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Dynamics of the Grand Bank Spawning Haddock Stock, its Biological Status and Outlook for the 1979 Year-class Abundance

by

V. P. Shestov
Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
Murmansk, USSR

Abstract

Data on distribution, age-size compositions of catches, maturity rate, fatness, spawning and the Grand Bank spawning haddock stock composition (Division 3NO), collected in the period from 8 April to 8 May, 1979, are represented.

Dynamics of spawning stock and maturity rate of the 1949-1975 haddock year classes are considered. It is found that the 1958-1965 year classes abundance was estimated by a number of females at the age of 6-7 years, spawning for the second and third times. Compared to 1972-1978, in 1979 the abundance, biomass of the spawning haddock stock and mean age of specimens increased; repeat spawners dominated in the stock.

Size and composition of the spawning stock, high fatness of mature fishes, particularly, of females, early spawning under the moderate warm hydrological regime, probable coincidence of the mass haddock larvae hatching terms with great number of young copepods, relatively favourable wind activity and waters circulation on the Grand Bank in 1979 have to favour the appearance of more numerous progeny of haddock, compared to those for a set of previous years.

Introduction

No relationship between the progeny abundance and number, fecundity, age-size composition of parents and correlation of recruits and repeat spawners, males and females in the spawning stock was found in many haddock stocks (Thompson, 1930; Raitt, 1933; Parrish, 1950; Hodder, 1963, 1966; Baranenkova, Khokhlina, 1967; Templeman, 1972; Sonina, 1973, 1973a, 1975, 1976; Schuvaiev, 1975; Tormosova, 1980). However, it was observed that the abundance of haddock progeny on the Georges Bank increased with a growth of the parents' number up to a certain level, after which an inverse relationship was revealed, and the fluctuations in progeny size were maximum at the average abundance of parents (Herrington, 1948). For this haddock (Grosslein, 1966) and that from the North Sea (Lundbeck, Sahrhage, 1956) the year classes were more often strong if a number of parents was great, and they were poor, when a similar number was small. Deficiency in haddock spawners probably negatively influences upon the abundance of progeny (Hodder, 1966).

The lack of the relationship between the parents numbers and progeny abundance is mainly often explained by the fact that the quality of parents' gonads is not taken into account. Quantity and quality of gonads are conditioned by abundance of parents, rate of their growth and maturity, correlation of spawning classes in the spawning stock (Sorokin, 1957; Hodder, 1963; Hylen, Dragesund, 1973; Sonina, 1973, 1973a; Nikolsky, 1974; Shapiro, 1975; Vladimirov, 1975).

The haddock on the Grand Bank is a fish with complex type of the spawning stock, extensive areas of spawning and feeding migrations, high fecundity, low fatness of eggs. The fluctuations for these fishes are, to a greater degree, determined not by a number of parents (naturally at their certain quality), but by factors of progeny mortality at an early ontogeny (Parrish, 1950; Gulland, 1965; Sonina, 1969, 1973, 1973a, 1975, 1976; Ponomarenko, 1973, 1977, 1979; Nikolsky, 1974).

Tormosova (1980) considers that survival of haddock eggs in the North Sea is mainly determined by non-biological factors and does not depend upon the eggs' quality. However, indicating the low survival of fairly large eggs under unfavourable conditions for their development in March-April 1971, the author passes over in silence the fact that these eggs are mainly laid by the recruits at the age of 2-3 years.

A possible influence of some factors upon the 1979 haddock year class abundance on the Grand Bank is considered below.

Material and methods

Data were collected in Division 3NO in the period from 8 April to 8 May 1979 during the fry assessment and total trawl survey of the demersal fish stocks in cruise of the trawler "Suloy". The trawlings were carried out by a 31 m kapron trawl with a small-meshed kapron insertion in the codend. The duration of each trawling was 1 hour at the vessel speed of 3.5-3.6 knots.

All the haddock caught was measured; otoliths were taken from most of the fishes, sex and maturity stages of gonads were determined due to a 6 indices scale, developed for cod (Sorokin, 1957, 1960), the masses of ungutted fish and their liver were determined. The fatness of haddock was assessed by the ratio of liver mass to fish mass (in %). The age of fish was determined by otoliths ashore, the estimate of annuluses and spawning "stamps" was made on transverse break with a 16-fold magnification.

