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INFLUENCE OF WINTERING TEMPERATURE CONDITIONS ON THE SURVIVAL OF YOUNG COD AND HADDOCK IN THE BARENTS SEA

by

I.Ya.Ponomarenko

Abstract

In the southern Barents Sea the survival of bottom-dwelling cod and haddock from the first to the third years of life (from 0+ to I+ and from I+ to 2+) is subjected to high yearly fluctuations. These fluctuations are to a large extent synchronous as between 25 year classes of cod and haddock that is indicative of the existence of common factors influencing on the survival of the young of both species.

It was revealed that temperature conditions in the Barents Sea in the period of wintering or temperature minimum (February-May) are one of such factors. The survival coefficients of cod and haddock go down (both from 0+ to I+ and from I+ to 2+) in the years with negative water temperature anomalies in the period of seasonal minimum and they rise to higher values in the years with positive anomalies. The survival of the young from 0+ to I+ is most dependant on the temperature conditions of wintering (correlation coefficients are 0.75 for cod and 0.71 for haddock).

The obtained relationships are used to forecast the survival

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of the young and to improve the strength of the succeeding recruitment to the fishing stock in advance.

Résumé

La survivance des jeunes poissons de morue et d'églefin en stage démérsale dans la région sud de la mer de Barentz au cours des premières années de la vie (de 0+ à 1 et de 1+ à 2+) est soumise à des fluctuations annuelles considerables. Ces fluctuations sont à un fort degré synchronnes pour les 25 classes d'âge consécutives de morue et d'églefin ce qu'indique sur l'existance des facteurs communs influants sur la survivance des jeunes poissons de deux espèces!

Il est découvert que les conditions de température dans la mer de Barentz au cours de l'hivernage ou périodes des basses températures(février - mai) est un de ses facteurs. Les coefficients de survivance de morue et d'églefin (pour des individus à l'âge de 0+ à 1+ comme pour ceux de 1+ à 2+) sont basses pour les années avec des anomalies négatives et s'accroîtent pendant ceux d'anomalie positives. Se sont les plus jeunes exemplaires à l'âge de 0+ à 1+ (coefficients de correlation 0,75 pour la morue et 0,71 pour l'églefin) dont la survivance dépende au plus haut degré des conditions de température pendant l'hivernage.

Les relations découvertes sont utilisées pour des prévisions des coefficients de survivance et pour la précision préalable de la nombre de recrutement successifs au stock exploité.

Introduction

In autumn the pelagic young of 0-group cod and haddock change for a near bottom pattern of life and become accessible for a bottom trawl. Annual estimation of the bottom-dwelling cod and haddock abundance was conducted by the Polar Institute in the Barents Sea with the aim of estimating the strength of the succeeding recruitment to the fishing stock in advance and long-term catch forecasting. Results of these estimations are regularly published in Annales biologiques.

Along with 0-group fish (0+) the abundance of the young at the age of 2 incomplete years (I+ or I-group) and three incomplete years (2+ or II-group) smaller than 36 cm is annually estimated in the autumn-winter period. Thus, during the first three years of life the abundance of each year class is estimated three times. As many years' experience shows, the strength of the recruitment is most reliably characterized by the abundance of the young at 2+years of age, and least reliably at 0+. It is explained by the fact that the mortality of the young at the end of the first year of life is still rather high, and that is particularly important, it is not similar in different year classes.

Our investigations were also aimed at revealing the causes of dissimilar survival of young cod and haddock from 0+ to I+ and from I+ to 2+ in different years. An attempt was made to evaluate the effect of temperature conditions on the survival of the young of individual year classes.

Materials and methods

When calculating coefficients of survival for 25 year classes of cod and haddock we used data on determining the abundance of the young of commercial fishes in the southern Barents Sea (excluding the area of Central Elevation). Because we have excluded the area of Central Elevation, the coefficients given in the paper in some cases slightly differ from those that can be obtained from published data.

