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MATURITY RATE OF THE LOFOTEN-BARENTS SEA COD IN 40'S AND 90'S

by

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INTRODUCTION

The Lofoten-Barents Sea cod Gadus morhua morhua L. is the species with a long life cycle and much extended period of maturity onset, what is important for adaptation, since it leads to a stabilization of spawning population abundance, i.e. fish from abundant yearclasses spawn during several years and compensate deficiency of spawners in those years when specimens from scanty yearclasses attain maturity.

Most of cod attain maturity at 80-90 cm length, however, some specimens remain to be immature even at 100-110 cm length. And "only on attaining 115 cm length , all cod specimens are mature" (Glebov, 1963). According to T.I.Glebov, minimum length of mature males is 37 cm and 42 cm - for females. A.S.Baranenkova and N.S.Khokhlina (1964) pointed to the spent cod males of 38 cm and females of 45 cm long found. Hence, cod maturity onset is determined not only by a body length, but also other factors among which genetic factors are probably the most important.

It is likely that the groups of early-maturing, medium - maturing and late-maturing specimens are available in cod population and under an influence of those or other reasons, in particular, of intensive fishery, the abundance ratio of the groups mentioned may essentially vary (Borisov, 1978). No strict evidences of this hypothesis are available. It is difficult to prove a fact of genetic variations in a natural population (Allendorf et al., 1991). However, a selective impact of fishery upon intrapopulational differentiation by such important polygenic features as sex, age, rate of maturity and growth, duration of life, has been already shown for a number of fish species (Altukhov, 1994). Probably, similar mechanisms also exist in other fish species and only time will prove this.

MATERIALS AND METHODS

To estimate a rate of cod sexual maturity, biomass and age composition of the spawning stock in specific years a relatively simple method was suggested for dividing the stock into mature and immature portions on the basis of data from field analyses for cod gonads, usually done when taking age samples (Ponomarenko

et al., 1980). Data were retrieved by separate age and length groups, by males and females for each of the three areas, i.e. the southern Barents Sea (Subarea I), Bear Island - Spitsbergen area (Div.IIb) and northwestern coast of Norway (Div.IIa). As a result of the retrieval the number and percent of mature fish were determined in each age and length group from cod analyzed during autumn-winter migration to wintering and spawning grounds (November-February). Gonads of the first- and repetitive maturing cod differ most clearly from those of immature specimens during the months mentioned. Besides, as indicated by T.I.Glebov (1963) in his paper, the occurrence of mature cod in the Barents Sea is the highest in December-February.

Under field conditions maturity of cod gonads were visually staged by 6-point scale developed by B.P.Sorokin (1957, 1960). When retrieving the data fish with gonads at maturity stage I and II in November-February were considered to be immature and mature - at maturity stages from II-III to VI-II. While cod belongs to a group of fish with a prolonged multy-intermittent type of egg extrusion, " a start of vacuolization phase during a heavy growth of ovocytes takes place probably simultaneously in all ovocytes subjected to extrusion in the next spawning season" (Sorokin, 1957). Hence, one can assume that cod, which did not attain the gonads maturity stage- III in November-December, were not mature and would not participate in spring spawning. T.I.Glebov (1963), as well as G.Rollefsen and E.Sivertsen (Glebov, 1963), pointed to the annual spawning of cod attained maturity. However, some publications have become available in recent years, in which a possible miss of spawning is stated (Oganesyan, 1993). This can be confirmed by the analysis for spawning zones on otoliths.

RESULTS

The first results from the analysis done by the method given above pertained to 1966/1967-1977/1978 (Ponomarenko et al., 1980; Ponomarenko et al., 1985), then the data for earlier and later years (Ponomarenko , Yaragina, 1981; I.Ponomarenko, 1982; Ponomarenko, 1984; Lebed, Ponomarenko, 1985, 1986; Yaragina, 1988) were added and the materials for 1946-1990 were analyzed and given in Fig.1. The method suggested allowed to perform a retrospective analysis for a rate of sexual maturity of cod males and females within several decades and to reveal the main trends of the variations occurred.

Validity of the data obtained by this method on the relationship between mature and immature specimens in cod separate age groups was tested by comparing the calculated and actual (observed) age composition of "skrei" on the Lofoten spawning grounds (Ponomarenko et al., 1980; Ponomarenko, 1984; Jakobsen, 1978, 1979). A well pronounced agreement between the calculated and actual composition indicates a sufficient reliability of the method widely used for annual assessment of the spawning stock of cod and other fish at present (Anon., 1991, 1992), as well as when calculating the spawning stock total fecundity (Serebryakov et al., 1984; Ponomarenko, 1984; I.Ponomarenko, 1982).

Historical data from field analyses for gonad maturity stages confirmed a concept of extended period of the beginning of cod

sexual maturity (Maslov, 1944; Rollefsen, 1954; Mankevich, 1964; Glebov, 1963; Garrod, 1967; Ponomarenko, 1968). A portion of specimens (below 1%) of less than 50 cm long attains maturity at age 3-4, whereas the others become mature only by 12-14 yr and in the rarest cases - by age 16. The main bulk of cod attains maturity by 8-10 yr at 80-90 cm length and 4.0-5.5 kg weight. Nevertheless, cod at age 7 and even 6 are sometimes predominant in the spawning stock, if it is presented by rich yearclasses, the abundance of which is much higher than the amount of fish at age 8 and older. Such situation was for example observed in 1976 (Jakobsen, 1978), although in total only 4.5% of mature specimens were among 6-year-olds from the very rich 1970 yearclass.

