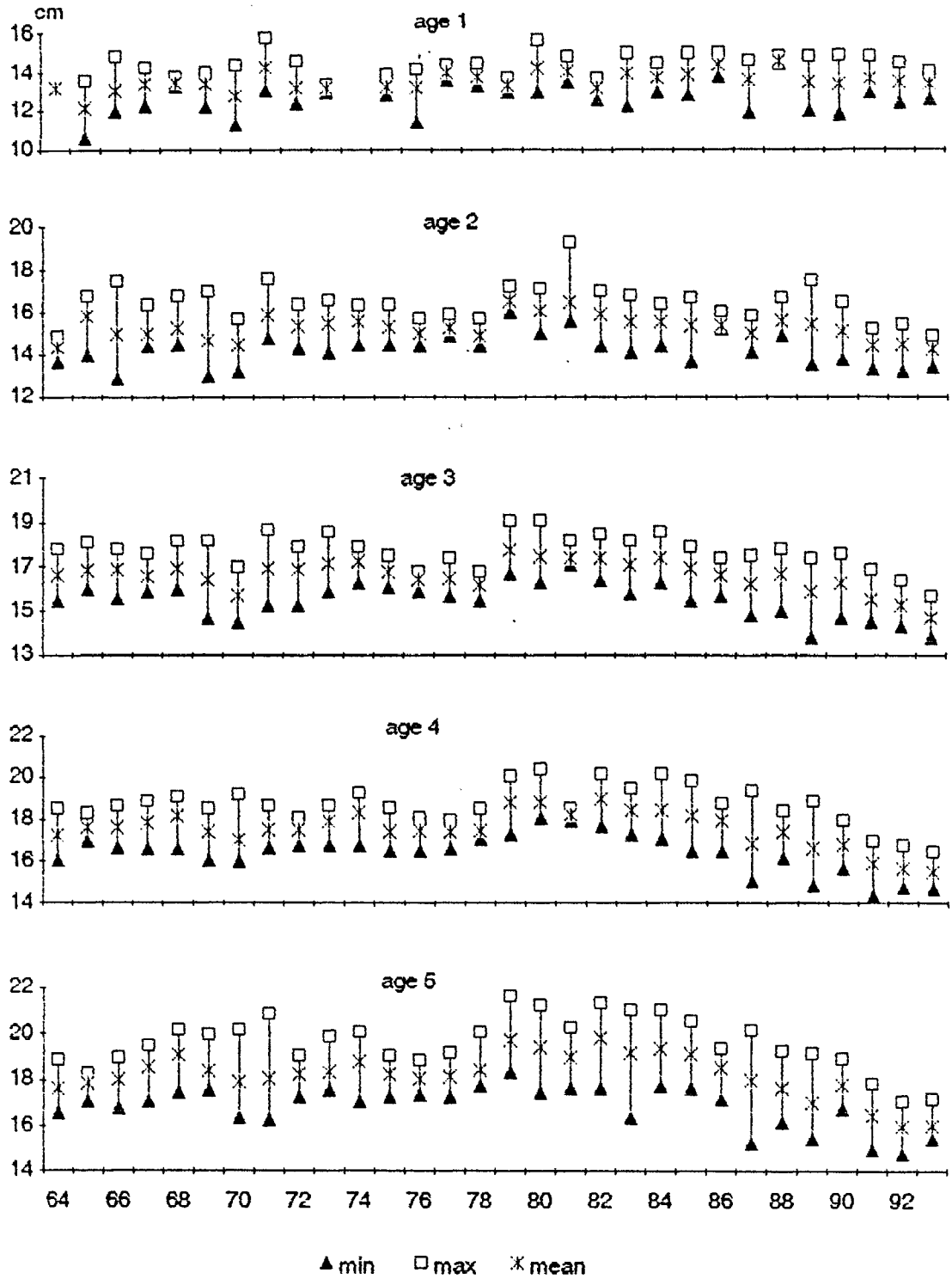


Fig 1 Herring length-at-age fluctuations in the period of 1964-1993 (age groups 1-5)