An average catch (number of specimens) per trawling hour is taken as the abundance index. The coefficient of survival was determined from the ratio : average catch of the young at age I+ per trawling hour/average catch of the young at age 0+ of the same year class; average catch of the young at age 2+/average catch of the young at age I+; average catch of the young at age 2+/average catch of the young at age 0+.

It might be well to point out that this ratio, that received the name coefficient of survival (SC I+/0+, SC 2+/I+, SC 2+/0+), is proportional to the absolute coefficient of survival but not equal to it because of varying catchability of fishes of different ages. Younger specimens, even though they are more numerous, are caught in relatively smaller quantities than older ones because of wider and more dispersed distribution. Therefore, coefficients of survival (SC) derived by the above method are often more than 1, and only in the cases of a very high mortality they are less than 1. The absolute coefficient of survival is always less than 1 and only at 100% survival it is equal to 1. Thus, SC cannot be used to estimate the percentage of survived and dead specimens

of individual year classes but they are quite suitable to compare quantitatively the survival of the young of different year classes for regular intervals.

To characterize living conditions of the young of different year classes we used data on water temperature on standard hydrological sections in the Barents Sea. The positions of the sections are as follows : No.6 (The Kola section) 70°30' - 72°30'N and 33°30'E; No.8 (stations 1-4) 68°51'N - 37°20'E and 69°39'N - 38°04'E; No.10 - 70°49'5''N - 41°51'E and 71°25'N - 40°32'E. Sometimes we used data on water temperature on the North Cape - Bear Island section.

Temperature conditions of wintering of the young are evaluated on the basis of average water temperature in the 0-200 m layer for four (February-May) or two (as a rule, March-April) months of the year which are coldest in hydrological respect.

Discussion

Coefficients of survival for cod and haddock varied greatly as between 25 year classes. Thus, for cod SC I+/0+ varied from 0.13 to 7.59 (58 times), SC 2+/0+ varied from 0.21 to 11.91 (57 times), SC 2+/I+ varied from 0.30 to 10.08 (34 times). For haddock these coefficients varied from 0.29 to 4.21, from 0.33 to 4.70 and from 0.40 to 9.33 respectively (Tables 1,2). From these it follows that a given survival of the bottom-dwelling cod and haddock from 0-group to II-group can significantly influence on the recruitment abundance. This generated a need for the development of methods of forecasting the survival to improve the values of the strength of the succeeding recruitment to the commercial

stocks of cod and haddock in advance.

A comparative analysis of interannual fluctuations of SC of young cod and haddock for the southern Barents Sea showed that they are synchronous to a large extent. This is indicative of the existence of common causes influencing on the survival of the young of both species. Two circumstances made it possible to assume that the temperature factor had a significant influence on the survival of the young :

1) Barents Sea is a peripheral area for cod and haddock distribution;

2) Considerable interannual fluctuations in the heat content of water masses are observed in the Barents Sea.

It would be natural to suppose that not too high but too low temperature can limit the survival of young cod and haddock in the investigated area. For these reasons we decided to correlate SC of the young of different year classes with water temperature in the Barents Sea in the period of seasonal minimum that is most dramatic for the survival of the young (February-May).

Bottom-dwelling young cod and haddock go through the first and second temperature minimum (wintering) during two years (February-May) following the year of origination. It was found out that coefficients of survival of young cod and haddock, as a rule, rise when anomalies of water temperature are positive and vice versa.

As evident from Figures 1 and 2, the warm winters of 1951,1954, 1970, 1973 were responsible for high SC for young cod and haddock of the 1950, 1953, 1969, 1972 year classes (0+ to 1+) and 1949,1952, 1968, 1971 year classes (I+ to 2+), and conversely the cold winters of 1953, 1956, 1958, 1963 were responsible for low SC for the 1952, 1955, 1957, 1962 year classes (from 0+ to I+) and 1951,

1954, 1956, 1961 (from I+ to 2+) year classes. Temperature conditions are apparently most favourable for the survival of fishes of those year classes the young of which spend the first and second winters at positive anomalies of water temperature.

