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Distribution, Biology, and State of the Northwest Atlantic Saury, *Scomberesox saurus* (Walbaum) *(Scomberesocidae)*, stocks

by

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Abstract

In the given paper new data concerning the peculiarities of the Northwest Atlantic saury life cycle are presented.

The saury is a schooling pelagic fish inhabiting the area from Newfoundland to Cap Blanc. In summer the saury occurs in the northern parts of the area, where it feeds. In the fall and at the beginning of the winter the species migrates to the reproduction areas, where it spawns and hibernates.

Vertical distribution of the saury is limited to the surface isothermal layer. The largest recorded depth of the saury occurrence is 50 m.

The water temperature is the main factor controlling the saury distribution. The spawning takes place at the temperatures of 15.0-24.8°C. In the feeding ground the species occurs at the temperatures of 8.3-21.0°C.

The mass to length ratio for the saury is expressed by the formula $W = 0.0068L^{3.0045}$.

Saury belongs to the fishes with short life cycle and high growth rate. By the end of the first, second, third and fourth years of life the saury attains the lengths of 17.4, 24.4, 29.2 and 33.4 cm respectively (average values). The catches are mainly represented by 2-3 year old fish.

The saury is easily attracted by artificial light sources which fact is assumed as a basis in the fishery for this species. Side traps are used as a fishing gear. The saury catch per fishing day on Georges Bank was 30.8-42.6 ton in the 1970 to 1974 period. The possible annual catch of 3 400 - 3 800 thous. ton may be recommended for the Northwest Atlantic area.

Introduction

The saury, Scomberesox saurus (Walbaum), is a schooling pelagic fish widely distributed in the Northern Atlantic, the USA and Canadian waters inclusive.

The problems of the distribution and biology of the species have received little consideration. Some comments concerning the saury distribution and morphology may be found in the papers by the American and Canadian oceanologists (Bigelow and Schroeder, 1953, Leim and Scott, 1966).

The saury stocks were fished in the period from 1970 to 1974. Therefore, in addition to biological material tha data on the peculiarities of the fishery of this species and on the stock state are also presented.

Material and Methods

The present paper is based on the material obtained in the scientific-research and searching cruises performed by the AtlantNIRO and Zaprybpromrazvedka from 1968 to 1974. In searching and fishing operations the positive reaction of saury to artificial light sources was considered.

The ichthyological data were collected at 1 500 light stations. Side traps (20 x 25 m, 10 mm mesh size), dip- and conic nets (10 mm mesh size) were used as fishery gear. The fish was measured from the tip of the snout to the end of middle rays of the caudal fin.

The studies aimed at isolating the saury stock units in the Northern Atlantic have not revealed any characteristics indicating the presence of separate populations within the area (Nesterov, Gaikov, in press).

The scale of the saury female maturity stages based on the histological analysis data and external ovary characterstics was applied to determine the fish maturation state.

Stage I. The ovary contains 3 types of sexual cells: oogenes and oocytes of the period of premeiotic transformations and initial phase of protoplasmatic growth. The second type cells of 36-50 μ in size prevail in the ovary. All these cells can be discerned only by means of the microscope.

Externally the ovaries look like thin white or greyish threads (1.2-2.0 mm in diameter). A longitudinal blood-vessel if feebly marked on the ovaries.

Stage II. In addition to sexual cells characteristic of stage I the oocytes in the protoplasmatic growth phase with developed follicular membrane of 140-170 μ in diameter can be observed in the ovary. Therefore, in the ovary at maturity stage II the oocytes in different phases of protoplasmatic growth are present.

The ovary diameter is 1.8-2.5 mm across the section. The coloration is white, sometimes with pinkish tint. The oocytes cannot be discerned through the ovary membrane with the naked eye. The surface of the ovaries is covered by longitudinal and transversal blood-vessels.

Stage III. The ovaries contain the oocytes in the first phase of trophoplasmatic growth. The ovary size in the phase of primary yolk filling ranges between 430 and 860 μ. Besides, the sexual cells of all previous phases are present in the ovaries at maturity stage III.

The largest diameter of the ovaries across the section is

2.2-3.3 mm. The diameter of the anterior part of the ovary is greater than that of the posterior part. The ends of the ovary are pointed, the coloration is pink or reddish, transversal blood-vessels branch out. The eggs can be seen through the ovary membrane with the naked eye.

Stage IV. This stage corresponds to the phases of yolk filled oocyte and yolk confluence. The oocytes increase to 2 900 μ . Simultaneously, the oogenes, that is the oocytes of premeiotic transformations of protoplasmatic growth can be observed in the ovaries.

The ovaries occupy the entire cavity of the fish body, their ends are rounded. The ovary diameter is 7-13 mm. The ovary membrane is entirely transpierced with blood-vessels, the coloration is intense orange, the eggs can be easily seen through the membrane and visually attributed to three generations.

Stage V. In addition to mature oocytes of maximum sizes (about 3 200 μ) histological preparations contain the cells at the beginning of yolk homogenezation, which corresponds to the phase of yolk filled oocytes. At this stage the ovary also contains the complete set of cells of previous stages.