Results of investigations

Distribution of haddock catches in 1979

The catches of haddock were entirely taken in Division 3O. The main catches of yearlings were obtained in the centre and south of division's slope in the 100-200 m depths at near-bot-

tom temperatures of 6.9-9.2°; the greatest catch (82 spec.) was taken in the centre of the slope in the 100-140 m depth at t° = 8.7°.

Haddock at the age of 3-6 years, mainly, matured, occurred along the whole slope in the 73-310 m depths at t°= 4.3-9.2°. The biggest catches were the following : 91 spec. (153 kg) - in the south of channel Haddock in the 135-175 m depths at t°= 8°; 45 spec. (51 kg) - in the centre of slope in the 87-100 m depths at t°= 6.4° and 39 spec. (59 kg) - in the west of slope in the 97-155 m depths at t°= 5.8°.

Age-size composition of catches in 1979

As in 1978, the haddock of the 1975 year class, 40-67 cm long, on the average of 52.3 cm, dominated (49.5%) in the 1979 catches. The yearlings (33.8%) , 17-25 cm long (20.6 cm) were the second by their abundance, the 5 year-olds (9.9%), 43-70 cm long (55.5 cm) were the third ones.

In Division 30 the average catch of haddock more than 35 cm long constituted 6 specimens (8.9 kg) per hour trawling compared to 1-6 specimens (0.3-4.9 kg) taken in 1972-1978. The average catch of the 1976 and 1977 year classes haddock constituted less than 1 specimen, but of the 1978 year class - over 3 specimens.

Dynamics of haddock spawning stock

The spawning stock of the Grand Bank haddock of the 1949-1960 year classes mainly consisted of the fishes at the age of 4-7 years (on the average 5.9 years) and included 9 spawning classes (Table 1). Among the males and females the recruits constituted 38.9 and 36.6%, respectively. 1.7% of males and 2.2% of females for the first time reached the maturity at the age of 3+ (Table 2). A number of recruits (recruitment) was less than that of repeat spawners (carry-over) and haddock had the third, the most

complex type of spawning stock due to Monastyrsky's classification (1949, 1952, 1953). The stock included many year classes of different abundances and inspite of intensive fishing it maintained a high abundance, low rate of growth (Fig.1) and maturity, prolixity of its terms, lowered fecundity. Decreased reproductive capacity of stock, i.e. the rate of replacement at the expense of recruitment (Monastyrsky, 1952) was compensated by many ages structure of carry-over, recurrence of spawning, omission of it once or some times by elder specimens.

In relation to poorness of year classes since 1957, and also with maximum yield of haddock in 1960-1961 the stock abundance since 1962-1963 sharply decreased inspite of the fishery lack (Templeman, 1965, 1966, 1972; Shestov, 1972; Templeman et al., 1978). The rate of growth and maturity of the 1961-1970 year classes increased, the duration of life and portion of carry-over in the spawning stock reduced. Similar variations in dynamics of the Grand Bank haddock stock were registered by Canadian researchers (Templeman et al., 1978, 1978a).

Due to our data the spawning stock of the 1961-1970 year classes mainly consisted of the fishes at the age of 3-5 years (on the average 4 years) and included only 4 spawning classes, 32.8% of males and 39.2% of females matured for the first time at the age of 3 years. The recruitment to males and females constituted 63.2 and 49.5%, respectively; on the average it was more than carry-over, that characterized the second, more ordinary, than the third one, type of spawning stock. The percentage of carry-over in the total haddock abundance decreased up to 53%, compared to 56.3% in the year classes up to 1961.

On the whole, a further increase of rate of growth and maturity of the 1971-1978 year clas ses was observed. The latter was marked by appearance of single males, matured at

age of 2+ in 1975-1976. In 1977 mature males and females in the 1975 haddock year class constituted 64.4 and 1.1% and in 1978 - 68.8 and 44.3%, respectively. Simultaneously, a further decrease of abundance and reduction of mean age of the spawning stock fishes and increase of percentage of recruits, which in 1977 constituted among the males and females 96.8 and 27.7%, and 88.3 and 83.3% in 1978, respectively, had been observed. In 1977, carry-over was represented by haddock at the age of 4 -9 years, in 1978 - of 4 years. It should be noted that in 1978, the part of the area along the south-western slope of the Grand Bank was not covered with trawlings.

Transfer of the spawning stock from more complex type into the ordinary one is the adaptation of fish to replacement of abundance and reproductive capacity of stock at the expense of acceleration of the rate of its renovation (at a shorter life cycle, mass and early maturity of year classes), annual spawning and increase in fecundity with increase of growth rate (Monastyrsky, 1952; Sonina, 1973, 1973a; Nikolsky, 1974).