The survival of the young at ages from 0+ to I+ is most dependent on the temperature conditions of wintering. The young does not make active migrations and spend winter in those areas to which they are brought by the current by the moment of sinking to the bottom. The relationship between SC I+/0+ and the average water temperature in the 0-200 m layer during the four coldest months of the first wintering is expressed by correlation coefficients 0.57 for cod of the 1950-1964, 1969-1974 year classes (n=21) and by 0.54 for haddock of the 1950-1964, 1967, 1969-1974 year classes[x/] (n=22) (section No.6); the correlation coefficients for section 8 (stations 1-4) are 0.56 and 0.61, for section 10 they are 0.70 and 0.68 respectively. The correlation coefficients for the above sections for two coldest months are 0.58 and 0.55, 0.57 and 0.62, 0.75 and 0.68 respectively.

The multiple correlation coefficient between SC I+/0+ (y) from one side, and water temperature in the period of seasonal minimum on the three mentioned sections ($x_1 x_2 x_3$) from the other side, proved to be 0.75 for cod and 0.71 for haddock.

Standard hydrological sections No.6, 8, 10 intersect the Main and Coastal branches of the warm Murmansk Current. The low-

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x/ The 1965-1968 year classes of cod and 1965, 1966, 1968 year classes of haddock were very poor, and the 0-group fish were practically absent in the trawl catches, therefore SC I+/0+ were not estimated for these year classes.

est SC for young cod and haddock was registered in the years when the average water temperature made up less than 1.5°C on the three mentioned sections during the two coldest months.

Survival of young cod and haddock at ages from I+ to 2+ depend to a lesser degree on the temperature conditions of wintering than survival of the young at bottom stages from 0+ to I+. It is determined by the fact that the young at age I+ and older is already capable of migrating actively : in winter they leave the coolest parts of shoal waters and concentrate along the cores of the jets of warm currents.

Nevertheless, for some years the relationship between SC2+/I+ and temperature conditions of the second wintering are rather clearly traced, for example, for the 1949-1954, 1964-1973 year classes of cod and the 1965-1972 year classes of haddock (Fig.2). But for 25 year classes of cod and haddock (1949-1973) as a whole, the relationship between SC 2+/I+ and water temperature on the Kola section in the period of seasonal minimum is expressed by correlation coefficients 0.41 and 0.40 respectively. Correlation coefficients for the North Cape-Bear Island section are equal to 0.46 and 0.29; for section No.8 they are 0.35 and 0.40, and for section No.10 they are 0.26 and 0.52 respectively. The multiple correlation coefficient between SC 2+/I+ (y) from one hand, and water temperature in the period of seasonal minimum on the four mentioned sections ($x_1 x_2 x_3 x_4$) from the other hand, proved to be equal to 0.50 for cod and 0.52 for haddock.

Judging by published data of experimental observations the low water temperature (below 2°C) upsets the normal osmoregulation of young cod and haddock (Fyodorov, 1967, 1967a), deteriorates the conditioned-reflex activity and inhibits the defensive conditioned

reflexes (Gerasimov and Tseeb, 1967). All these factors by far lead to decline in the vital capacity of the young which become an easier prey to predators. However, as our observations show, young cod do not stop feeding even when water temperature is below 0°C.

The found relationship between the survival of young cod and haddock and water temperature in the season of temperature minimum is used to forecast the coefficients of survival and to improve in advance the values of the strength of the recruitment to the fishing stock.

Water temperature in the period of wintering is an important but not a sole factor that significantly influences on the survival of the young at bottom stages. As many years' investigations of the O-group cod showed, condition, fatness and length of the young which depend on earlier feeding, is also a very important criterion of the survival. All other things being equal, the large, well-fed young fish survive better than small and lean one (Ponomarenko, 1973).