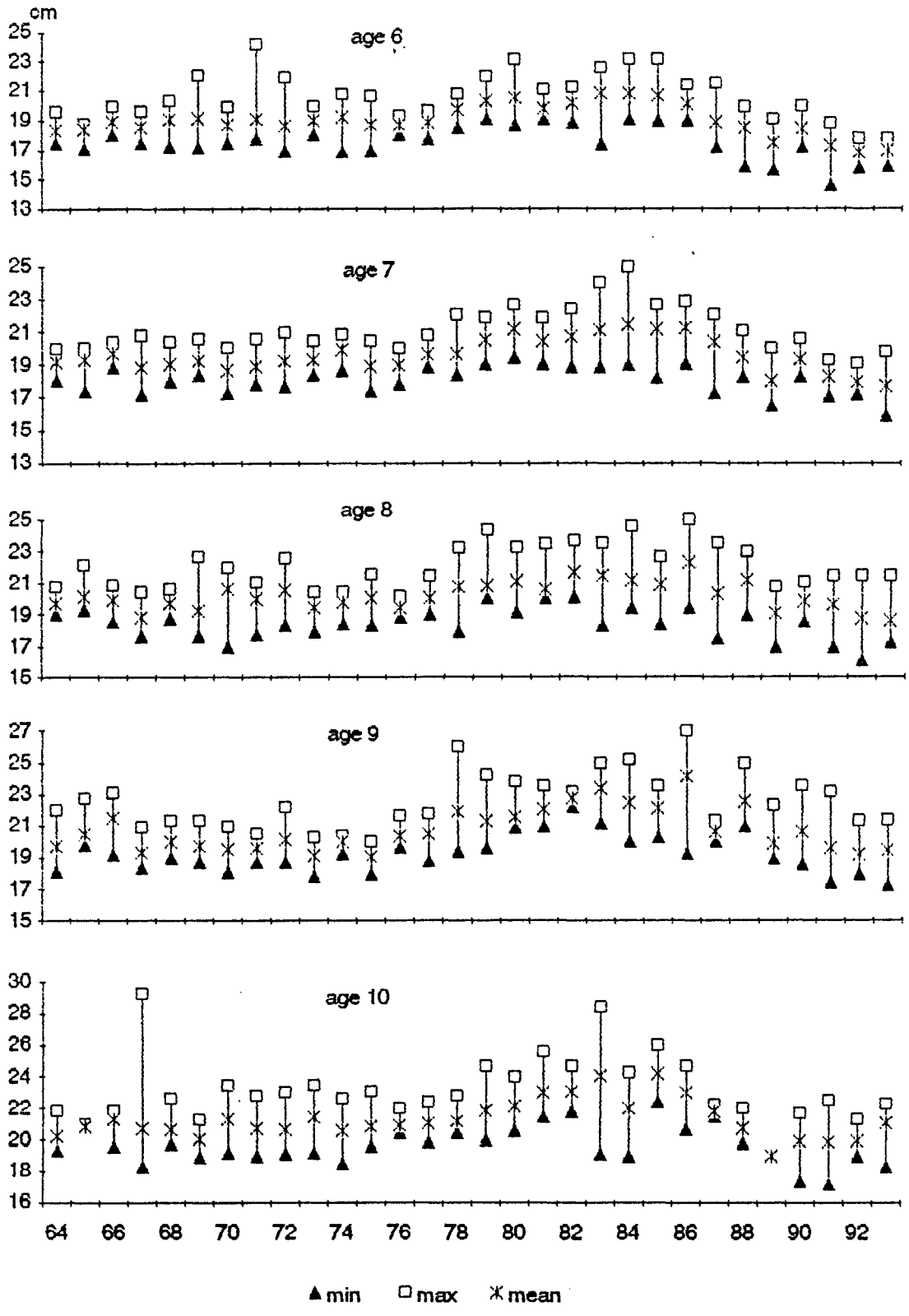
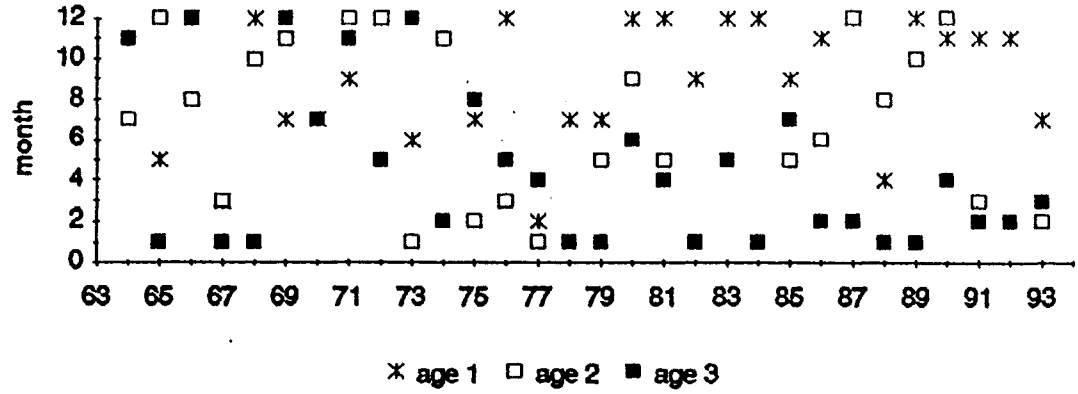
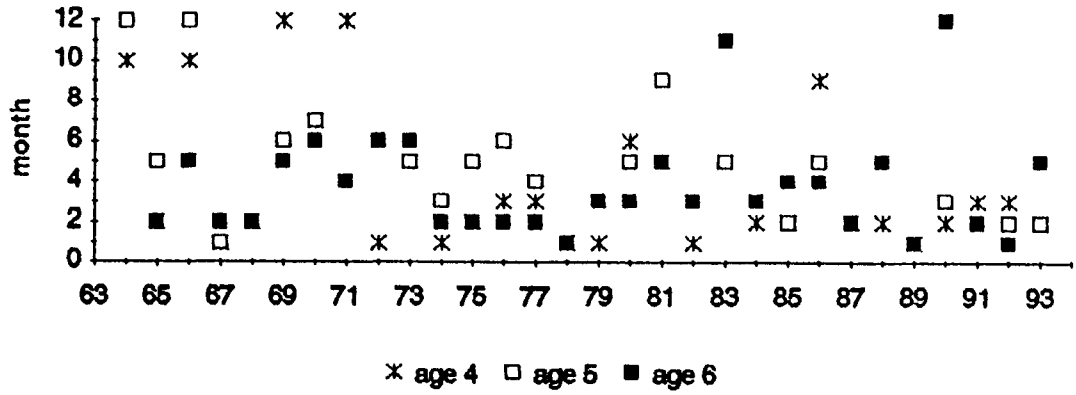


Fig 2. Herring length-at-age fluctuations in period 1964-1993 (age groups 6-10)