In 40-80's cod mature specimens at age 6-9 predominating made up 12% of the total amount of fish analyzed from the whole area surveyed, with the specimens at age 8-10 being prevalent in 50's, at age 7-8 - in 60's, at age 8-9 - in 70's and at age 6-7 - in 80's (Fig.1). The highest amount of mature specimens was registered at the northwestern coast of Norway (59.5%) and much lesser - in the fattenning areas, in the southern Barents Sea (5.3%) and in the Bear Island - Spitsbergen area (9.9%) (Ponomarenko, 1984).

Relationship between the rate of sexual maturity and growth is shown in the paper by V.P.Ponomarenko and co-authors (1985). In the second half of 60's and in 70's the higher growth rate of cod was observed in 1967, in 1971-1972, with the lowest being in 1969 and in 1974-1975. In the years of a high growth rate a percent of mature specimens from all age groups was somewhat higher than the mean values and was by 45-35% higher (among 6-9 year-olds) compared to the years of low growth rate. Therefore, the earlier maturity of cod in 60's and 70's, compared to 30's and 40's (Rollefsen, 1954; Garrod, 1967), was largely related to an increase in its growth rate, since the relative number (%) of mature fish from the length groups studied did not endure essential variations, especially in fish below 80 cm long (Fig.3).

Most authors (Maslov, 1944; Rollefsen, 1954; Glebov, 1963; Ponomarenko, 1968; Konstantinov, Nevinsky, 1969; Ponomarenko et al., 1980) noted the earlier maturity of males against females. Analysis for the historical data of 50's - 80's indicate the percent of mature specimens from the younger age groups (3-5 yr) to be approximately similar among males and females.

However, by 6 years the maturity rate of males has already been markedly higher than that of females. Discrepancies in the percent of mature males and females increase and then begin to decrease by age 9, as far as all males and females attain maturity by 13-14 yr. As a result of asynchronous maturation of males and females, among mature cod at age below 10 (Table 1) and in the length groups below 90-95 the males are preponderant and females - among the larger specimens (Ponomarenko, Yaragina, in press). Adult age groups (17-22 yr) are mainly represented by females, however, very few fish at this age occur in samples. Among the cod at age below 9 analyzed (mature and immature) the sex ratio is close to 1:1 with a minor predominance of males, but females prevailing in older age (Ponomarenko et al., 1985).

Duration of life in males is probably shorter than that in females.

DISCUSSIONS

Raise in sexual maturity rate of cod is well pronounced by the data from a number of authors presented the maturity ogives for different periods of years (Rollefsen, 1954; Glebov, 1963; Garrod, 1967; Ponomarenko, 1968; Hylen, Dragesund, 1973; Hylen, Rorvik, 1983; Ponomarenko et al., 1980; Jorgensen, 1990). The methods used to calculate the ogives are different, therefore sometimes it is impossible to estimate a rate of changes.

Comparison of the data obtained by the same method for 50's, 60's and 70's showed no essential variations relative to the number of mature fish by length and age groups studied. At the same time it should be noted that a wide range of fluctuations in these parameters is observed in separate years and yearclasses. Such fluctuations not always result from distinctions in cod growth rate and their reasons are not completely evident yet (Ponomarenko, 1984).

When considering the data on males and females separately a noticeable increase in males maturity rate is observed in 70's, whereas no increase was registered in that of females, i.e. a percent of mature specimens from the most groups did not change, even reduced a little.

These observations somewhat differ from T.Jorgensen's (Jorgensen, 1990) data, according to which the distinctions in each sex maturity rate in the period of observations over the 1923-1976 yearclasses became smaller. Probably, it was due to the fact that only the materials from the Lofoten fishery have been used and cod also spawn to the north and south of the Lofoten, with the younger age groups spawning northwardly (Lebed et al., 1983). In 80's the most amount of spawners was recorded on the spawning grounds between the Lofoten and Soroy (Sundby, Bratland, 1986; Mukhina, Yaragina, 1988). Hence, the younger age groups with males prevailing are presented to a small extent in Jorgensen's analysis.

Thus, as to a raise in maturity rate, a sexual dimorphism in cod has been found, i.e. females occurred to be more consistent compared to males (Ponomarenko, 1984). According to a conclusion on the sexual dimorphism formulated by V.A.Geodakyan (1982), if any feature is more pronounced in males then the same feature will grow in a whole population. Actually, in 80's a considerable increase in sexual maturity rate took place in a whole population and it was continuing early in 90's.

Rise in maturation of cod may be accounted for by a considerable increase in its growth rate in the first half of 80's, but probably not only for this, since a percent of mature specimens has grown much among the cod of the same length in 80's (Fig.3). A proportion of mature specimens has mainly grown in cod of 65-80 cm long, with a portion of mature males increasing most of all in fish at 60-70 cm and females at 70-80 cm length when considering sex separately (Fig.4).

