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Fluctuations of Cod Year-class Strength in the North Atlantic in Relation to the Spawning Stock Biomass and Survival Conditions

by

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Abstract

Long time series of spawning stock biomass and year-class strength fluctuations at age 3 was analysed in the North-Eastern Arctic cod, Faroe Plateau cod, West-Greenland and Icelandic cod, Labrador and Grand Bank cod. The ratio of 3 years olds to the spawning biomass in the year when they were born was regarded as modification of survival condition index. The surival condition index of different populations was compared in the Western North Atlantic and the Eastern North Atlantic. Some opposite trends in survival conditions are discussed for in the Eastern North Atlantic and the Western North Atlantic.

Year-class abundance fluctuations in fish populations are known to reflect reproduction conditions and survival during early life on the one hand and parentuial stock dinamics on the other. Year-class abundance fluctuations are estimated either on the basis of comparison between absolute year-class abundance at a given age in different years or by relating relative abundance to the average abundance of a year-class during a definite long-time period. With reference to demography reproduction coefficient is the ratio of the number of oranisms survived to that of the born ones which is practically survival rate. The ratio between the number of fish to have reached definite age and the total number of eggs spawned or an indirect indicator which is spawning stock biomass has been traditionally used in fisheries studies(Bevertovand Holt, 1957; Ricker, 1958). This paper makes an attempt only to apply cod year-class abundance dinamics to estimates of fluctuations and the comparison in different populations with ame of revealing trends in formation of early life conditions of cod populations in the North Atlantic.

Material and methods

Spawning stock biomass and abundance of three year- olds were derived from ICES Working Group Reports (Anon., 1980, 1981, 1983, 1983a, 1988, 1989a, 1989b, 1990, 1990a) Bishop and Baird, 1990; Buch and Hovgard, 1990.

Survival rate(S) is obtained as the ratio between the abundance of three year olds(R) and spawning stock biomass(P) in the year when they were born:

$S = R/P$,

where S is taken in terms of fish abundance per 1 tonn of spawning stock. The number of born and survived animals per one thousand of parents is traditionally used as reproduction index as referred to human beings birth rate as given as the abundance of children born per 1 thousand of population. Concerning fish the survival rate should be better considered as proportion of those riched the age of three years in the total abundance of the eggs spawned since the eggs in this case imply the actual number of organisms born in this population. However determination of egg abundance presents considarable difficulty due to inaccurate data sampling during ichtyoplankton surveys. Population fecundity can be viewed as a more adequate representarion of total egg abundance or to be more exact of the abundance of eggs to be spawned in a given year but estimation of this value demands annual assessments of individual absolute fecundity, which is a very complicated task to fulfil in the present and almost unrealistic against the retrospective background. Year-class survival rate was used by Beverton and Holt(1957),Ricker(1958) and by other researchers though under different context.

Results

West Greehland cod. (**Fig. 1**).

This stock is characterized by extremely wide range of yearcass abundance fluctuations and by long term periods of spawning stock depression thus the abundance of strong year-class of 1957 was more than by two order higher than that of the weak year-class of 1977. The spawning stock showed changes by two orders accordinglv. A decrease in the abundance and biomass of the spawning stock which actually accompanied the onset of high exploitation rates of cod in 1956 proved to be stable and it coincided with appearance of weak year-classes in the period from the early sixties and almost up to mid-seventies.

Survival rate fluctuations were more than by two and a half orders with those in the period of 1956-1972 not exceedidng one order. In 1973 this value appeared to be ten times as high as in the year when the highest on record abundant year-class of 1957 was born. In 1984 it proved to be fifty times as higher. It is during this years when strong year-classes of cod were recordered thogh the abundance was not as high as that of those born before 1964 when spawning stock was by 1 - 2 orders higher than during the following years.

Cod of Labrador and Northern Newfoundland(2J-3KL) (**Fig. 2**).

Year-class abundance of this stock does not vary over such a wide range as the above described one does and it did not exceed one order. The spawning stock biomass declined continuously throught the period of 1962-1977 with the most abundant year-classes of 1962 and 1963 following on the maximum spawning stock biomass. Fluctuations in the spawning stock biomass were within one order whereas a permanent decrease in the spawning stock actually coincided with establishment of high exploitation rates in 1962-63. Survival rate also varied within one order with the maximum and minimal one recordered in 1978 and 1971 respectively. An upward trend took place in 1963 and 1986 and in the period from 1973 to 1962.

Cod of the Grand Bank of Newfoundland(3NO) **(Fig. 3).**

This stock shows changes in its abundance within one order and the strongest year-class emerged in 1963. The spawning stock size also varied within one order with peak recordered in 1983-87. The amplitude of survival rate fluctuations was 1,5 orders with the minimal and maximum values encountered in 1983 -1986 and 1962-1964,1975 respectively.

Cod of St. Pierre and Green banks(3PS) **(Fig. 4).**

Insignificant range of abundance fluctuations is typical for this stock. The abundance of the strongest year-class of 1984 exceeded that of the weakest one of 1976 by two orders only. Of the same magnitude were variations in the spawning stock which demonstrated its maximum and minimum in 1960 and in 1976 respectively. Survival rate dynamics was more significant but it did not exceed one order. The maximum values were noted in 1974,1978,1981 and 1982.

Icelandic cod. **(Fig. 5).**

The year-class abundance fluctuations are below 0,5 order in this stock and the spawning biomass changed within 0,3 orders. Survival rate varied within 1 order with the maximum and minimum in 1983 and 1969 respectively.

Cod of the Faroe Plateau. **(Fig. 6).**

Year-class abundance dynamics is not considarable and it lies within one order, which is also true for spawning stock fluctuations. The maximum and minimum year-class abundance was recordered in 1982 and 1963 respectively. The highest and lowest survival rates fall on 1963 and 1976 respectively.

Northeast Arctic cod. **(Fig. 7).**

Fluctuations in the year-class abundance are incredibly high in this stock. The abundance of a strong generation was more than by one order high than that of a weak one, which was accompanied by changes in the spawning stock size of one order only. Same was true for survival rate dynamics which showed its minima and maxima in 1964,1970,1975,1983 and 1978,1977,1966,1967,1986 respectively.

Discussion.