In 1979 the carry-over consisted of the fishes at age of 4–6 years prevailed in the Grand Bank haddock spawning stock but among the males and females the recruits made up 18.3 and 43.8%, respectively.

Relationship between haddock year classes abundance and spawning stock composition

We tried to reveal such relationship, taking the ICNAF data on fishing efforts, yield and size composition of the Grand Bank haddock in catches taken by Canadian trawlers in 1958-1968 for the basis of estimations. The following our data are also used: age-size keys, mean weights of size groups, mean rate of maturity and sexes ratio for the

haddock year classes caught. Eventually, we estimated a number of 3-year olds in catches (as index of relative abundance of the 1958-1965 year classes) per 100 hour trawlings in 1961-1968 and a number of females of different ages in spawning stock in 1958-1965 (Table 3).

In general the abundance of the 1958-1965 year classes turned out to be related to a number of females at the age of 6-7 years spawning for the second and third times ($r = 0.891 \pm 0.078$, $t_r = 11.42$). While estimating a number of elder and, especially, young mature females, the degree of relationship essentially decreased.

Thus, the level of progeny abundance of the Grand Bank haddock in initial link is apparently defined by a number of repeat spawners, but recruits are the reserve of spawning stock, which could increase the progeny abundance only under very favourable conditions for development and survival of eggs and larvae. A similar relationship is found for the Barents Sea cod (Ponomarenko, 1968).

Compared to 1972-1978, in 1979 the abundance and, particularly, biomass of the Grand Bank haddock spawning stock and average age of its specimens increased, the carry-over essentially prevailed in the stock. Consequently, size and composition of the spawning stock in 1979 have to cause the appearance of more numerous haddock year class, than those for a set of previous years.

Fatness of haddock in 1979 and their effect the abundance of year class

Comparison of haddock fatness in April 1979 and their mean fatness in April and May 1962, 1964-1977 is shown in Table 4. It is seen, that the fatness of males and, particularly, of females in April 1979 was higher than that in April due to the long-term data. It was essentially higher for the yearlings 16-25 cm long. It is known that more fat fry

weathers a hunger easier and is less affected by predators, parasites, epizooty (Nikolsky, 1974; Ponomarenko, 1973, 1979). Therefore, it can be assumed, that the mortality of the 1978 haddock year class at the first year of life was lower than that for many previous year classes and we have a right to expect their high survival in 1979.

More fat mature fishes have an increased fecundity and the gonads of higher quality (Nikolsky, 1974; Shapiro, 1975; Vladimirov, 1975). It is seen from Table 4, that males and, especially, females 31-50 cm long in April 1979 had slightly higher fatness, than those in April 1962, 1964-1977. Mature fishes up to 41 cm long were mainly the recruits. It's more important, that the specimens (especially, females) 41-50 cm long had an increased fatness and they composed the bulk of spawning males and considerable part of such females. Females 51-60 cm long also had an increased fatness, they constituted the bulk of recruits and repeatedly spawning females. In April 1979 the fatness of fish 31-50 cm long in general was even considerably higher than that in May - in spawning peak for the Grand Bank haddock due to the long-term data.

Consequently, an increased fatness of haddock spawners, especially, females in 1979 compared to that on the basis of the long-term data, is also assumed to have possibility for appearance of more numerous progeny than those for a great set of previous years.

Maturity and spawning of haddock in 1979

More fat fishes mature earlier and in relatively greater number (Raitt, 1933; Monastyrsky, 1953; Hodder, 1963). So, in 1979 compared to 1964-1973 the Grand Bank haddock matured faster, earlier and in relatively greater quantity started to spawn (Table 5): in April 1964-1973 the majority of haddock only became matured, 5.9% of fish spawned and 5.0% of speci-

mens spawned out, mainly, males, in April 1979, 27.6% of mature fish spawned, 23.8% of fish spawned out.

More earlier and mass spawning in 1979 was due to not only high haddock fatness, but also to increased heat content of the waters on the south-western slope of the Grand Bank, that was occupied abnormally warm for a given period of the year Atlantic waters.

Displacement in terms more often concerns the start and peak of spawning, but terms of its end waried less (Bigelow, Schroeder, 1953; Glebov, 1963). The terms of spawning peak can be approximately determined by sexes ratio for mature haddock: among the maturing and spawning fishes before the spawning peak usually the males prevailed a little, in spawning peak - considerably more females were registered and to the end of spawning the ratio between the sexes is equalised.