Outwardly, the only difference of the stage V ovaries from those of the previous stage is coloration. The stage V ovaries are almost transparent due to the presence of large colourless eggs of older generation filling the large ovary volume and closely fitting their membranes. The eggs of the next generation are also transparent, however, they are dark-yellow. The ovary is resilient, the eggs begin running from oviducts when the ovary is slightly pressed.

Stage VI-IV. The ovaries at this stage are characterized by the presence of empty (brust) follicles. Non-spawned mature oocytes can be occasionally found in histological preparations. The oocytes of older generation about 1 000 μ in size are in the phase of yolk filled oocytes. All the subsequent phases are represented in the ovary by corresponding sexual cells.

The ovary is soft, sparce non-spawned eggs can be seen sometimes through the membrane. The ovary is red, the coloration is more intensive posteriorly.

The intestine filling with food was determined according to the following scale: 0 - empty; 1 - little food; 2 - half filled; 3 - full; 4 - overfilled.

The saury stock assessment was made by means of visual route survey. The possible annual catch was estimated according to Beverton and Holt (1957).

Distribution Migrations

The area of the Atlantic saury distribution covers temperate and subtropical waters. In the Northwest Atlantic the species inhabits the area between Newfoundland in the north and Hatteras in the south. Occasionally saury appears off the USA and Canadian coasts (Bigelow and Schroeder, 1953; Leim and Scott, 1966), and is common in the open sea.

Within the distribution area there is a trend towards seasonal variability of the regions of occurrence of the adults. In the northern parts of the area the saury appears in the spring-summer period. By the end of the fall and in the winter it occupies more southern regions.

To elucidate the problem of saury migrations the charts are drawn showing the distribution of mass fish aggregations by month for the 1967 to 1974 period (Fig. 1).

To draw the charts the material of observations made at the light stations, the data obtained in search of fish with the application of the light facilities and the catch data were used. The winter period is characterized by the southernmost saury distribution. At this time the fish was recorded on the southern Georges Bank and further west. In the second half of December, however, the aggregations shifted in the southern direction to the waters with the temperature exceeding 16°C, where the spawning took place. At the end of December and beginning of January considerable aggregations of large spawning saury (the length over 30 cm at the age of 3.3+) occurred in the area southward of Hatteras. In winter the fish was observed over a vast area of the open sea (32°-36°N and 50°-70°W) and further east.

It is next to impossible to single out separate locations of the large or small fish (the length of 22-30 cm at the age of 2.2+) in the period in question, except for December, when the shelf area is occupied exclusively by small fish. The observations made in the winter season indicated a dispersed distribution of the saury aggregated in insignificant schools.

In March both the large and small fish occurred in the area between 35° and 40°N (Fig. 1).

In April and in May the intensive migration of saury begins to the north. The fish aggregations cross the Gulf Stream front, penetrate into relatively cold waters and disperse on Georges Bank and adjacent regions, as well as off the southern slopes of Grand Newfoundland Bank. In April, in the above-mentioned areas, only large individuals were recoreded. Later on, in May, the large fish was observed as far as 43°N and intermixed aggregations of large and small fish were found further south on Georges Bank and in the open sea as far as 40°N.

In the summer months, with the rise in the surface water temperature, the saury penetrated further north. In June the schools of the species could be found off the Gulf of Maine, on the Nova Scotian shelf as far as 44°N, and the southern slopes of Grand Newfoundland Bank. In July the saury aggregations were distributed in the areas southward of Newfoundland, on the southern Flemish Cap Bank and further east in the open sea. The shoals of large fish occur in the northernmost areas, and the intermixed aggregations of large and small fish can be found further south.

Searching operations carried out southward of 38°N did not discover the large fish in that area. In August, like in the previous months, the saury could be seen all over the USA shelf, northward of 40°N and on the Nova Scotian shelf. It was also recorded somewhat further north on Grand Newfoundland Bank.

The saury distribution at the beginning of the fall was similar to that in summer. In the September to November period, however, the fish aggregations began to move to the south. As early as October the shoals were found all over the Nova Scotian shelf, while in November they could be seen in the Georges Bank area. In this period the aggregations of large fish keep to warmer water, unlike the smaller fish, therefore, the boundary line of their distribution runs further south. The above phenomenon tells upon the mean saury sizes in the catches from Georges Bank in the fall period. They decrease due to reduced numbers of the exploited large fish (Fig.2).

A scheme of saury migrations is built based on the data obtained (Fig.3). As is evident from the scheme, the North Atlantic saury performes considerably prolonged latitudinal migrations. At the end of the spring and in summer the aggregations move northward. In the fall and at the beginning of the winter the fish migrates to the south. The saury of 3.3+ years old begins the spring-summer migration earlier than the fish of 2.2+ years old and in the fall the first group returns to southern areas earlier.