The greatest magnitude of year-class survival rate fluctuations was observed in the West Greenland cod where it was nearly three orders. The lowest one was typical of Greenlsnd cod. Faroe Plateau cod and 3PS cod demonstrated relatively narrow range of changes of survival rate. The highest survival rate as averaged for a long time series was recorded in the Northeast Arctic cod. The second next went the West Greenland cod. The Northeastern Arctic cod showed the highest geometric mean and mode of survival rate whereas the lowest mode was found in the West Greelland cod. The most significant variations of this parameter were typical of the West Greenland cod immediately followed by Northeast Arctic cod. **(Table 1).**

Assuming that survival rate indicates early life conditions for a given generation the wide range of fluctuations of this parameter in West Greenland and Northeastarctic cod points to the exposure of these populations to extreme environmental factors demanding species specific adaptations during early life.

There are certain correlations between survival rate fluctuations in time series in 3PS cod and 2J3KL cod (r = 0,636).

A closer correlation was observed between the trends in the survival rate dynamics of different populations (Table 2).

Some positive trends were revealed between Northeast Arctic cod, 3NO cod and Faroe Plateau cod, between West Greenland cod, Icelandic cod 2J3KL and 3PS stocks. Yet the degree of the correlations is not significant enough to establish any regular pattern. (Table 3).

The trend correlations can be attributed to climate changes in the North Atlantic which are reflected in survival conditions whereas short term lockal perturbations do have a more pronounced effect on survival rate (Fig. 8 and 9).

Table 1

Stocks	Years	R/SSB Min.	Max.	Average	Mode	Geom. mean	Variance	s.d.
W-Gr.	1956-1986 (31)	61.8	17325.2	1226.6	220.8	346.1	10257700	3202.7
NAFO Div 2J3KL	1962-1986 (25)	267.3	2588.1	1045.6	904.4	914.6	271220	520.8
NAFO Div 3NO	1959-1986 (28)	23.4	2071.7	702.2	625.7	451.9	291269	539.7
NAFO Div 3Ps	1959-1984 (26)	225.0	1222.0	642.9	595.1	575.8	87138	295.2
N-E Arctic cod	1964-1984 (23)	328.7	5327.8	1439.4	859.0	1067.7	1586260	1259.5
Faroe Plateau ood	1961-1987 (27)	111.0	1179.2	372.5	276.6	301.4	66472.7	257.8
Iceland cod	1963-1986 (24)	173.7	1155.1	454.7	360.8	403.6	63256	251.5

TABLE 2. Correlation Analysis

Data vectors or filename: ARKNORCO. lnKR
FARPLAT. KoefRepr
ICECOD. lnKR
WESTGRC.lnKR
LABR. KoefRepr
CODGRBNK.KoefRepr
CS3PS.KoefRepr

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<u>Sample Correlations</u>

	N-E-ARC	Faroes	Iceland	W-GR	2J3KL	3NO
		KR	lnKR	lnKR	KoefRepr	KoefRepr
lnKR N-E.ARC.		.2227 (21) .3318	.1545 (21) .5036	-.2302 (21) .3154	-.2800 (21) .2190	.1555 (21) .5009
KR Faroes	.2227 (21) .3318		.0878 (21) .7050	-.3050 (21) .1788	.0271 (21) .9073	-.2460 (21) .2824
lnKR Iceland	.1545 (21) .5036	.0878 (21) .7050		.4683 (21) .0323	-.1104 (21) .6338	-.0874 (21) .7064
lnKR W.Greenland	-.2302 (21) .3154	-.3050 (21) .1788	.4683 (21) .0323		.2538 (21) .2670	-.0448 (21) .8470
KoefRepr 2J3KL	-.2800 (21) .2190	.0271 (21) .9073	-.1104 (21) .6338	.2538 (21) .2670		.3514 (21) .1183
KoefRepr 3NO	.1555 (21) .5009	-.2460 (21) .2824	-.0874 (21) .7064	-.0448 (21) .8470	.3514 (21) .1183	
KoefRepr 3Ps	-.0512 (21) .8256	.4344 (21) .0491	.0123 (21) .9579	.2703 (21) .2360	.6356 (21) .0020	-.0308 (21) .8944

Coefficient (sample size) significance level

2J3KL	- 3Ps	μ = 0,636	N = 21	p = 0.002
Faroes	- 3Ps	μ = 0,434	N = 21	p = 0.05
W-Greenland	- Iceland	μ = 0,468	N = 21	p = 0.03

Table 3. Trends (smoothed) Fri Aug 23 1991 07:40:51 PM

Sample Correlations

	N-E Arct.	Faroe	Iceland	W-Gr	2J3KL	3NO
N-E Arct.		.4708 (21) .0312	.1803 (21) .4343	-.1548 (21) .5028	-.2248 (21) .3273	.4373 (21) .0474
Faroe	.4708 (21) .0312		-.3757 (21) 0.933	-.2739 (21) .2296	.1852 (21) .4215	.1862 (21) .4190
Iceland	.1803 (21) .4343	-.3757 (21) .0933		.5301 (21) .0134	-.1214 (21) .6001	-.3247 (21) .1510
W-Gr	-.1548 (21) .5028	-.2739 (21) .2296	.5301 (21) .0134		.5877 (21) .0051	-.1362 (21) .5560
2J3KL	-.2248 (21) .3273	.1852 (21) .4215	-.1214 (21) .6001	.5877 (21) .0051		.0429 (21) .8534
3NO	.4373 (21) .0474	.1862 (21) .4190	-.3247 (21) .1510	-.1362 (21) .5560	.0429 (21) .8534	
3Ps	-.0921 (21) .6913	.5154 (21) .0168	.0656 (21) .7776	.4473 (21) .0420	.6651 (21) .0010	-.4441 (21) .0437

Coefficient (sample size) significance level

Positive

N-E Arc.	Faroe	r = 0.471	n = 21	p = 0.03
	3NO	r = 0.437	n = 21	p = 0.05
Faroe	3Ps	r = 0.515	n = 21	p = 0.02
W-Gr.	Iceland	r = 0.530	n = 21	p = 0.01
	2J3KL	r = 0.588	n = 21	p = 0.01
	3Ps	r = 0.447	n = 21	p = 0.04
2J3KL	3Ps	r = 0.665	n = 21	p = 0.01