In 80's cod length-groups maturity ogive exposed a leftward and upward shift , which may be a result of a selective fishery decreasing the abundance of late maturing fish and increasing a portion of early maturing ones because the latter have more chances to spawn (Borisov, 1978).An extremely high importance of shrimp (Pandalus borealis) in cod diet (Ponomarenko, Yaragina, 1984; Ponomarenko, Yaragina, 1990; Yaragina, 1986) - high-calorie protein food rich with vitamins and microelements - could also contribute to more rapid growth and maturation. However, complementary studies are necessary for this suggestion.

In 80's 50% of cod maturation have approached age 7 (7-8 yr interval), whereas in 50's and 70's 50% of cod attained maturity at age 8-9 and at age 10-11 - in 40's (Fig.2). A retarded maturity rate of cod in 40's was probably related to shortening of fishery in the War time, reduction in fish growth rate and accumulation of late maturing specimens grouping in spawning population. According to Jorgensen's (Jorgensen, 1990) data the mean age of maturity (A_{50}) reduced from 10.5 to 8 yr in the 1923-1976 yearclasses, i.e. by 2.5 yr.

In the second half of 70's the maturity rate in males has grown, i.e. 50%-point of maturation was observed in 7-8 yr interval, whereas 50% of females attained maturity at age about 9, as in 50's and 60's. In 80's 50% of males at age 6-7 and females at age 7-8 attained maturity. From 50's-70's to 80's the 50%-point of maturation of females has shifted to younger age by 1 year and by 2 years - that of males, which resulted in essential rise in difference between the number of males and females mature from the age groups studied, especially among fish at age 6-7-8 (Fig.5). From 40's to 80's a gradual increase in a portion of males from spawning population may be a result of, firstly, a rise in maturity rate, compared to females, and secondly, a decline in abundance of older groups among which females are predominant.

According to D.F.Zamakhaev (1959) year-to-year fluctuations in sex ratio in spawning population is a natural phenomenon also available in virgin populations under asynchronous maturation of males and females and essential fluctuations in abundance of yearclasses. However, prevalence of males and reduction in a portion of females from spawning population matched with a decline in spawning stock and its early maturation.

Age frequency of older mature cod from the samples for 80's much reduced, no fish at age above 10 were nearly found in it. If in cod age samples collected in 40's fish at age 10 and older made up on the average 59.6% and 35% in 50's, then in 80's it constituted only 4.1%. Approximately the same variation was observed in absolute abundance of cod older than 9 estimated by VPA method (Anon., 1993) (Fig.6). Higher maturity rate and early maturation of spawning stock may be considered as a cod population "reaction" to the sharply reduced abundance and biomass. The latter decreased from 3 mill.t in 1960-1969 to 1 mill.t in 1980-1989, what was due to an extremely high fishing mortality of fish at age 5-10 in 80's , as well as to a minor recruitment to stock in the second half of 70's and in 80's. 10

cod yearclasses of 15 which appeared in 1975-1989 occurred to be poor (below 300 mill.individ. at age 3) and 3 to be lower than mean abundant. It should be noted that 8 of 10 poor yearclasses have been scanty already at the stage of eggs (Mukhina, 1992) what was probably due to higher deficiency of older fish having a higer individual fecundity and producing eggs with a large supply of nutritive substances compared to first spawning individuals. A portion of recruits markedly increased from 1932 to 1987. In 1932-1955 about half of specimens caught by a long line when fishing at the Lofoten
were recruits, their portion increased to 90% by the end of 60's. In 60's - 80's mean percent of the first spawning individuals constituted about 80% , essentially varying from year to year (Jorgensen, 1990).

CONCLUSIONS

Under a high abundance of cod spawners the yearly fluctuations of their number probably do not influence markedly the yearclasses strength. However, a probability of such effect arises and grows while reducing a spawning fund level (I.Ponomarenko, 1984; Mukhina, Yaragina, 1988).

While intensificating a fishery and growing of cod fishing mortality from 40's to 80's a steady reduction took place in its spawning stock, as well as sharp decrease in abundance of older fish, increase of maturity rate, early maturation of spawning population, drop in a portion of females in it, decline in recruitment abundance, stocks and catches of cod.

With due consideration of important and determinative role of environmental factors and, in particular, temperature conditions in a formation of each distinct yearclass abundance, it should be admitted that the total level of reproduction is estimated by the parental stock size and quality. Hence, in order to change a long-term trend of reduction in cod stock it is necessary to regulate a fishery so as to decrese a fishing mortality to optimum which will allow to maintain a sufficient amount of older spawners.

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Table 1. Ratio of males and females from different age groups of mature cod in 50's - 90's in the Barents Sea and adjacent waters (I+IIB+IIA)

AGE	50's	60's		70's		80's		I990/9I-I992/93
		1st half	2nd half	1st half	2nd half	1st half	2nd half	
4+(5)	I,3I	I,46	0,94	3,80	I,05	3,67	7,32	2,73
5+(6)	I,33	I,69	I,06	3,58	2,I4	2,69	2,82	2,I4
6+(7)	I,I2	I,49	I,90	I,60	2,08	I,92	I,3I	I,I5
7+(8)	I,09	I,66	I,43	2,64	I,83	I,38	I,00	I,0I
8+(9)	I,26	I,36	I,2I	I,26	I,59	0,87	0,68	0,82
9+(I0)	0,87	I,06	I,09	0,74	I,04	0,58	0,50	0,59
I0+(II)	0,79	0,77	0,70	0,5I	I,00	0,43	0,53	0,5I
II+(I2)	0,72	0,65	I,29	0,27	I,00	0,32	0,I2	0,I9
I2+(I3)	0,I2	0,60	0	0,57	0,50	0,I8	0,I4	0,40
I3+(I4)	0,86	0,57	0,33	0,60	0	0,20	0	0,25
Total	I,02	I,27	I,24	I,33	I,74	I,79	I,9I	I,0I

Table 2. Percent of mature fish among cod at different age during migration to wintering and spawning grounds in ICES areas I, IIa and IIb.