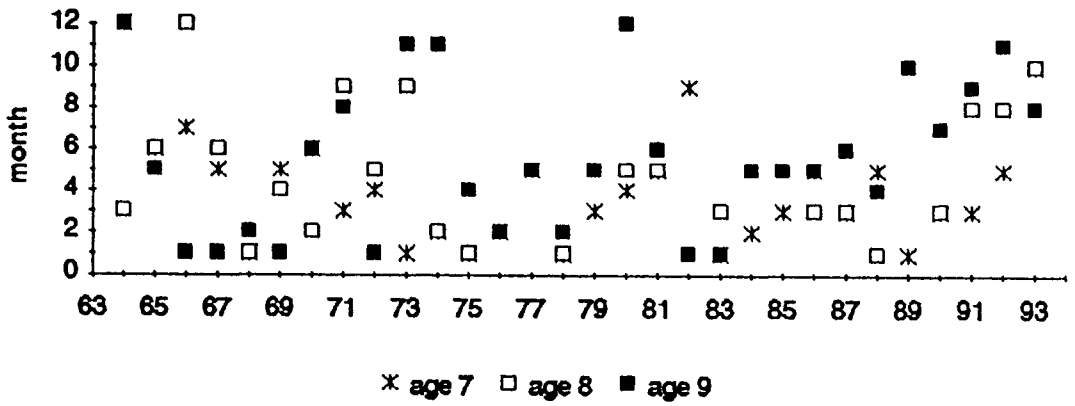


Fig 3. Yearly distribution of length maxima for herring age groups 1-9

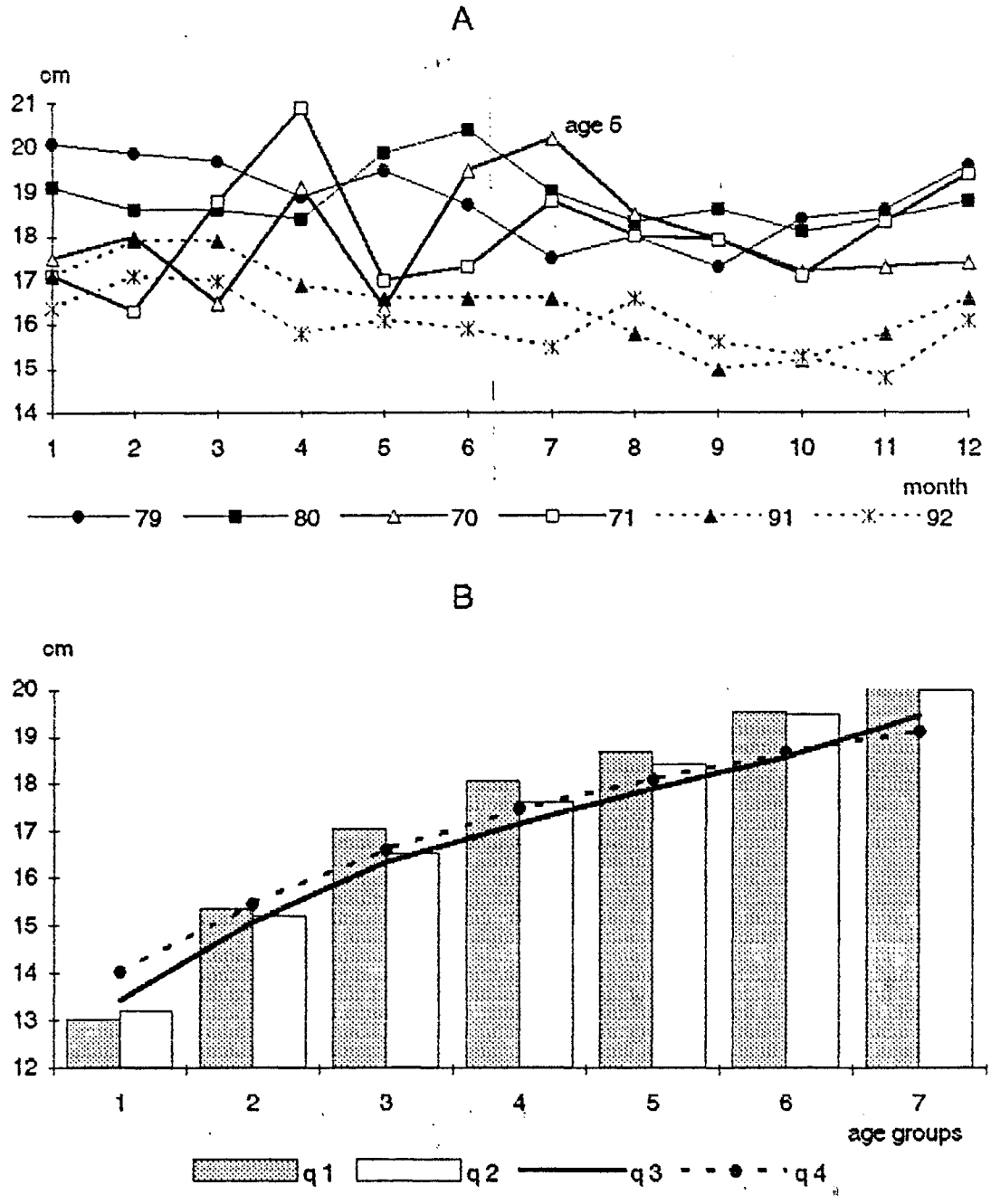


Fig 4 Annual changes of herring length (A is mean length of age group 5 in different years, B is mean length of age groups 1-7 averaged by quarters for period 1964-1993)