Negative

Faroe	Iceland	r = 0.376 P = 0.09
3NO	3Ps	r = 0.444 P = 0.04

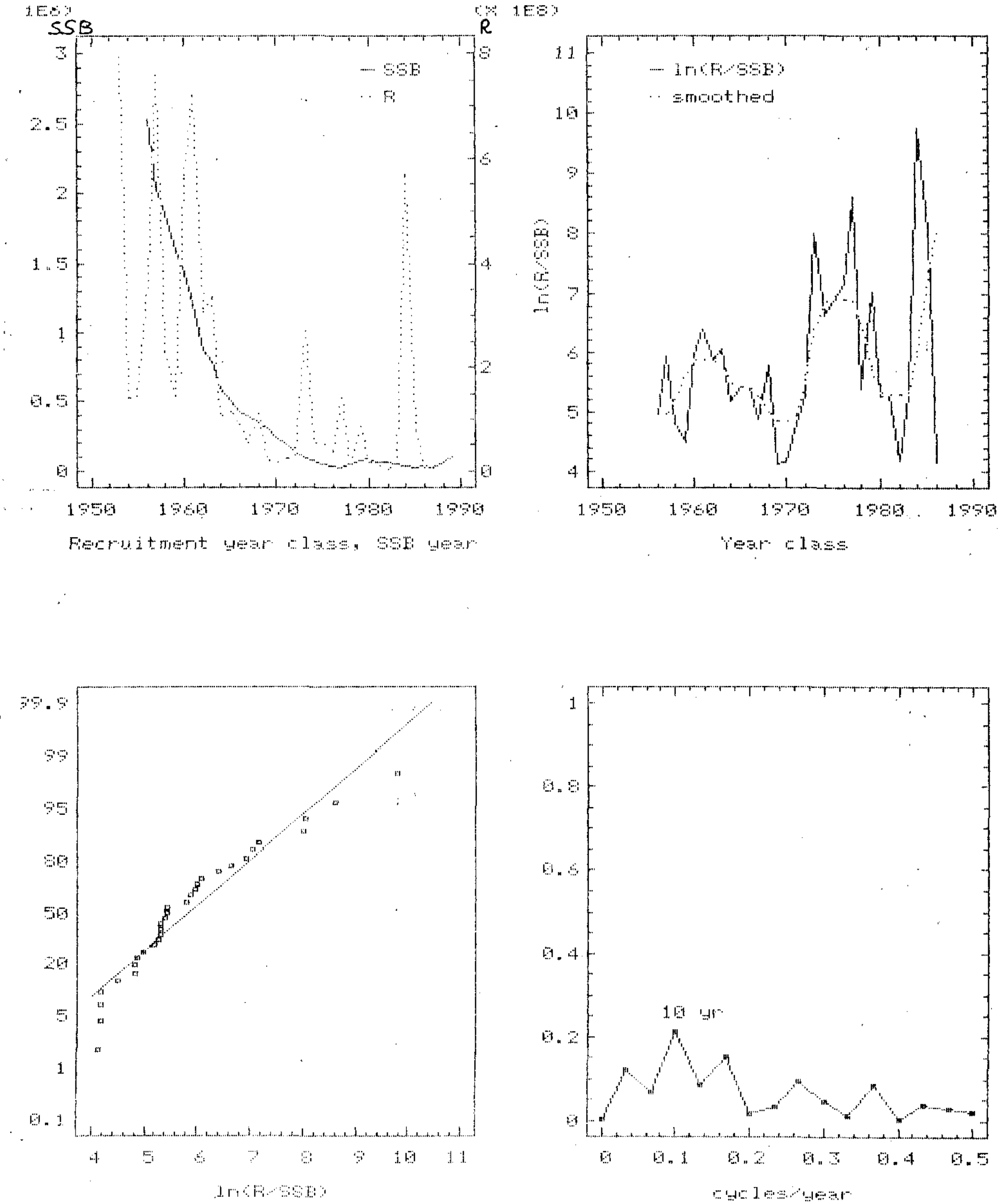


Fig. 1. West Greenland cod.