AGE	I958/59-I959/60	I960/6I-I964/65	I965/66-I969/70	I970/7I-I974/75	I975/76-I977/80	I980/8I-I984/85	I985/86-I989/90	I990/9I-I992/93
2+(3)	0	0	0	0,3	0,I	0,9	0,5	0,2
3+(4)	I,I	0,5	0,4	0,8	0,5	I,6	I,4	2,4
4+(5)	4,2	I,5	3,2	I,3	I,2	II,2	6,5	5,8
5+(6)	I0,6	5,8	4,8	3,6	6,8	2I,I	I9,8	25,8
6+(7)	I9,9	I9,9	I0,7	I6,0	20,5	45,I	43,8	66,2
7+(8)	43,4	48,4	27,4	30,5	49,0	64,4	68,2	86,I
8+(9)	66,I	70,7	47,9	62,4	68,7	79,0	86,7	95,3
9+(I0)	83,I	9I,7	58,2	82,7	73,2	95,4	93,3	99,6
I0+(II)	88,I	96,8	75,4	89,7	76,9	98,4	I00	98,5
II+(I2)	84,4	99,3	76,2	90,5	82,8	I00	I00	95,0
I2+(I3)	I00	I00	I00	I00	I00	I00	I00	I00
I3+(I4)	I00	93,2	I00	I00	I00	I00	I00	I00
I4+(I5)	I00	I00	I00	I00	I00	I00	I00	I00

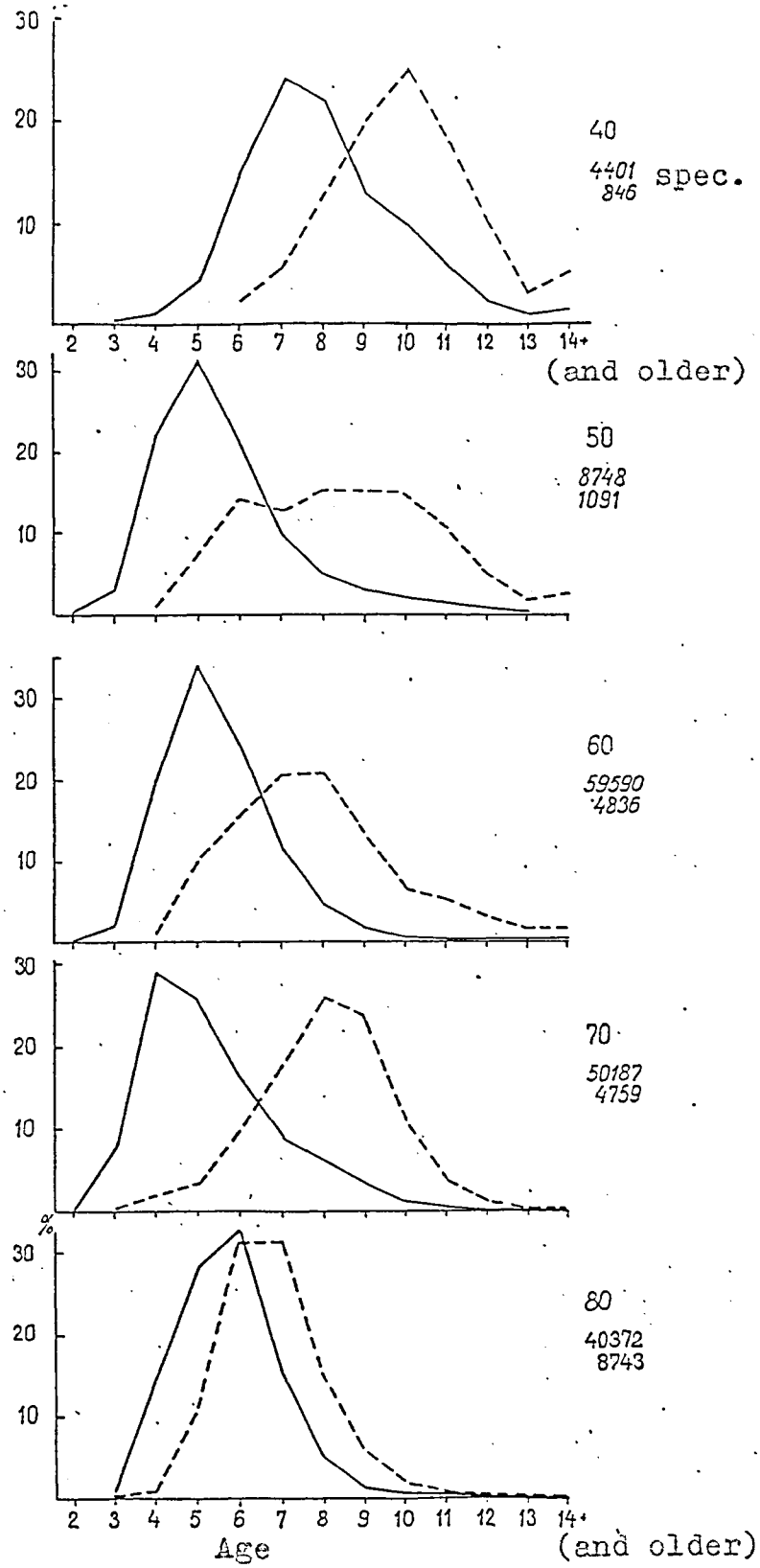

Fig.1. Age composition of analysed (solid line) and mature (dotted) cod in 40's - 80's. Numbers of analysed and mature fish are given in figures (lower)