A more precise forecast of the survival of succeeding year classes of cod is given by several variables : biological indices for O-group fish at the eve of wintering and temperature conditions of wintering.

The first experiment of forecasting gave satisfactory results. For example, a high survival of the bottom-dwelling young of the 1972 year class was predicted. Due to a very high survival from O-group to II-group fish the 1972 year class of cod joining the exploited stock proved to be considerably higher than average , and not poor, as might have been expected from the results of

assessments of the O-group fish of the given year class (Ponomarenko, Trambachev, 1975).

A high survival of the bottom-dwelling fish of the 1972 year class was to a large extent caused by warming up of the Barents Sea beginning since 1973. In connection with the positive anomalies of water temperature in the season of temperature minimum of 1975 a high survival of cod and haddock of the 1974 year class is expected as well. However, the abundance of the O-group cod of this year class was very low (Table 1). Therefore, despite a high survival of fishes from O+ to 2+, the abundance of cod of the 1974 year class recruiting to the fishing stock will be below long-term mean value.

Thus, when the abundance of the O-group fish at bottom stages is very low (less than 1 specimen per trawling hour) the survival from O+ to 2+ will not practically change the initial assessment of the recruitment strength : even at a very good survival from O+ to 2+ the recruitment to the fishing stock will be poor. Similarly, the initial assessment of the recruitment strength at the exceptionally high abundance of the O-group fish will remain almost unchanged: even at a relatively bad survival from O+ to 2+ the recruitment, with few exceptions, will be rich or above average.

The initial assessment of the strength of the succeeding recruitment can be significantly changed at the average, below average or higher than average abundance of the O-group fish depending on the survival from O+ to 2+. In case of a high survival at the given stage the recruitment will turn out to be good, and it will be poor in case of a low survival. The first and second winterings

of the young in the Barents Sea are the last critical periods in the formation of the year class abundance of the Arcto-Norwegian cod and haddock.

Conclusions

1. One of the causes of annual fluctuations in the recruitment abundance of the exploited stock of cod and haddock in the Barents Sea is a dissimilar survival of the young at bottom stages from the first to the third years of life (from 0+ to 2+) in different years. Maximal coefficients of survival are some tens of times more than minimal ones.

2. Interannual changes in the coefficients of survival of cod and haddock as between 25 year classes are to a large extent synchronous and are in agreement with interannual fluctuations of water temperature in the Barents Sea in the season of temperature minimum (February-May). In years with positive water temperature anomalies in the season of temperature minimum the coefficients of survival of cod and haddock rise (both from the first to the second and from the second to the third years of life), and they go down in the year with negative temperature anomalies.

3. The survival of the young at bottom stages from 0+ to 1+ is most dependent on temperature conditions of wintering (correlation coefficients are 0.75 for cod and 0.71 for haddock). The lowest coefficients of survival were registered for the years when the average water temperature was below 1.5°C in two coldest months on standard hydrological sections of the Barents Sea (No.6, 8, 10).

4. The obtained correlations are used to forecast the fish survival and to improve the values of the strength of succeeding recruitment to the exploited stock of cod and haddock in the Barents Sea.

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HEADINGS FOR FIGURES

to the paper by I.Ya.Ponomarenko "Influence of Wintering Temperature Conditions on the Survival of Young Cod and Haddock in the Barents Sea"

Fig.1. Coefficients of survival (SC I+/O+) of cod and haddock from the end of the first to the end of the second year of life (solid line) and water temperature in the 0–200 m layer on the section along the Kola Meridian in the period of temperature minimum (February–May) of the first wintering (broken line).

Fig.2. Coefficients of survival (SC 2+/I+) of cod and haddock from the end of the second to the end of the third year of life (solid line) and water temperature in the 0–200 m layer on the section along the Kola Meridian in the period of temperature minimum (February–May) of the second wintering (broken line).