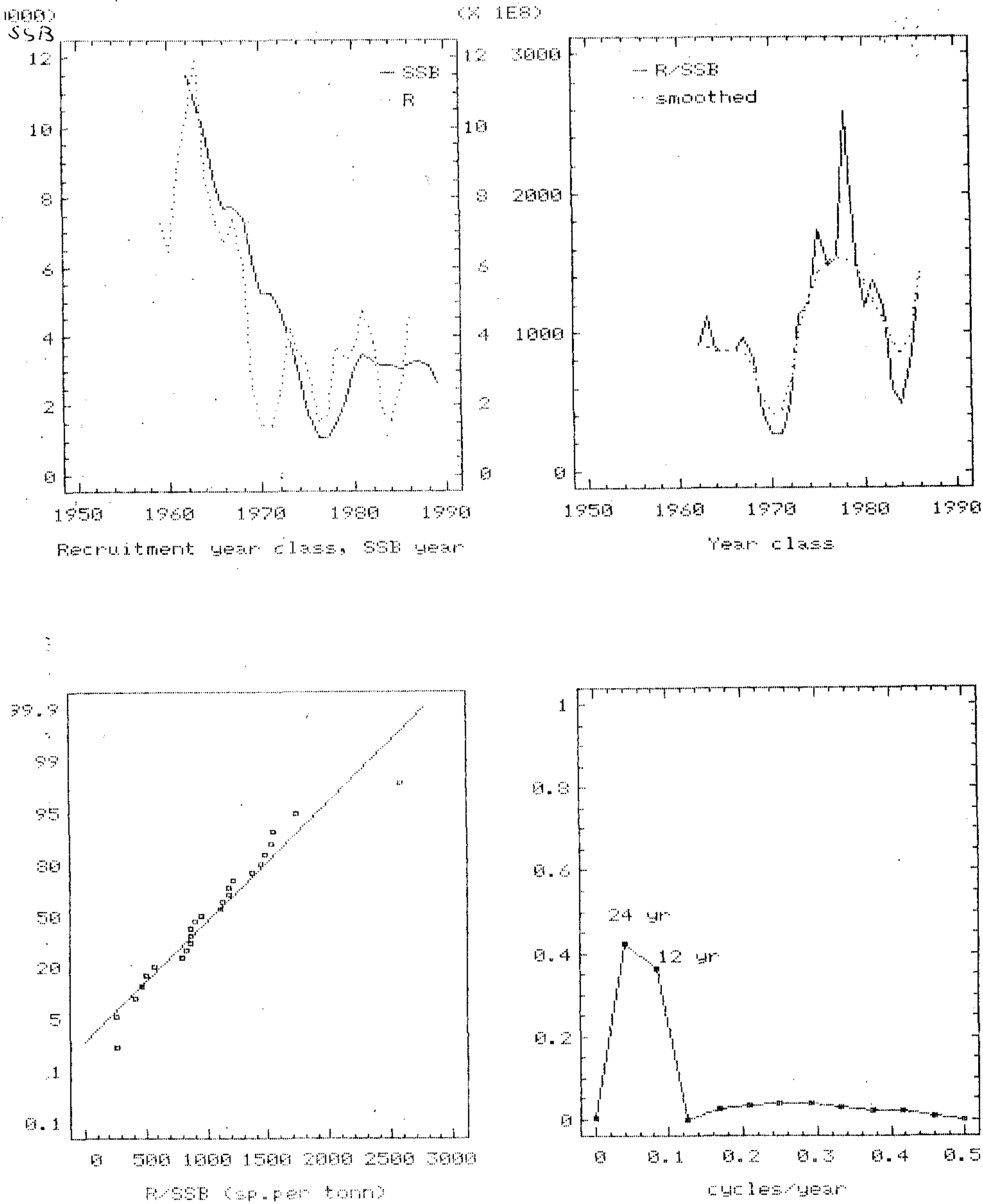


Fig. 2. Div. 2J+3KL cod.

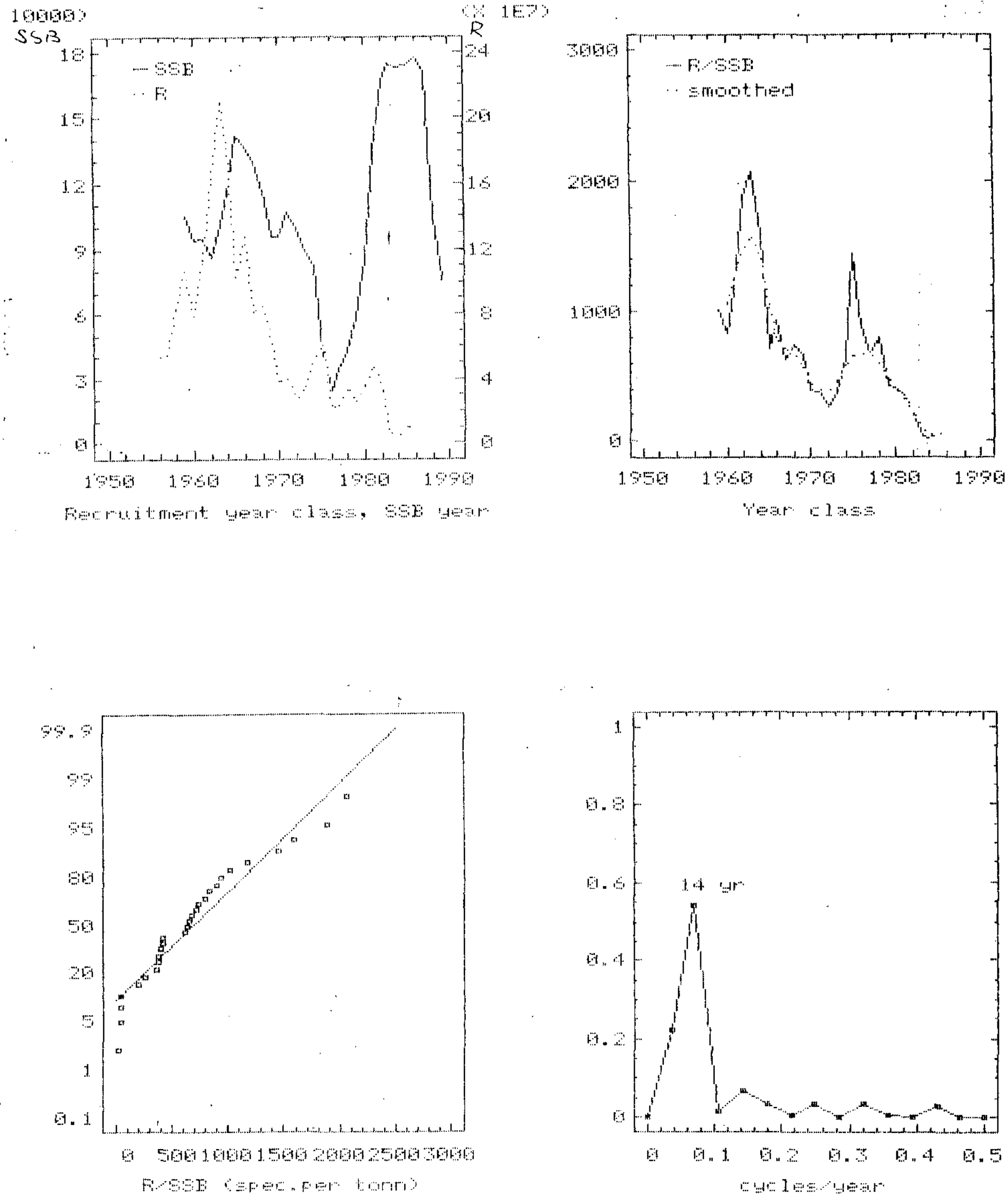


Fig. 3. Div. 3NO cod.