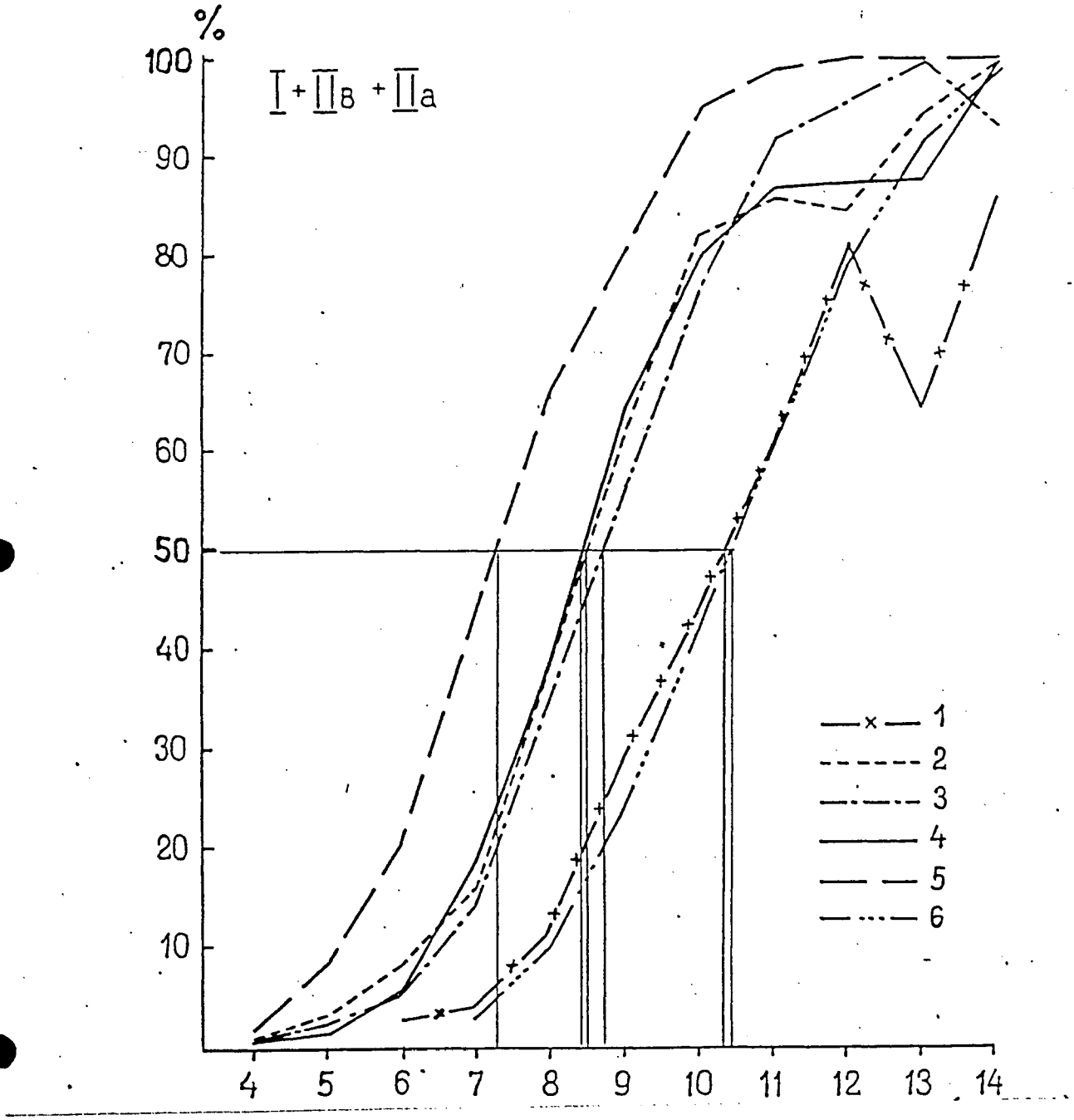

Fig.2. Maturity ogives of cod and location of 50-point maturation in 40's - 80's (1-5 according to our data:1-40's, 2 - 50's, 3 - 60's, 4 - 70's, 5 - 80's; 6 - 40's - by Garrod (Garrod, 1967).