Table 1

Abundance indices and coefficients of survival of young cod at bottom stages in the southern Barents Sea (without Central Elevation area)

Year classes	Average catch per trawling hour at different age, spec.			Coefficients of survival (SC)		
	0+	I+	2+	SC I+/0+	SC 2+/I+	SC 2+/0+
I949		I3,23	28,62		2,I6	
I950	I2,48	83,22	75,34	6,67	0,9I	6,04
I95I	I3,50	I9,53	5,90	I,45	0,30	0,44
I952	I,24	0,76	2,84	0,6I	3,74	2,29
I953	3,3I	I0,03	I0,62	3,03	I,06	3,2I
I954	25,95	I3,93	5,39	0,54	0,39	0,2I
I955	6,66	0,84	8,47	0,I3	I0,08	I,27
I956	II,55	II,76	I0,32	I,C2	0,88	0,89
I957	20,55	4,04	II,29	0,20	2,79	0,55
I958	I0,04	7,66	I5,70	0,76	2,05	I,56
I959	I0,42	4,70	I7,63	0,45	3,75	I,69
I960	7,08	3,93	9,27	0,56	2,36	I,3I
I96I	2,92	2,53	2,36	0,87	0,93	0,8I
I962	I4,42	4,90	6,96	0,34	I,42	0,48
I963	74,52	I0,56	2I,33	0,I4	2,02	0,29
I964	39,60	56,89	48,95	I,44	0,86	I,24
I965*		0,I5	0,55		3,67	
I966*		0,22	I,46		6,64	
I967*		0,88	I,43		I,62	
I968*		0,70	6,80		9,7I	
I969	I,84	5,79	I0,45	3,I5	I,80	5,68
I970	20,I4	62,68	74,34	3,II	I,I9	3,69
I97I	6,90	5,29	37,26	0,77	7,04	5,40
I972	4,48	33,99	53,34	7,59	I,57	II,9I
I973	I6,I2	I4,I2	73,73	0,88	5,22	4,57
I974	0,87	3,97		4,56		