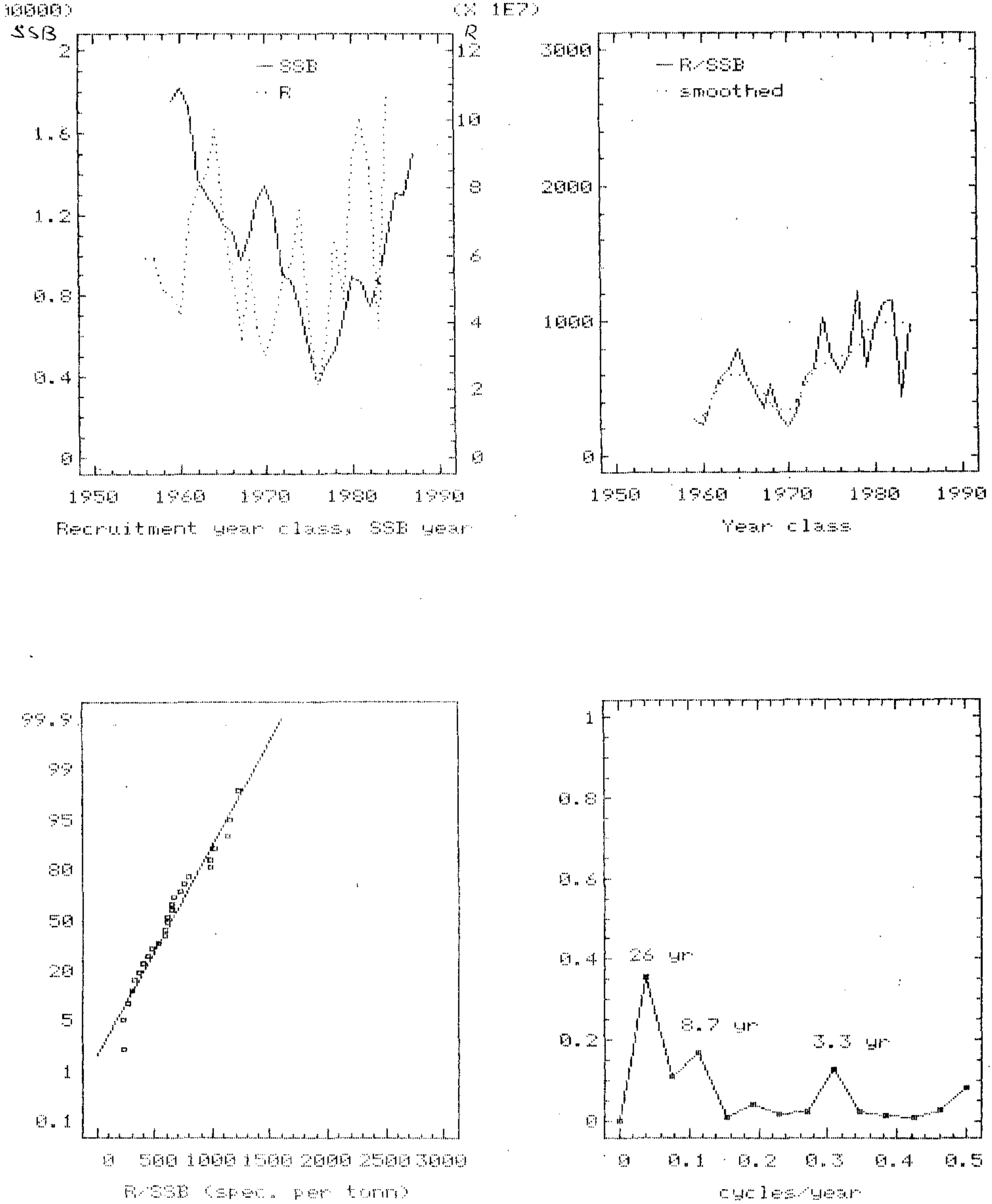


Fig. 4. Subdiv. 3Ps cod.

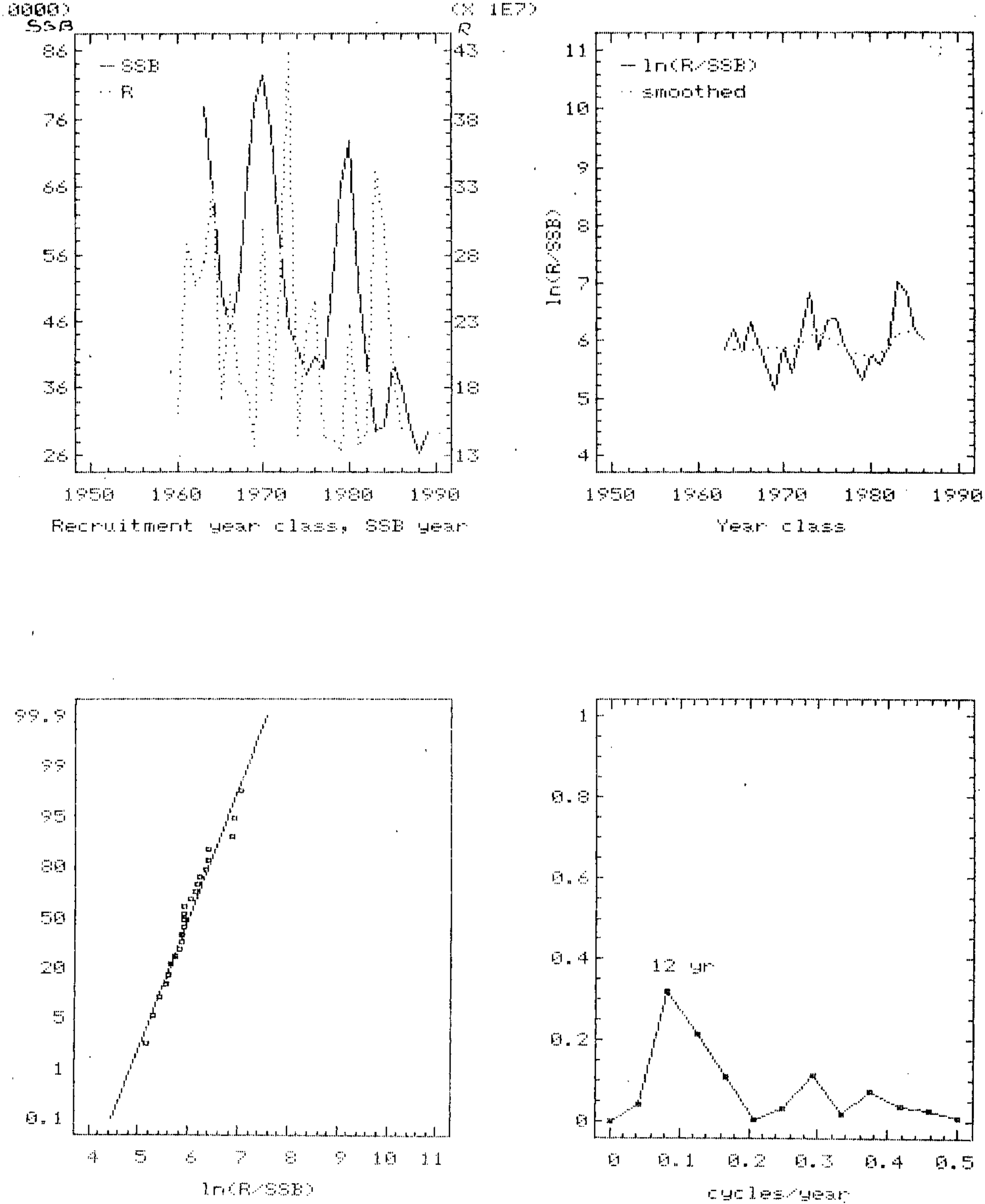


Fig. 5. Icelandic cod.