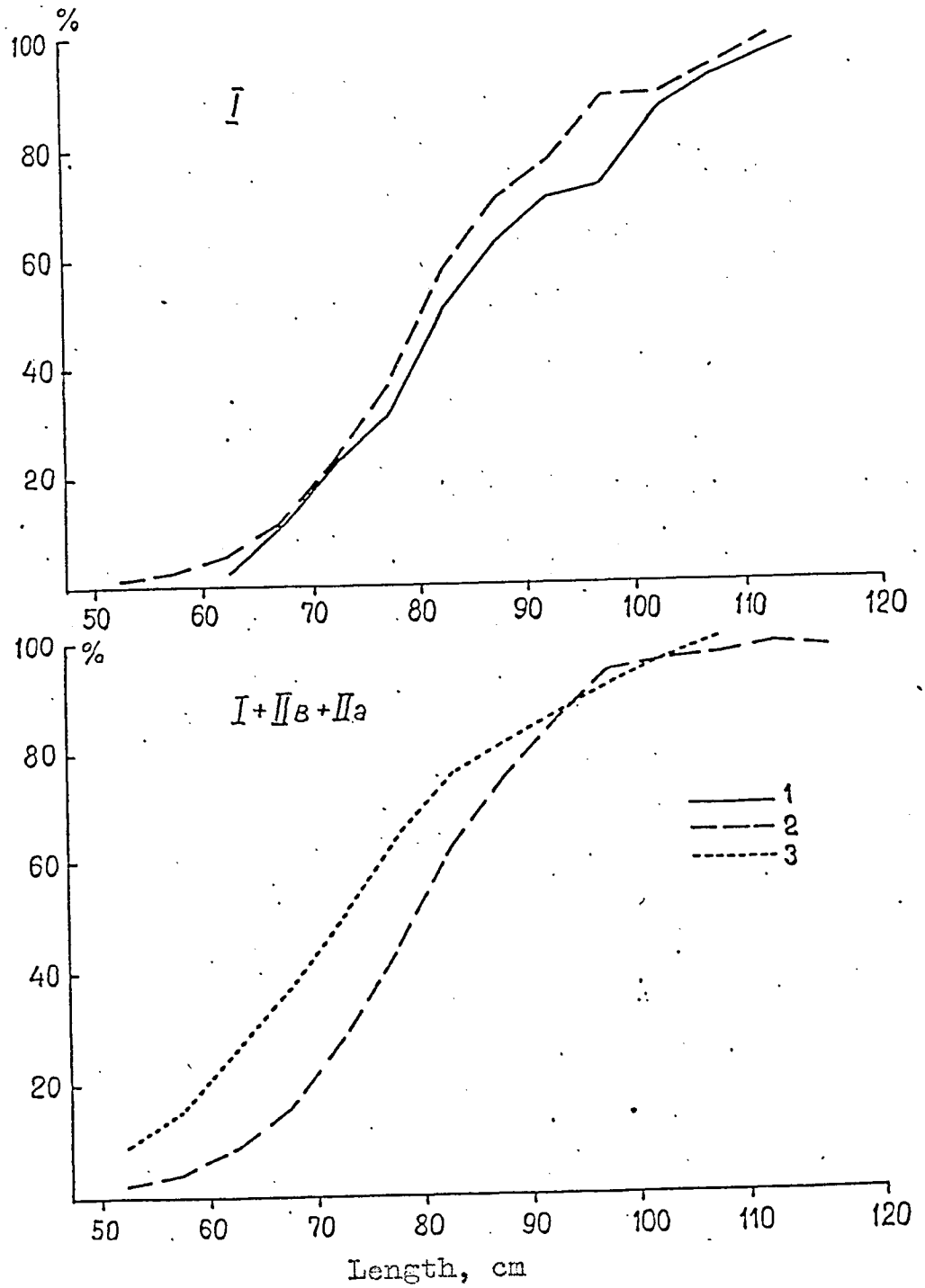

Fig.3. Percent of mature fish among cod at different length in 30's - 40's (1) by Glebov's data (1963), in 60's-70's (2) - by Ponomarenko's data (1984) and in 80's - by our data.