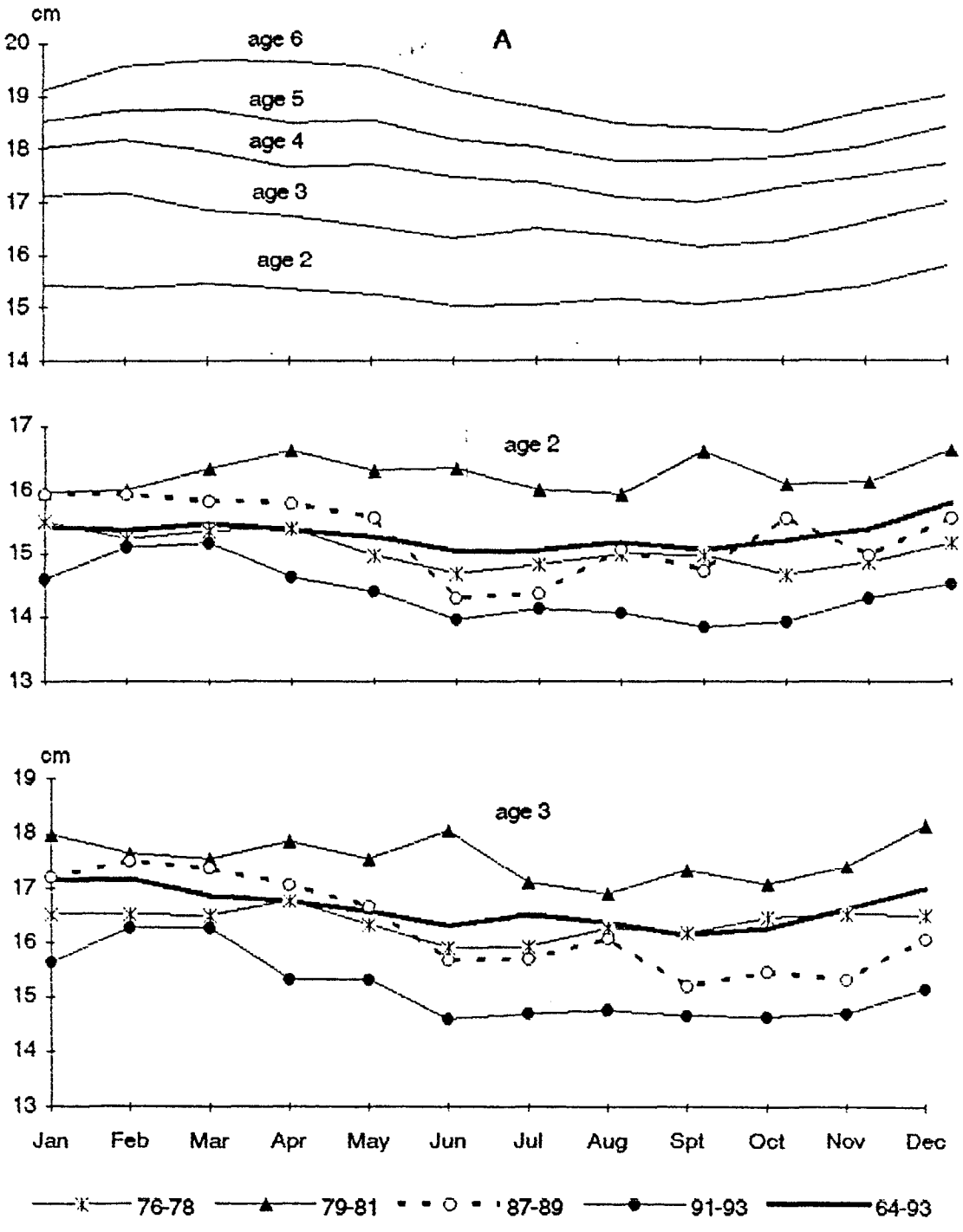


Fig.5 Annual changes of herring mean length for age groups 2 and 3 averaged by three-year periods (A - mean for 1964-1993)

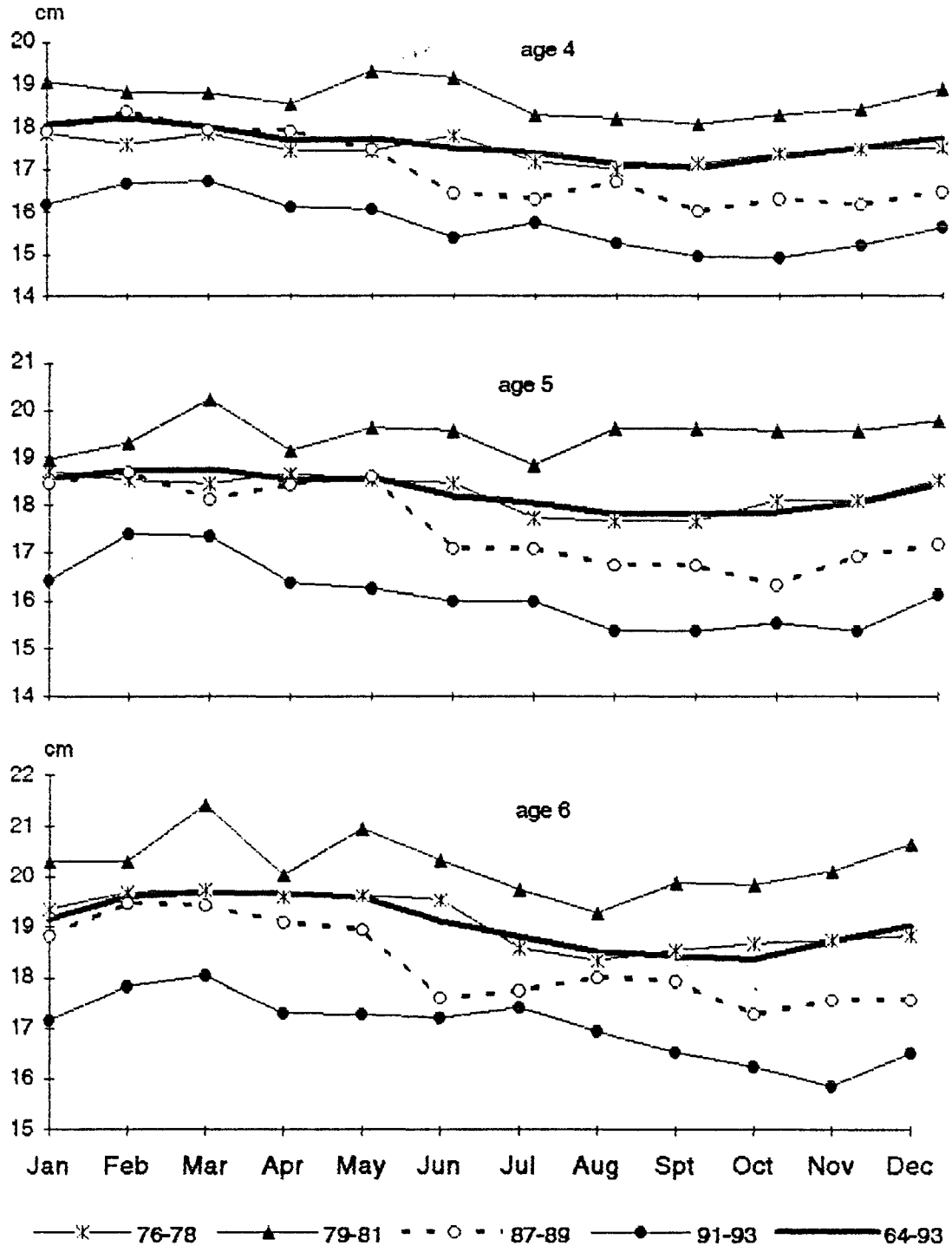


Fig.6 Annual changes of herring mean length for age groups 4-6 averaged by three-year periods