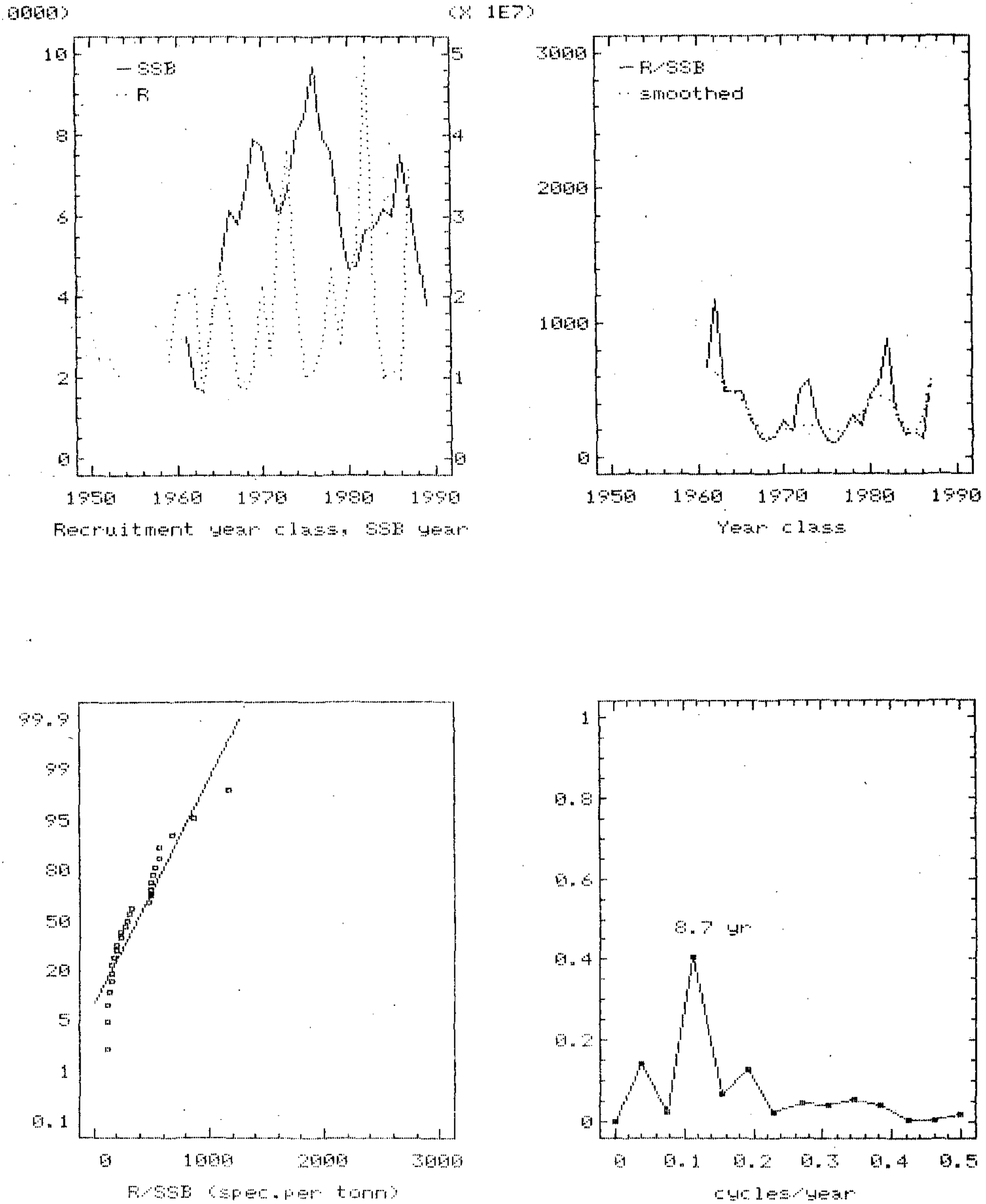


Fig. 6. Faroe Plateau cod.