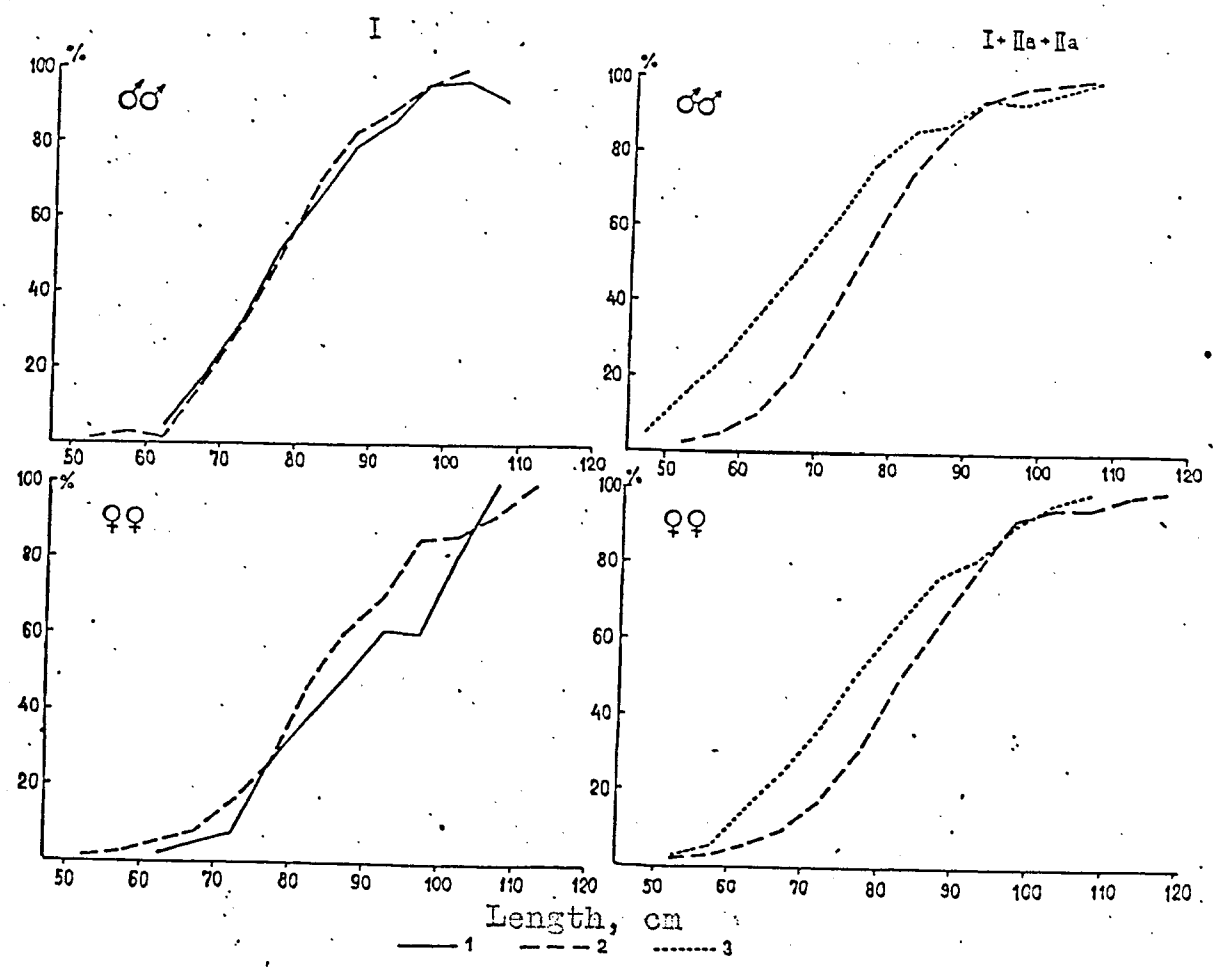

Fig.4. Percent of mature fish among cod males and females. See Fig.3 legend.