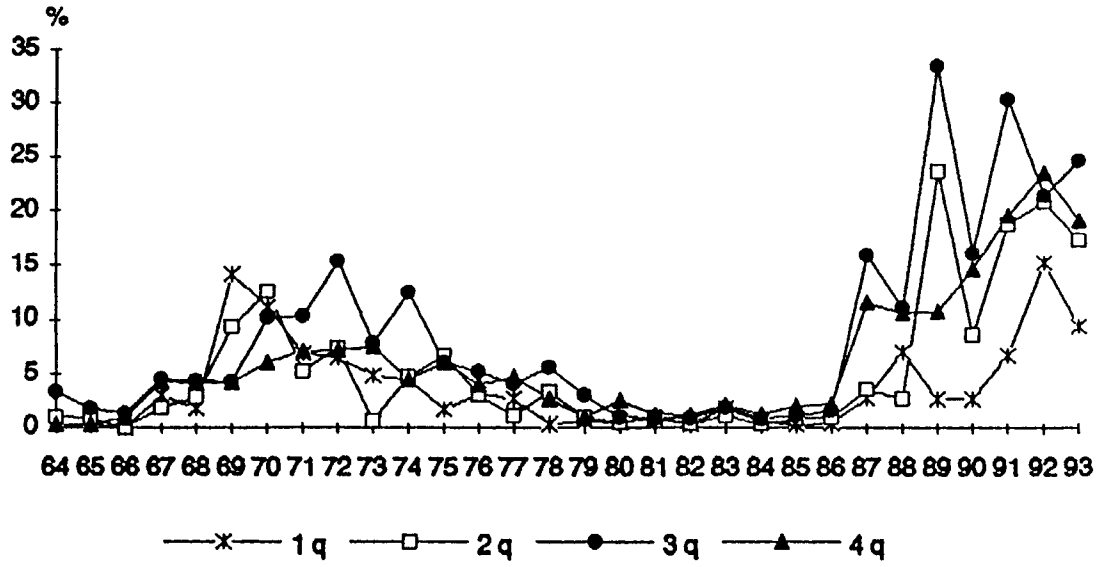


Fig . 7 The share of gulf herring (%) during the period 1964-1993

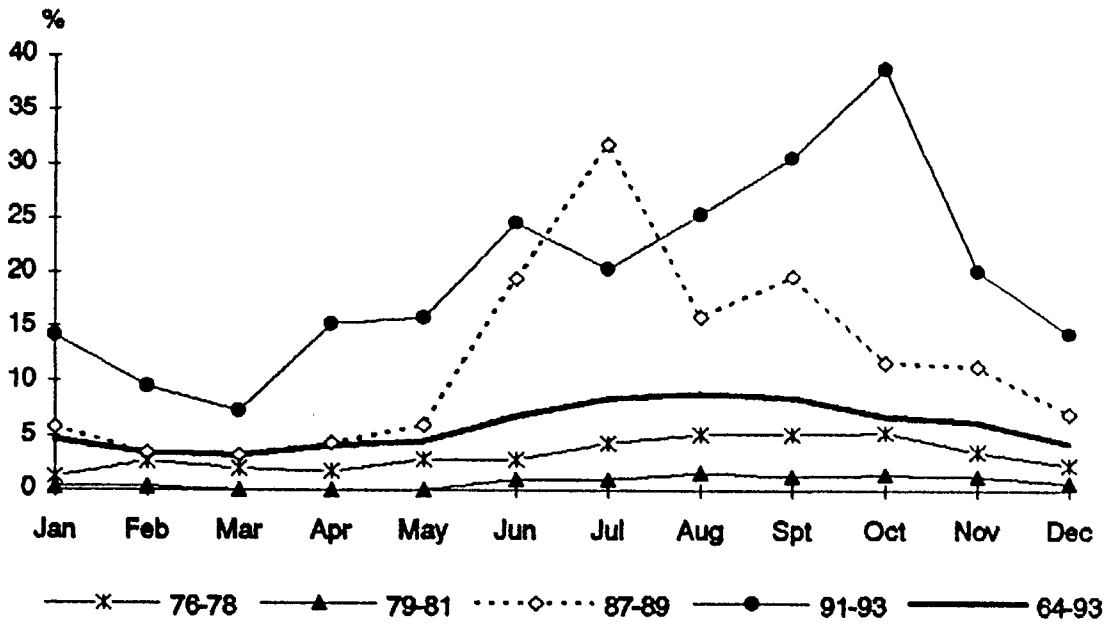


Fig. 8 Annual changes of the share of gulf