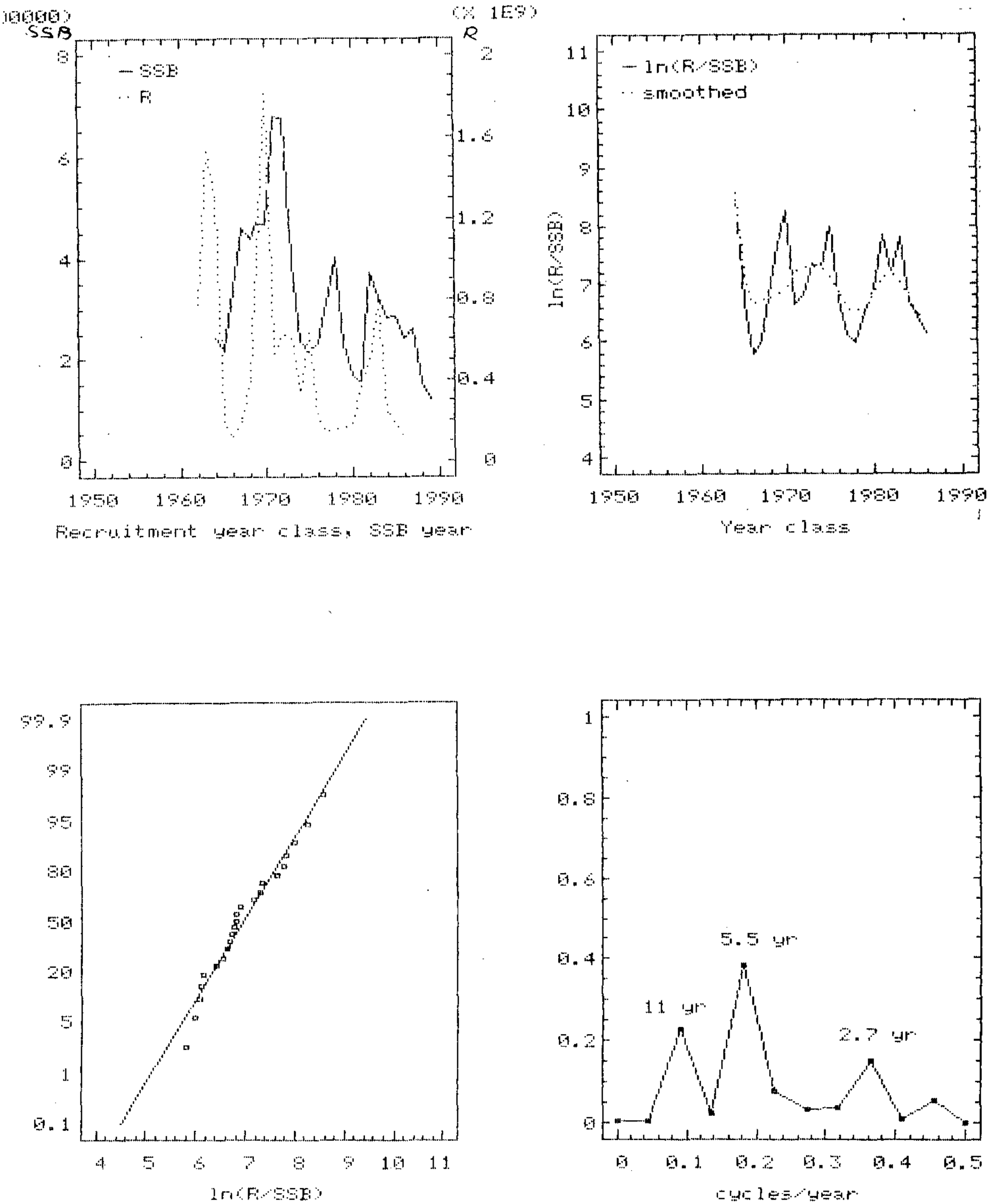
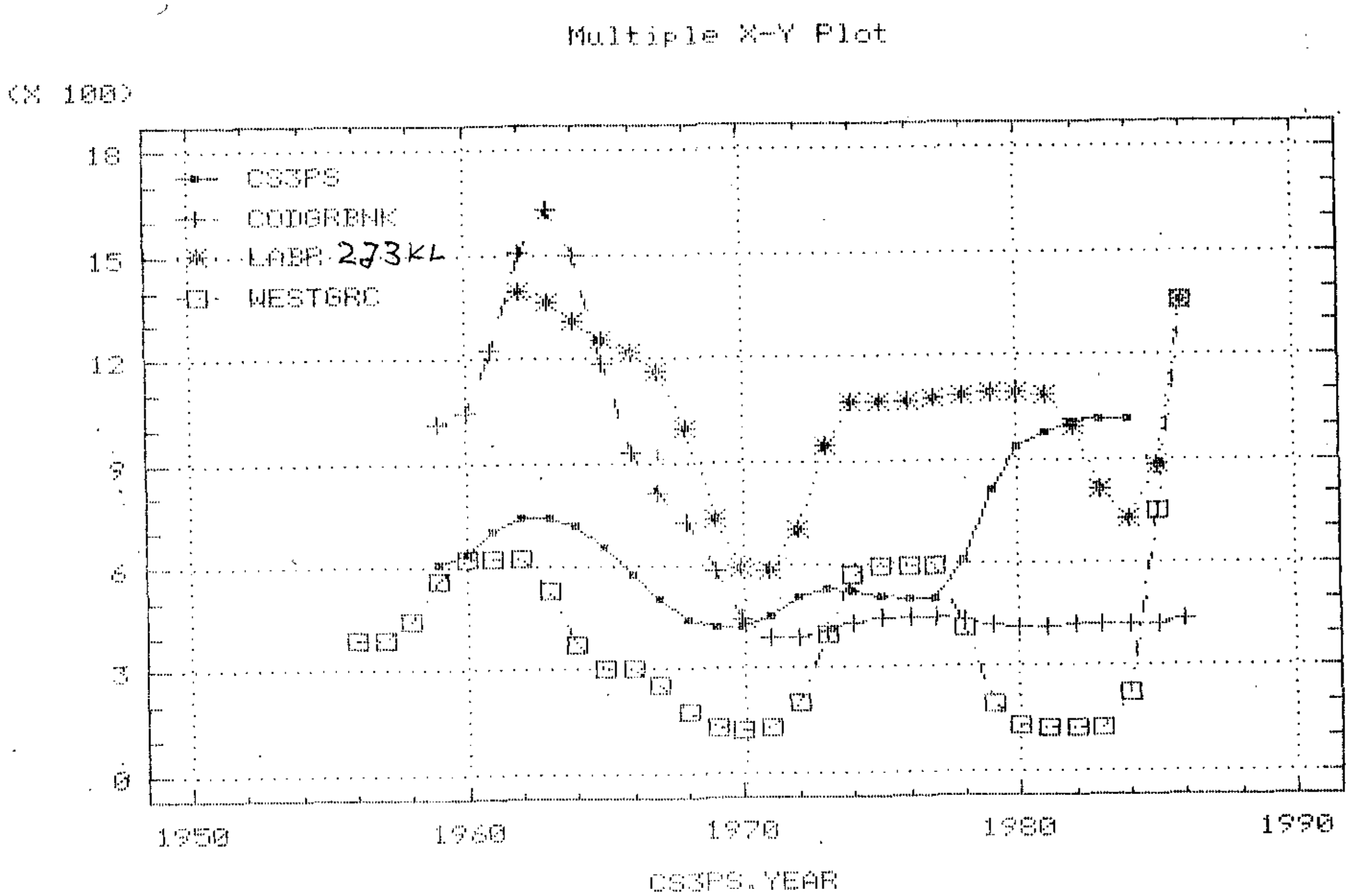


Fig. 7. Northeast Arctic cod.