In April 1979 the sexes ratio for mature haddock was equal. Among the maturing and spawning fishes males slightly dominated (55.3%); majority of males had gonads of V maturity stage (55.5%), of females - of IV maturity stage (78.1%). Among the spawned out haddock the females (66%) prevailed, 15.9% of males and 31.8% of females spawned out. Apparently, that the spawning peak in 1979 falled approximately to late April - early May, but not to the second half of May - early June, as earlier often marked (Hodder, 1963; 1966; Templeman, 1965; Shestov, 1967; Serebryakov, 1971; Templeman et al., 1978a).

Influence of terms of plankton development upon the abundance of haddock year classes

An increased heat content of waters usually causes not only earlier spawning, but also spawning over a greater area, acceleration in development of eggs and larvae, their extensive area and low density , in consequence of which larvae develop

better with necessary abundance of food, they transfer from one stage of development to another faster, more survived (Colton, 1968; Baranenkova et al., 1973). While coincidence in terms of mass plankton development and hatching of haddock larvae the abundant year classes appear more often, when there is no coincidence, - the poor year classes are registered (Sysoeva, Bazlova, 1967; Schuvaiev, 1975).

The beginning of phytoplankton development on the Grand Bank is observed more often in April (Movchan, 1962), in warm years - in March/April at most, while abundance of young copepods - the main food for haddock larvae - in April/May (Cole, 1969, 1970; Garrod, Parrish, 1969; Glover, 1970; Robinson, 1972). In moderate warm years copepods biomass is equal to the long-term mean for a year as a whole and above it in May/June.

The spring 1979 is close to the level of moderate warm years in heat content of the Grand Bank waters. Hence, we can expect for essential coincidence in terms of mass hatching of haddock larvae (second half of May - early June) and zooplankton development.

Influence of waters circulation upon the abundance of the haddock year classes

While determining the abundance of fish generations many scientists paid their greater attention to wind currents and variations in waters circulation, particularly in areas, where the spawning grounds were not extensive and were conterminous with zones of unfavourable conditions for development and survival of fishes at earlier stages (Rollefsen, 1930; Chase, 1955; Templeman, 1955; Hill, Lee, 1958; Baranenkova, 1965; Corlett, 1965; Tormosova, 1980).

Haddock spawning grounds on the south-western slope of the Grand Bank are situated at the northern edge of warm currents. Hence, the larvae and eggs can be transported by cyclonic eddies, wind currents, stipulated the size and configura-

tion of eddies, either into the ocean or to the north: in the ocean; fingerlings inevitably will die in the period of sinking to bottom, but while transporting far to the north the haddock progeny can be brought into the cold waters, limited its development and survival (Thompson, 1939; Hodder, 1963, 1966; Templeman, 1965, 1966, 1972). Therefore, more succes sful year classes of the Grand Bank haddock have to appear in April-October with predominance of southern winds, poorer ones - at northern winds. The development of anticyclonic gyres, secondary eddies in their limits, convergence of waters to the axis of gyres over the bank prevent the eggs and larvae from outflow (Serebryakov, 1971; Borovkov, Kovalyov, 1976).

In April 1979 on the Grand Bank the northern and eastern winds of 4–5 force prevailed; the winds caused the outflow of eggs from the bank constituted 64.9%, the winds of opposite directions - 34.8%. Favourable winds were registered in May, and, especially, in the first half of June: in May the winds of 2-6 force conditioned the keeping of eggs and larvae on the bank constituted 77.5%; the winds of 3-4 force of opposite directions - 20.9%; in the first half of June only 9.6% of winds of 4–6 force caused the outflow of eggs and larvae from the bank.

In April 1979 an extensive anticyclonic gyre over the south-western shelf, occupied by its edge the south-western slope caused the keeping of eggs over the bank. Inside the gyre there were two secondary eddies. A small anticyclonic eddy was registered off the slope in the west of bank, where small catches of mature haddock were taken.

Thus, wind activity and, especially, an extensive anti - cyclonic circulation of the waters over the Grand Bank Shallows had also to cause the appearance of relatively abundant haddock year class.