herring by three-year periods

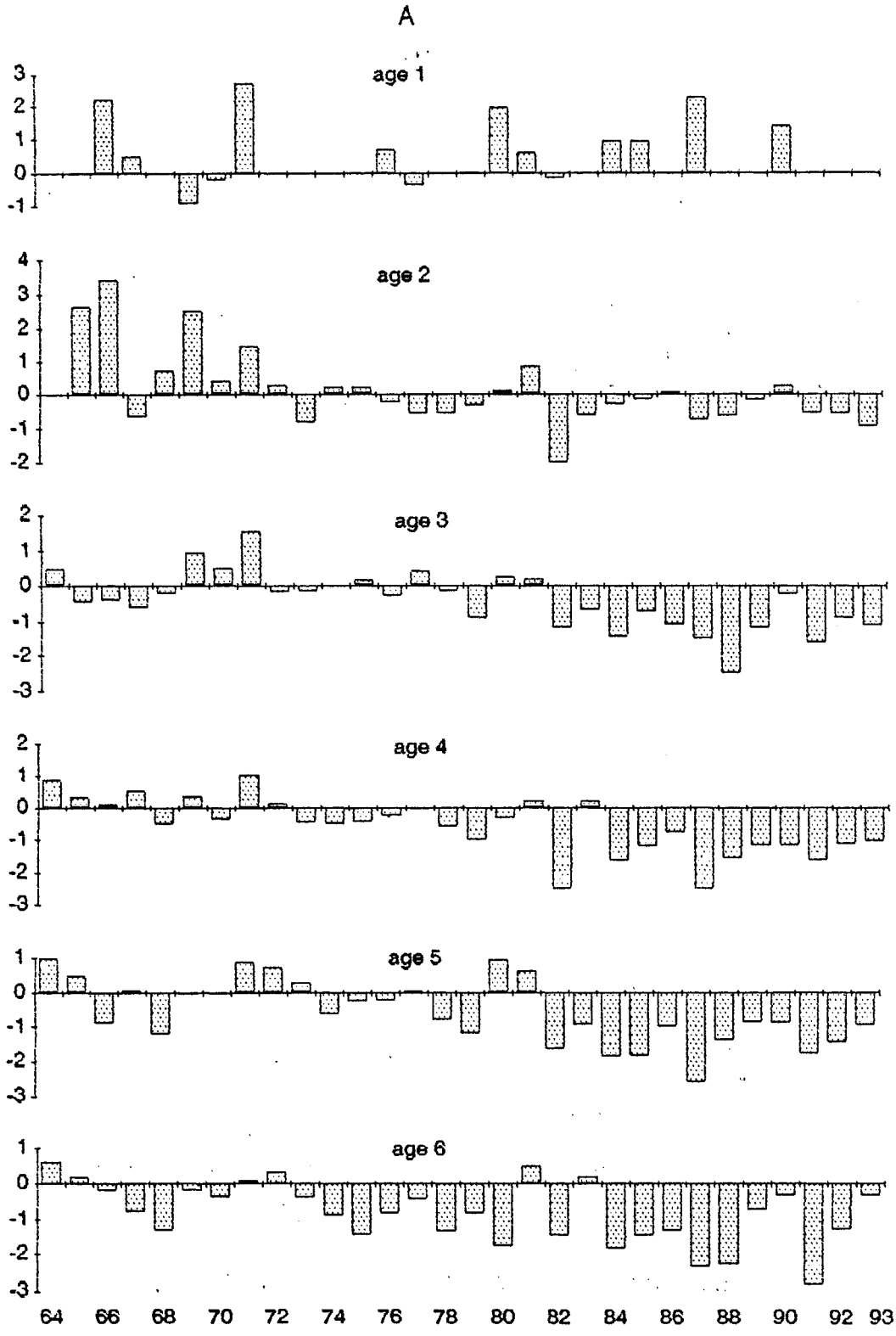


Fig. 9 Yearly increments (cm) from quarter 1 to quarter 4 of the same year

(to be cont.)

B (continuation of Fig 9)