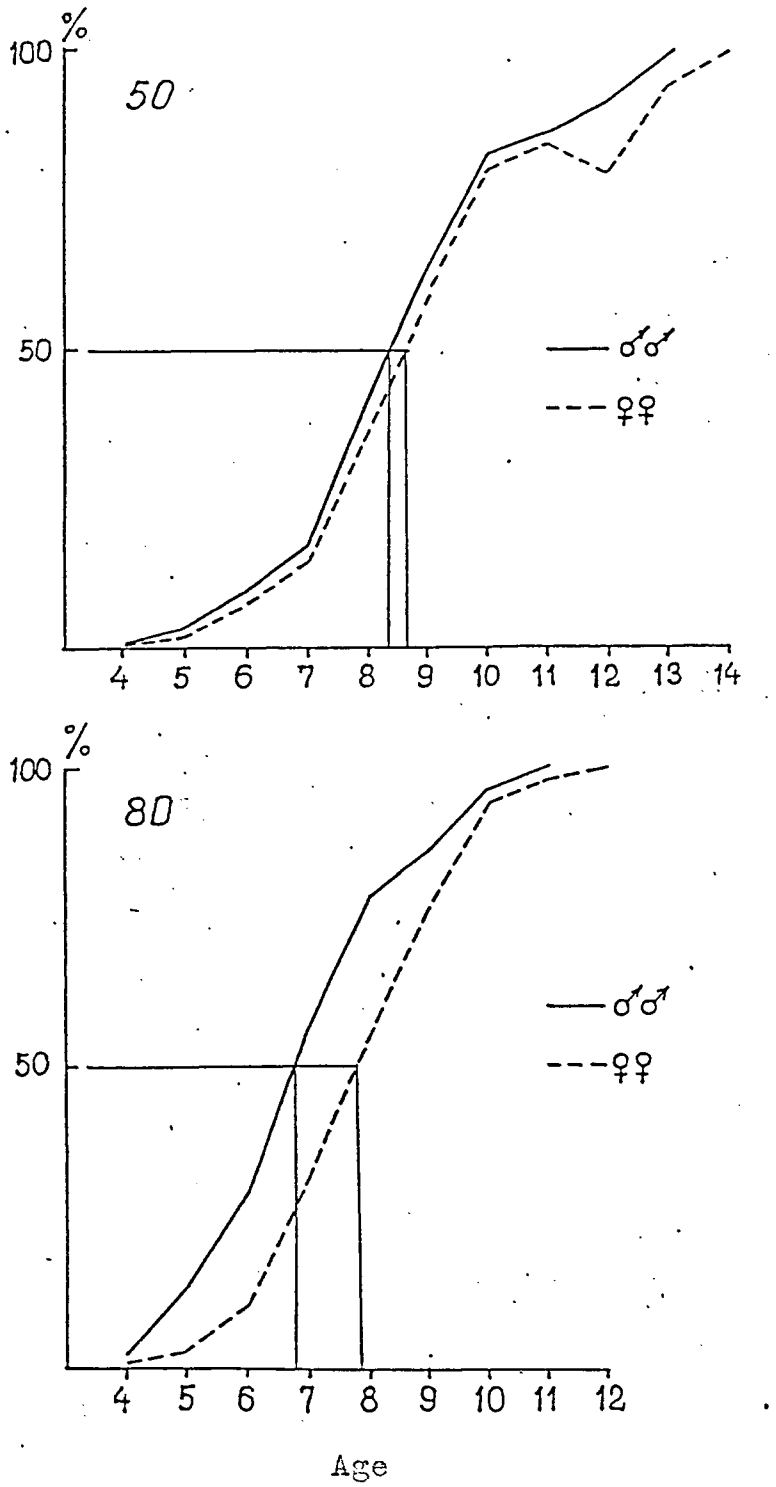

Fig.5. Percent of mature specimens among cod males and females in 50's and 80's,

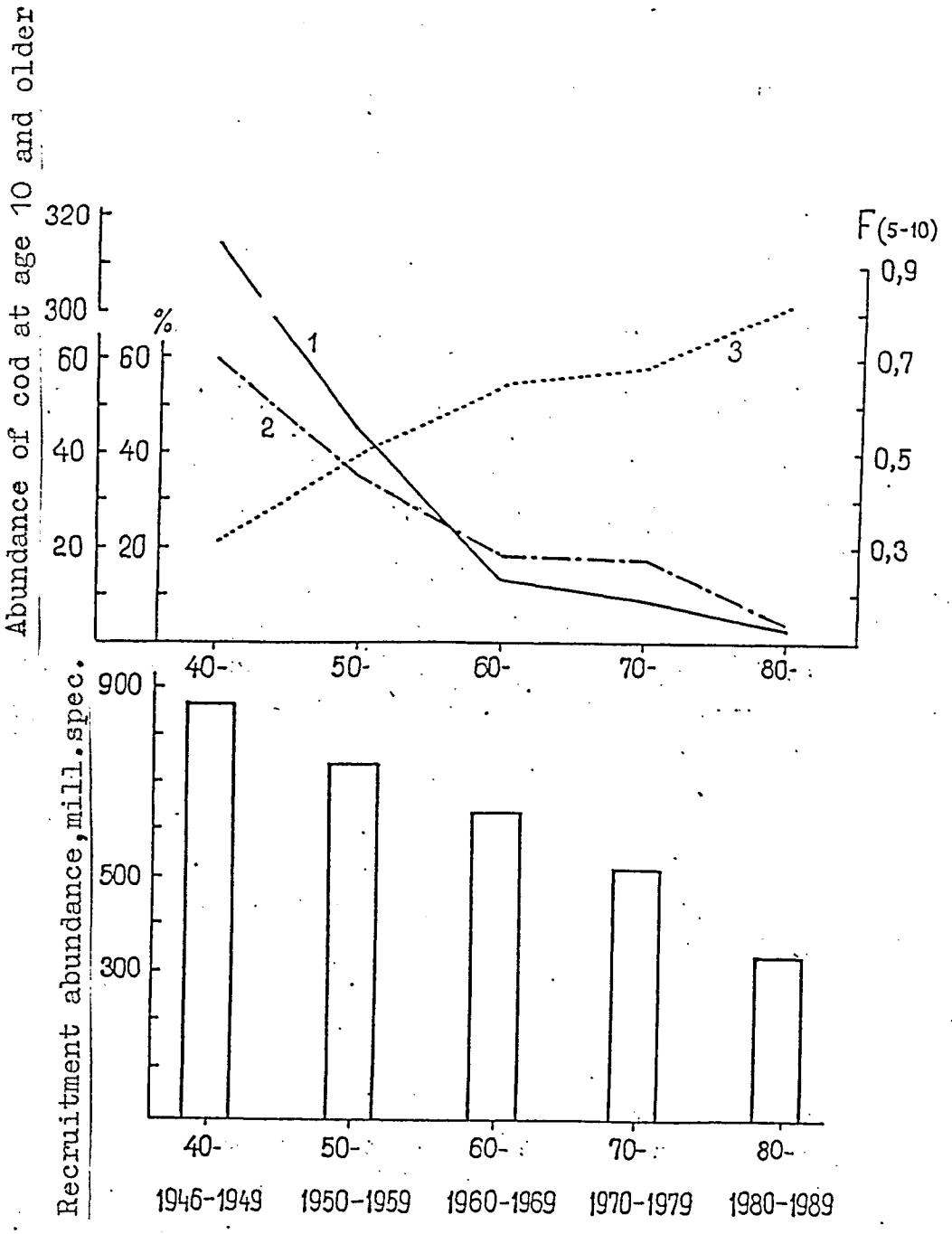

Fig.6. Yearclass abundance of cod at age 3 (columns)* in 40's - 80's in comparison with abundance of older fish (1 - absolute abundance of cod above 9 yr**, 2 - its percent in age samples) and with a coefficient of fishing mortality of cod at age 5-10 yr** (3)

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* - by ICES Working Group calculations (Anon., 1983, 1993)

** - for 60's - 80's - by WG calculations (Anon., 1993), for 40's - 50's - by V.L.Tretyak's calculations