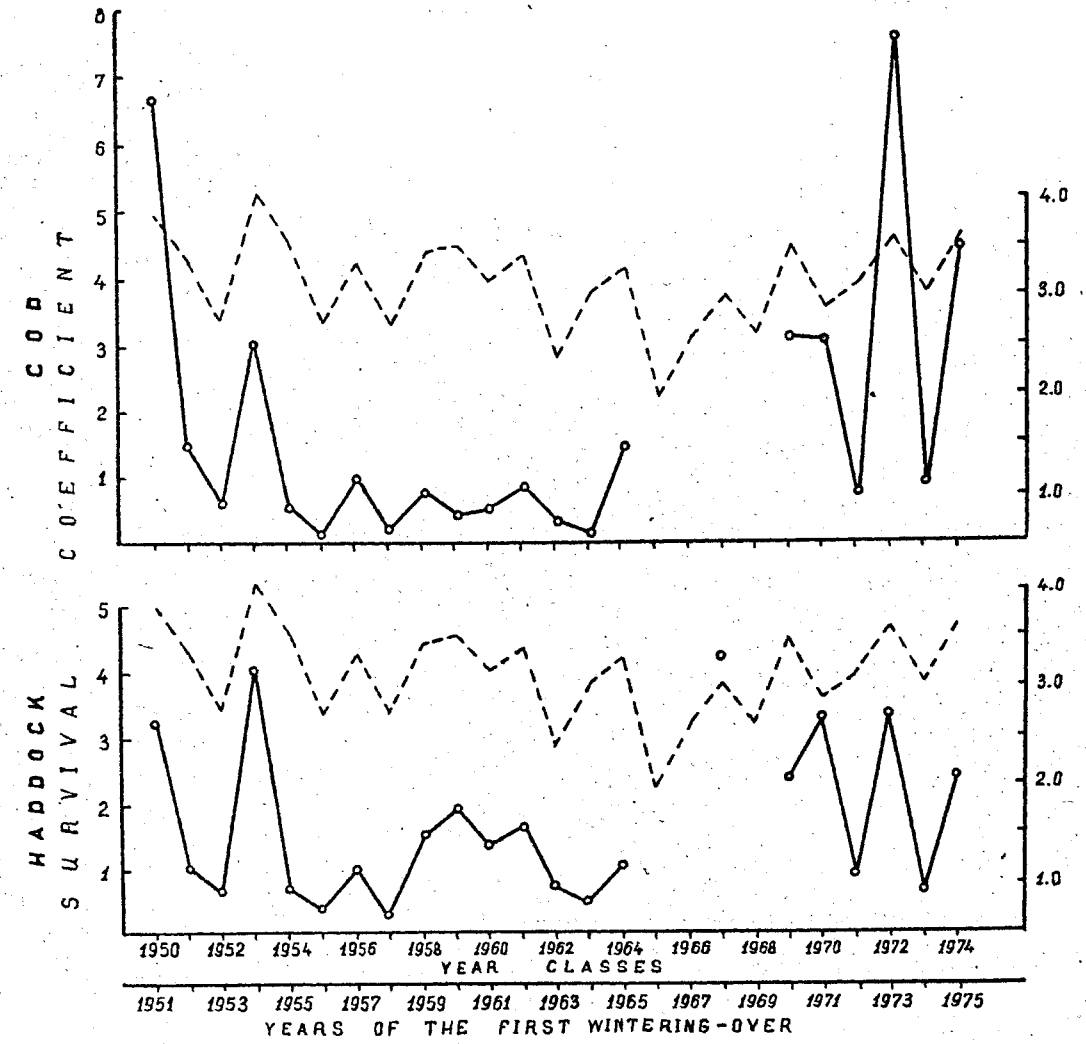
* 0-group fish was not practically met with in trawl catches.

Table 2

Abundance indices and coefficients of survival of young haddock at bottom stages in the western, coastal and central areas of the southern Barents Sea (without Central Elevation area)

Year classes	Average catch per trawling hour at different age, spec.			Coefficients of survival (SC)		
	0+	I+	2+	SC $\frac{I+}{0+}$	SC $\frac{2+}{I+}$	SC $\frac{2+}{0+}$
I949		I,05	9,80		9,33	
I950	67,27	2I5,I0	250,07	3,20	I,I6	3,72
I95I	I8,00	I8,53	9,82	I,03	0,53	0,55
I952	7,35	4,53	9,47	0,62	2,09	I,29
I953	9,36	37,82	25,3I	4,04	0,67	2,70
I954	I0,I2	7,20	3,34	0,7I	0,46	0,33
I955	7,77	2,92	3,3I	0,38	I,I3	0,43
I956	2I,08	20,48	26,87	0,97	I,3I	I,27
I957	3I,33	9,I5	I3,23	0,29	I,45	0,42
I958	2,48	3,72	5,08	I,50	I,37	2,05
I959	7,I0	I3,60	33,36	I,92	2,45	4,70
I960	30,05	40,I2	72,34	I,34	I,80	2,4I
I96I	3I,49	50,4I	33,50	I,60	0,66	I,06
I962	4,78	3,44	3,62	0,72	I,05	0,76
I963	I6,73	8,80	II,53	0,53	I,3I	0,69
I964	II,60	II,96	I5,45	I,03	I,29	I,33
I965*		0,I3	0,05		0,38	
I966*		0,07	0,20		2,86	
I967	3,23	I3,60	7,73	4,2I	0,57	2,39
I968*		0,63	3,39		5,38	
I969	3I,43	68,95	II9,92	2,I9	I,74	3,82
I970	9,79	33,23	3I,36	3,39	0,94	3,20
I97I	3,48	3,II	8,88	0,89	2,86	2,55
I972	2,65	8,70	3,49	3,28	0,40	I,32
I973	I3,47	8,22	4,66	0,6I	0,57	0,35
I974	I4,7I	35,I0		2,39		