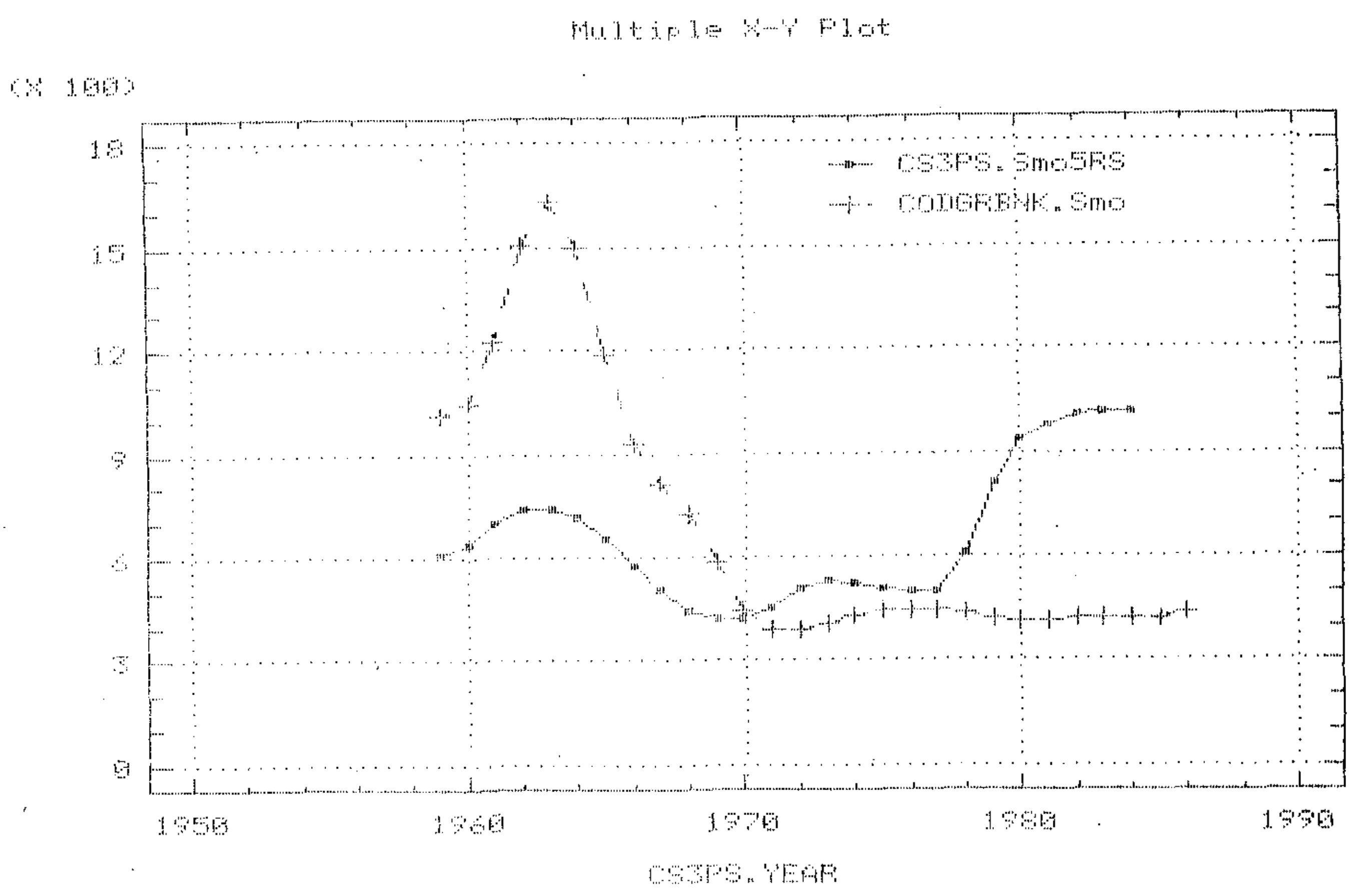


Fig. 8. Western North Atlantic cod survival rate fluctuation trends.

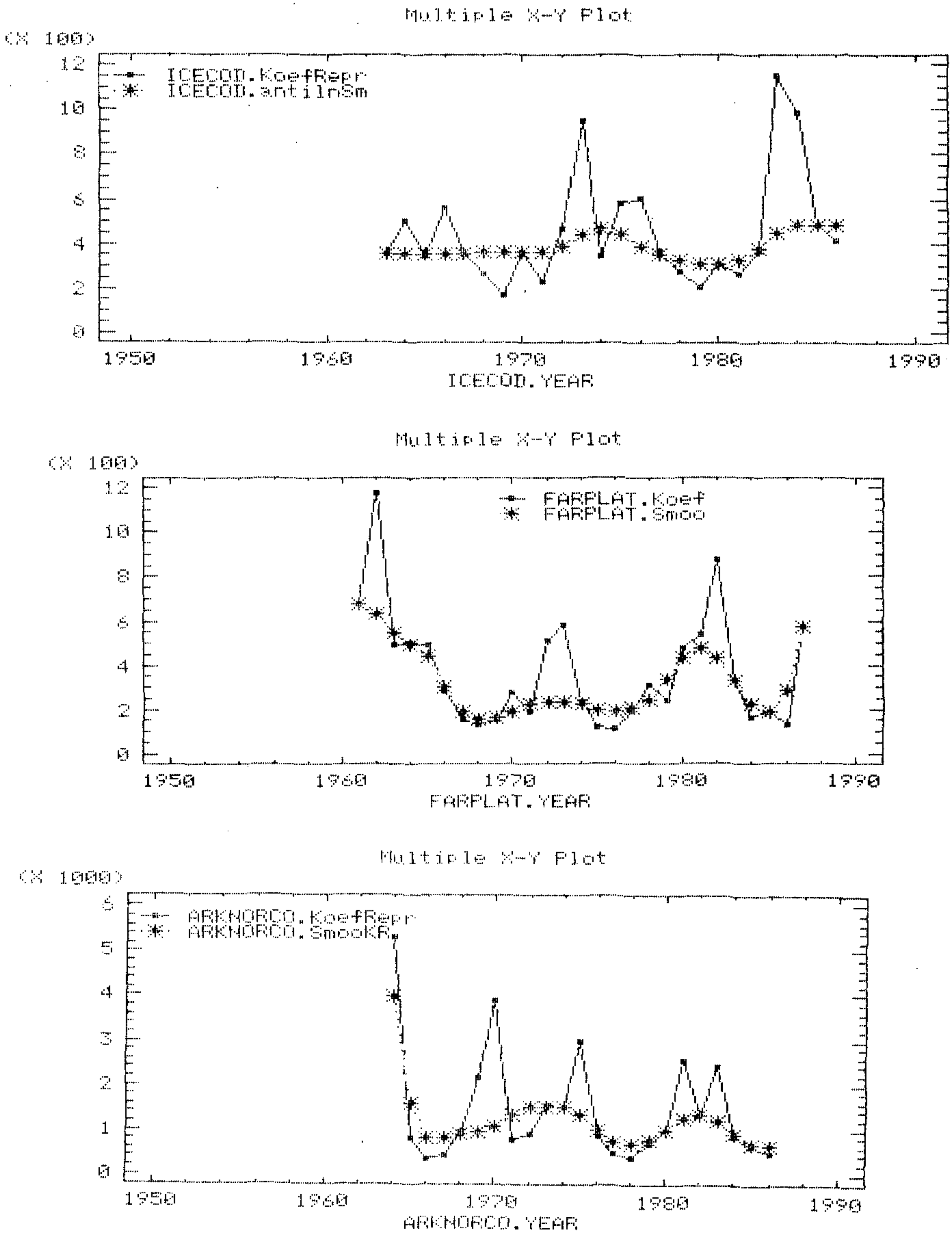


Fig. 9. Eastern North Atlantic cod survival rate fluctuation trends.