Conclusions

In spring 1979 compared, at any rate, to 1972-1978, the

abundance, and, to a greater extent, biomass of the Grand Bank mature haddock and mean age of fish in the spawning stock, in which repeat spawners essentially prevailed, had been increased. High fatness of mature haddock, especially, of females was observed. An early spawning of fish under the moderate warm hydrological regime was registered in the south of bank. In May and, especially, in the first half of June, in the south of bank the winds caused keeping of the haddock eggs and larvae over the bank prevailed. In April an extensive anticyclonic gyre (with two secondary eddies inside) over the south-western bank shelf occupied by its edge the south-western slope of the bank - the area of haddock spawning grounds caused the same phenomenon. A small anticyclonic eddy was observed off the slope in the west of bank, where greatest catches of mature haddock were taken.

All these factors and also probable coincidence in terms of mass hatching of haddock larvae with abundance of young copepods, their main food, have to cause the appearance of more successful haddock year class in 1979 acompared to those for a great set of previuos years.

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Table 1. Number of recruits and repeat spawners (in %) in spawning haddock stock of the 1949-1960 (I) and 1961-1970 (II) year-classes in Divisions 3NO. (Numerator - males; denominator - females.)

Age, years	Spawning classes																Number of fish	
	Recruits		2		3		4		5		6		7-9					
	I	II	I	II	I	II	I	II	I	II	I	II	I	II			I	II
3	100,0 / 100,0	100,0 / 100,0															11 / 23	261 / 305
4	93,1 / 92,8	37,9 / 39,0	6,9 / 7,2	62,1 / 61,0													131 / 251	340 / 441
5	74,8 / 71,4	56,4 / 9,7	23,8 / 26,7	21,2 / 59,3	1,4 / 1,9	22,4 / 31,0											485 / 859	170 / 236
6	16,3 / 9,9	73,9 / 9,7	66,6 / 68,9	17,4 / 22,6	16,1 / 19,5	8,7 / 45,1	1,0 / 1,7	- / 22,6									514 / 859	23 / 31
7	7,1 / 0,9	- / 20,0	14,2 / 17,9	100,0 / 60,0	67,5 / 66,1	- / 20,0	9,7 / 13,5	- / -	1,5 / 1,6	- / -							267 / 436	2 / 5
8	10,7 / -	- / -	6,7 / 3,4	- / -	21,3 / 24,7	- / 100,0	26,0 / 42,7	- / -	22,6 / 25,8	- / -	2,7 / 3,4	- / -					75 / 89	- / 1
9	5,7 / -	- / -	—	—	9,4 / 5,3	- / -	26,4 / 31,6	- / -	39,6 / 47,4	- / -	17,0 / 14,0	- / -	1,9 / 1,7	- / -			53 / 57	- / -
10							5,9 / 9,1	- / -	29,4 / 40,9	- / -	58,8 / 40,9	- / -	5,9 / 9,1	- / -			17 / 22	- / -
11	11,1 / -	- / -							- / 9,1	- / -	11,1 / 36,4	- / -	77,8 / 54,5	- / -			9 / 11	- / -
12-13													100,0 / 100,0	- / -			8 / 6	- / -
Total:	38,9 / 36,7	63,2 / 49,5	32,5 / 35,2	31,8 / 41,1	18,5 / 19,0	5,0 / 8,7	4,6 / 5,0	- / 0,7	3,0 / 2,6	- / -	1,4 / 0,9	- / -	1,1 / 0,6	- / -			1570 / 2613	796 / 1019

Table 2. Number of mature haddock of different ages in Divisions 3NO estimated by spawning "stamps" on otoliths (in %; n - number of fish).

Age, years	1949-1960 year classes				1961-1970 year classes			
	Males	n	Females	n	Males	n	Females	n
3	1,7	651	2,2	1029	32,8	795	39,2	778
4	20,5	640	24,8	1012	52,9	643	68,4	644
5	78,2	620	88,1	975	76,8	221	86,1	274
6	92,4	556	98,7	870	88,9	26	91,2	34
7	94,4	283	100,0	436	100,0	2	83,3	6
8	92,6	81	100,0	89			100,0	1
9	96,3	55	100,0	57				
10	94,4	18	100,0	22				

Table 3. Number of females of different ages in the Grand Bank spawning haddock stock in 1958-1965 and a number of 3-year-olds of the same year-classes per 100 trawling hours carried out by Canadian trawlers (denominator - %).