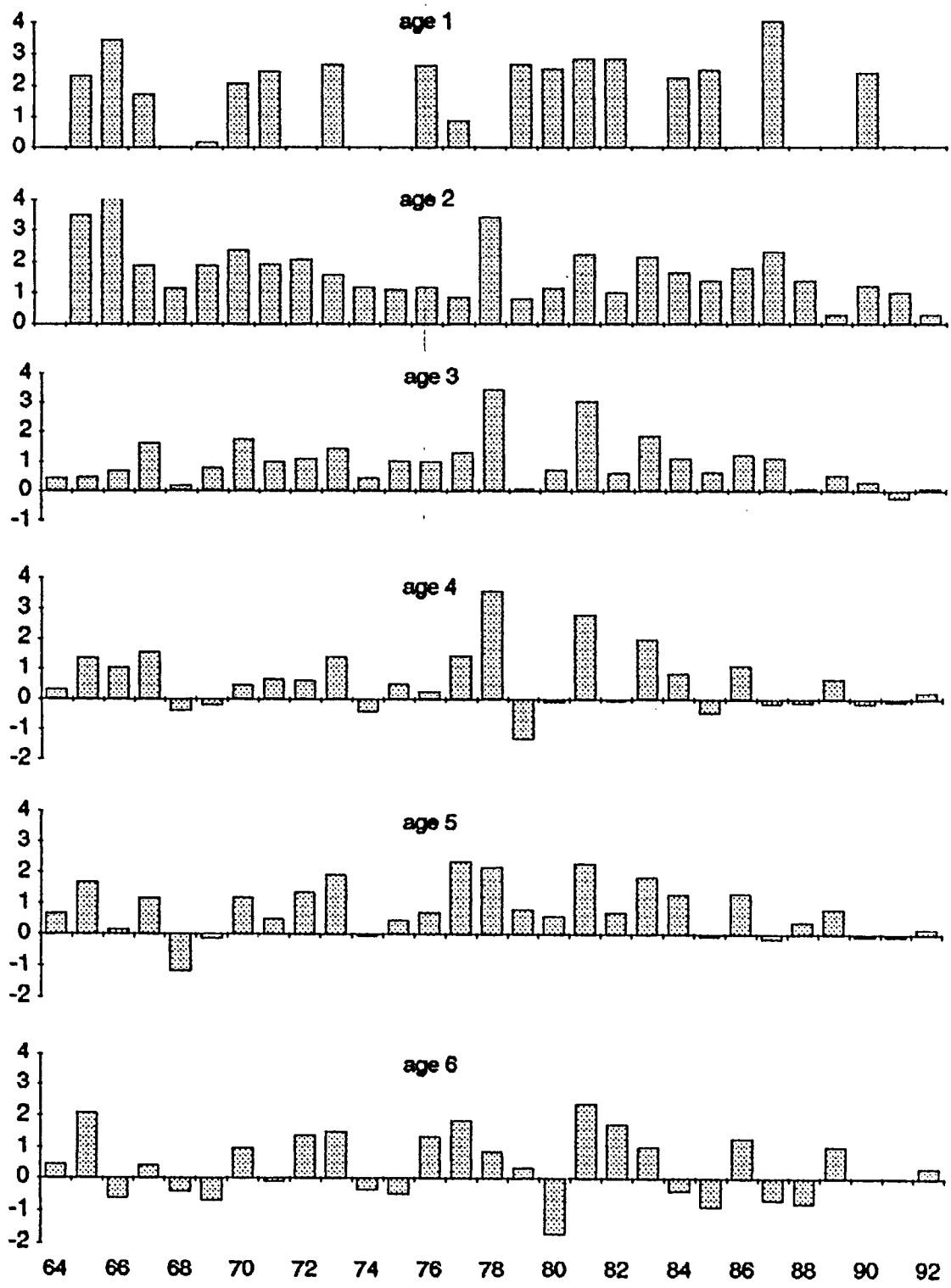


Fig. 9 Yearly increments (cm) from quarter 1 to quarter 1 the next year

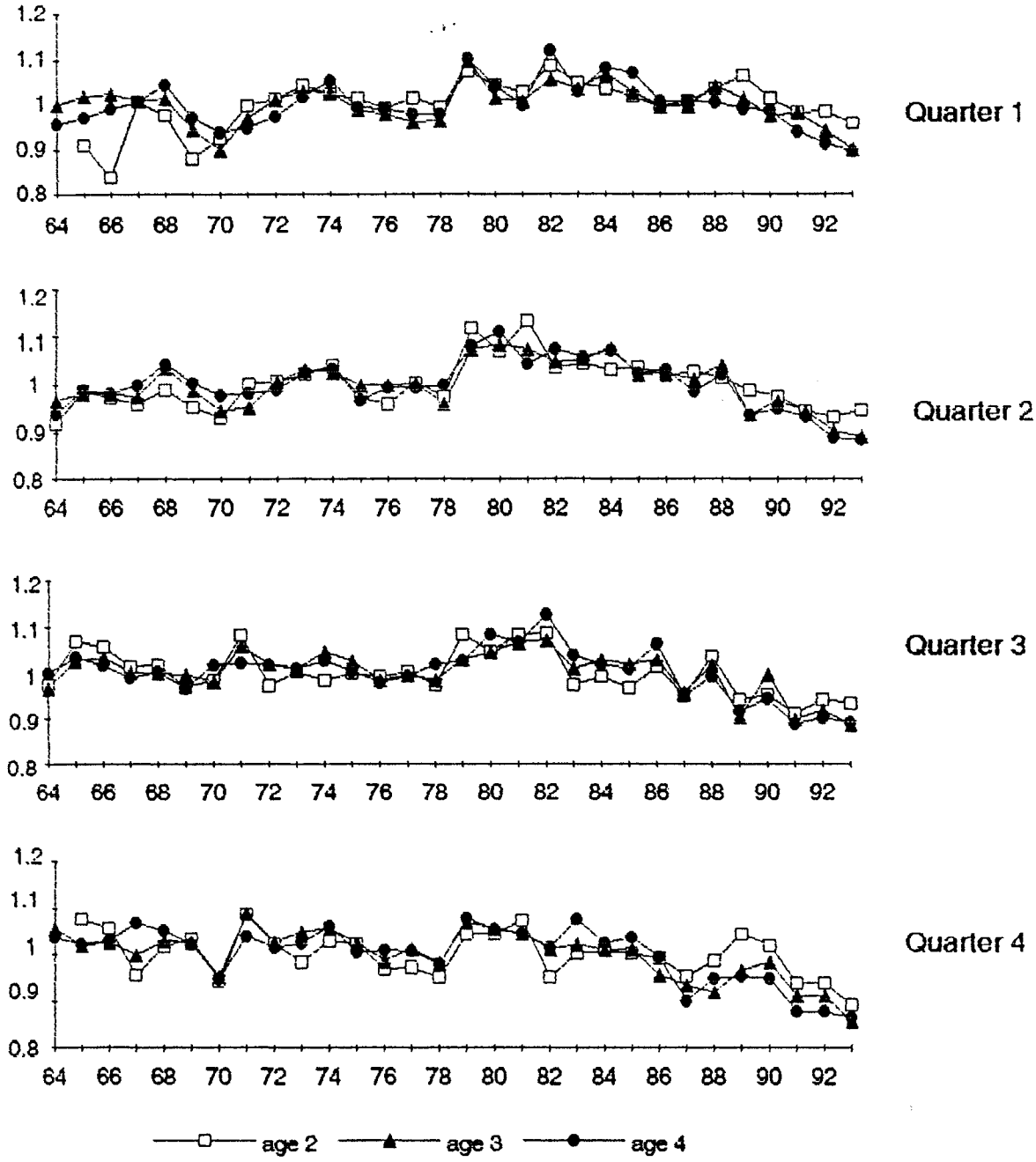


Fig 10.Deviation from mean length (1964-1993) for age groups 2-4 .