* 0-group fish were not practically met with in trawl catches.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YEAR CLASSES
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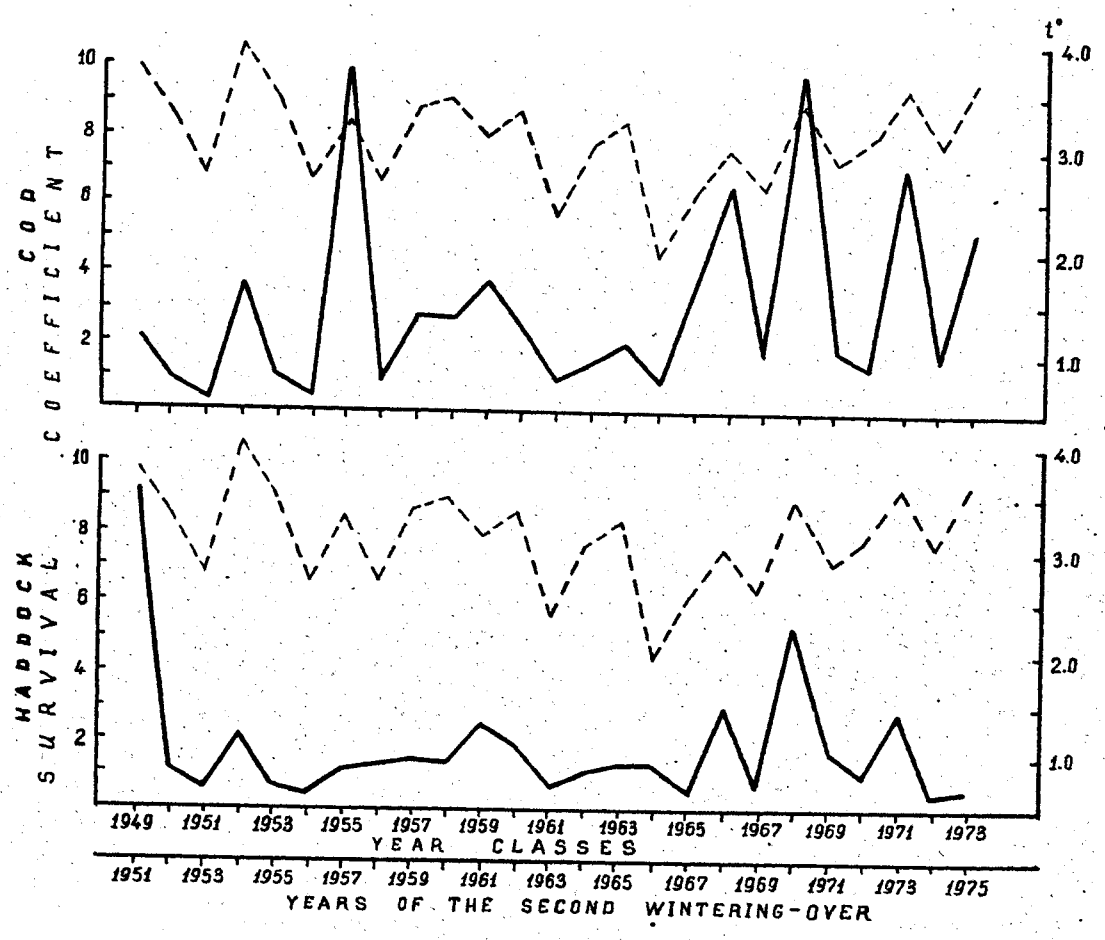
YEARS OF THE FIRST WINTERING-OVER

Fig. 1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YEARS OF THE SECOND WINTERING-OVER

Fig. 2

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