Years	Age, years								Total	No. of 3-year-olds of year class
	3	4	5	6	7	8	9	10		
1958	148	367	14433	8759	8362	4809	1192	401	38471	3571
	0,4	1,0	37,5	22,8	21,7	12,5	3,1	1,0	100,0	
1959	454	1689	11756	15034	6135	1992	1369	1756	40185	7149
	1,1	4,2	29,3	37,5	15,3	4,9	3,4	4,3	100,0	
1960	7	1204	18917	7494	6901	1285	260	968	37034	546
	+	3,2	51,1	20,3	18,6	3,5	0,7	2,6	100,0	
1961	37	374	18763	61573	2515	2710	2034	1625	89631	8432
	+	0,4	21,0	68,8	2,8	3,0	2,3	1,7	100,0	
1962	74	994	670	7986	36947	283	1230	647	48831	6885
	0,1	2,0	1,4	16,4	75,7	0,6	2,5	1,3	100,0	
1963	6	624	1325	1971	5922	6687	686	373	17594	182
	+	3,5	7,5	11,2	33,8	38,0	3,9	2,1	100,0	
1964	1762	239	523	585	146	330	472	81	4138	1298
	42,5	5,8	12,6	14,2	3,5	8,0	11,4	2,0	100,0	
1965	1439	1070	224	154	155	29	77	120	3268	1304
	44,0	32,7	6,9	4,7	4,7	0,9	2,4	3,7	100,0	

Table 4. Mean fatness of the Grand Bank haddock in April (1), May (2) 1962, 1964-1977 and in April 1979 (3). (Denominator - number of fish.)

Length, cm	Males			Females			Total no. of haddock		
	I	2	3	I	2	3	I	2	3
to 20	2,I4	I,99	2,34			2,38	2,I4	I,99	2,35
	I	6	20			8	I	6	28
2I-30	I,47	2,27	I,86	I,67	2,3I	I,8I	I,53	2,28	I,84
	I7	30	20	8	I8	I7	25	48	37
3I-40	I,99	2,2I	3,2I	I,98	2,34	3,47	I,99	2,27	3,34
	I36	52	4	7I	46	4	207	98	8
4I-50	2,7I	2,86	3,24	2,I4	2,73	3,24	2,54	2,80	3,24
	220	I37	36	94	I27	27	3I4	264	63
5I-60	3,07	3,00	2,0I	2,60	3,04	2,77	2,85	3,02	2,59
	I02	66	I5	93	89	49	I95	I55	64
6I-70	3,I0	3,64	I,9I	2,5I	3,I5	2,34	2,76	3,36	2,I6
	I5	2I	5	2I	28	7	36	49	I2
7I-90	3,57	3,52		4,34	3,I4		4,09	3,35	
	7	5		I5	4		22	9	
Total:	2,57	2,78	2,6I	2,37	2,79	2,8I	2,49	2,78	2,72
	498	3I7	I00	302	3I2	II2	800	629	2I2

Table 5. Maturity of the Grand Bank haddock in April 1964-1973 (1) and 1979 (2), in %.

Maturity stages	Males		Females		Total number of fish	
	I	2	I	2	I	2
III	40,3	2I,5	22,I	6,6	35,5	I4,0
IV	46,7	I5,9	72,8	53,2	53,6	34,6
V	6,8	46,7	3,4	8,4	5,9	27,6
VI				I0,3		5,I
VI-II	6,2	5,6	I,7	3I,8	5,0	I8,7
No. of fish	I6I	I07	59	I07	220	2I4

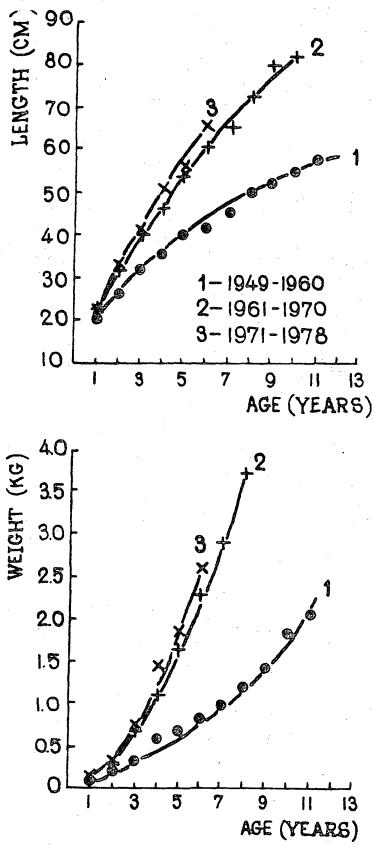

Fig. 1. Linear and weight growth of the Grand Bank haddock of the 1949-1960, 1961-1970 and 1971-1978 year-classes.