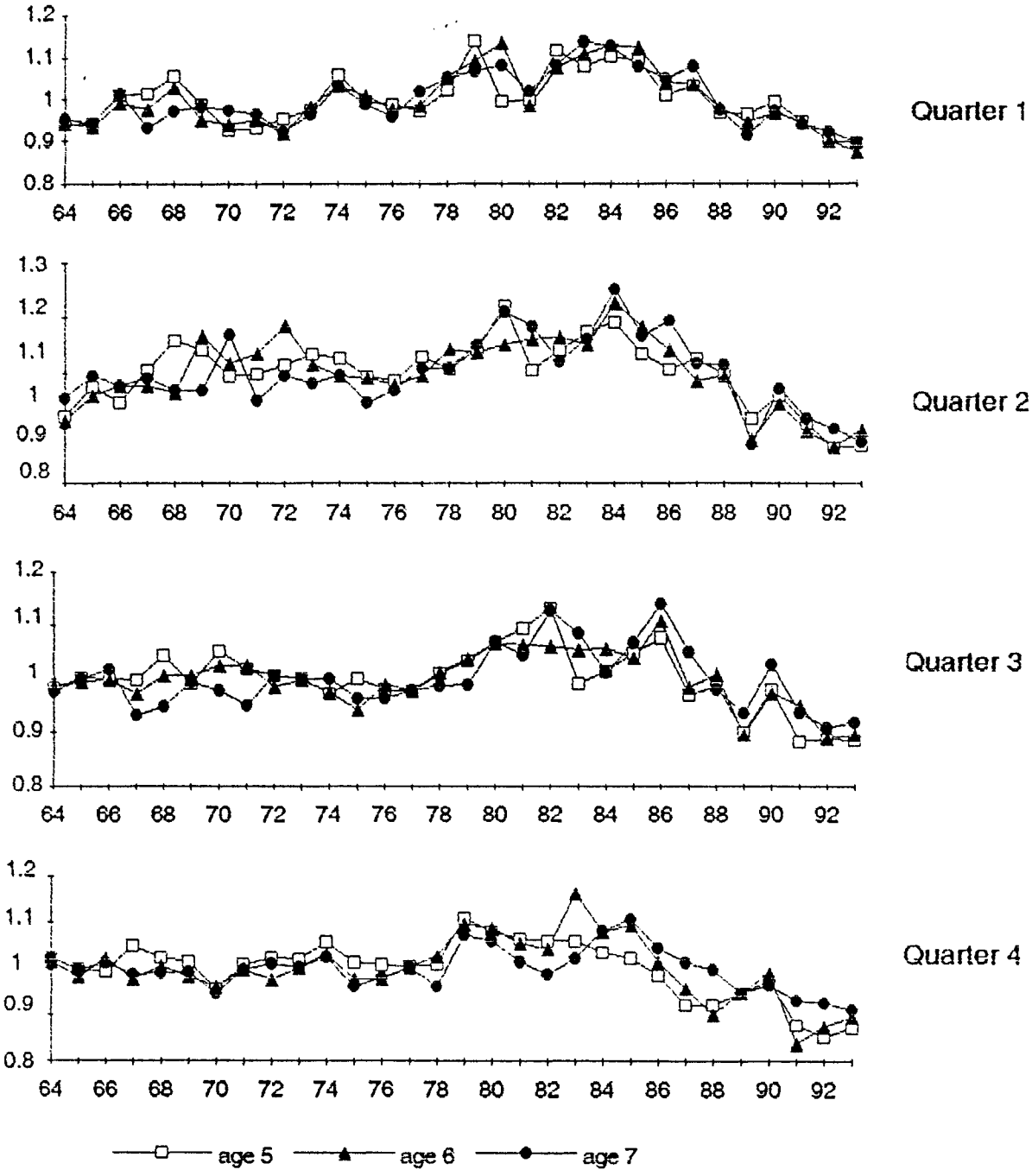
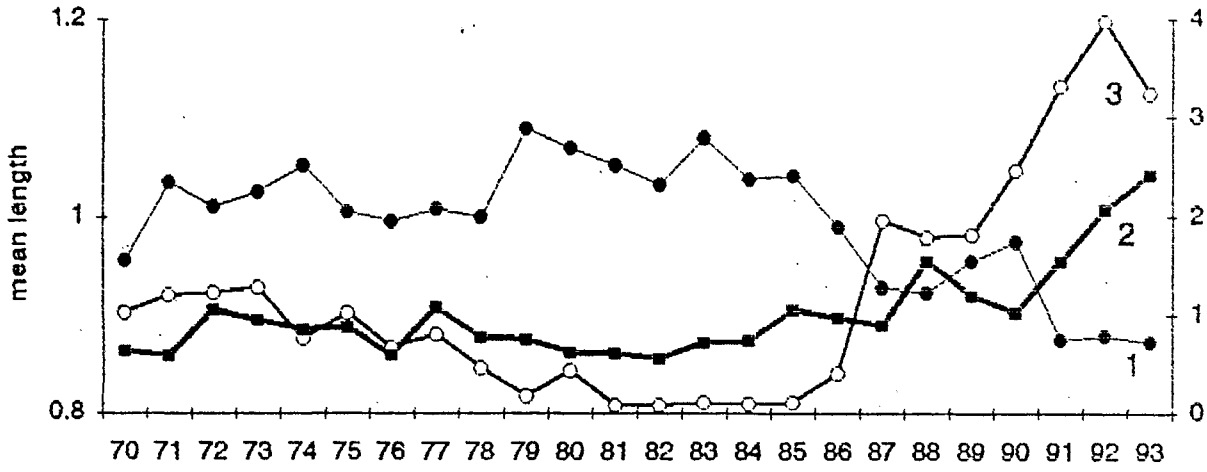


Fig 11. Deviation from mean length (1964-1993) for age groups 5-7



1 - mean length of age groups 3-6 in quarter 4
2 - stock number (age groups 2-10) of gulf herring in the Gulf of Riga
3 - the share of gulf herring in the sea in quarter 4

Fig. 12 Long-term dynamics (deviations from mean values) of herring length-at-age, the amount of gulf herring in the sea and stock size of herring in the Gulf of Riga