The following functional regions of the area under study can be distinguished based on the data of the spacial saury distribution:

a) reproduction region of the area;

b) feeding region of the area;

c) the region to which the plankton larvae and fry are drifted

(Nesterov, Shiganova, 1976). There is a good correspondence between the data on the spacial distribution of the adult saury in the regions of different functional purpose and the dynamics of the stomach filling and steatosis of the intestines for the year period (Fig. 4).

The bathymetrical saury distribution is limited to the isometric surface layer, where it performs vertical diurnal migrations. At night the fish mainly keeps to the surface, and in the day-time it descends to deeper horizons. The largest recorded depth of the saury occurrence is 50 m. The eggs and larvae have always been recorded in the uppermost water layer of 0-1 m.

The water temperature is the principal factor controlling the saury distribution. The temperature range of its habitat varies between 8.2 and 24.8°C. The eggs and larvae occur at 16.2-23.7°C (the optimum temperatures are 17.3-21.0°C). The pre-spawning and spawning saury was observed at the temperatures of 15.0-21.0°C. In the feeding ground the fish was recorded at the temperatures of 8.2-21.0°C.

Reproduction

Judging from the egg, larva, fry and spawning fish occurrence the reproduction of saury takes place southward of the Gulf Stream frontal zone (Nesterov, Shiganova, 1976). The annual dynamics of the spawning fish abundance indicates that the reproduction of the saury usually occurs in the winter-spring period (table 2). The minimum length and age of the spawners, both males and females, are 28 cm and 2 years respectively.

The bulk of the spawning fish is represented by the individuals of 2.2+ and 3.3+ years old.

Length, mass, growth

The body length of the saury in the catches by side traps varies between 18 and 39 cm at the mass of 19-200 g. From the length composition curves for the fish caught in the fall-winter period two size groups of 23-30 and 31-37 cm can be distinguished with the mean mass of 55 and 110 g respectively. A dependence between the mass and length is expressed by the formula:

$$W = 0.0068 \quad L^{3.0045}$$

where W is the fish mass, g, and L is the fish length, cm.

The saury age is determined from the scales (table 3); no difference has been recorded between growth rates of males and females (Nesterov, 1974).

According to the Bertalanfi's equation the linear growth of saury is expressed by the formula:

$$L_t = 45.437 \left[I-\bar{e}^{0.279\ (t\ +\ 0.728)} \right]$$

and the mass increase by

$$W_t = 312.199 \left[I-e^{-0.834\ (t\ +\ 0.834)} \right]^3$$

where L_t is the length, cm, and W_t is the mass, g.

Fishery

The Soviet fishery for the saury was conducted from 1970 to 1974 by the ships of SRT and SRTM class equipped with the light technique of the Pasific saury type and side traps (Zilanov, 1968; Kozhemiakin, 1974).

The fishery in the Georges Bank area is based on the fish migrating southward, where it feeds. The area is subject to the influence of the warm Gulf Stream water in the south and cold water masses of the Labrador Current in the north. Along the interaction boundaries of the currents the inflows are formed resulting in intensive mixing of the water masses. The saury aggregations keep on the side of cold waters. The Gulf Stream waters with high temperatures appear to be a temporary hydrological barrier preventing the fish from movement further south. The stable commercial saury aggregations maintain in the Georges Bank area from August to December.

The fishing duration is determined by thermal conditions of the area. The saury migrates to the south with the decrease of the water temperatures down to 9.2°C. Usually, the fish stays on the southern parts of the Bank until mid-December. In 1969, however, the aggregations were recorded there in January while in 1973 the fish was absent from that area as early as December.

The optimum temperatures at which the saury aggregations were observed differ by month. To estimate their values 2 039 catches taken by side traps were analysed and the number of the fish caught within the 1° interval counted by month (table 4). The mean temperature values gradually decreased from September to December and were 16.9, 14.3, 11.8 and 11.5°C respectively.

Provided that the weather conditions and the moon phases (most important factors determining the character of the fish response to the light) are favourable, the effective fishing may be conducted during 12-18 nights a month.

The main indices of the commercial cruises are given in table 5. The saury catches per effort and the total catch increase from September to November-December. Such an increase may be attributed to increased positive response of the fish to the light.

The observed trend towards the increase of the catches per fishing effort in the 1970 to 1973 period is stipulated by improved fishing gear and the searching and exploitation tactics. In the above-mentioned years 10 8, 15.3, 40 6, 23 7 thous. ton of the fish were caught by the light-fishing vessels.

The age composition of the saury in the commercial catches maintains approximately at the same level (table 1).

A certain increase of the mean age and length of the fish caught is evidentely due to varying migration times of different-age individuals and unstable fishing season changing from year to year. The bulk of the catches is made of 2 and 3 year olds.

The complex of biological data and commercial statistics makes it possible to estimate the minimum value of the saury catch in the Northwest Atlantic. The saury biomass value was determined from the results of the route survey on abundance conducted by the ships of SEVRYBPROMRAZVEDKA, The mean biomass value of the fish was estimated as 9 000 thous. ton. The total mortality rate (Z) of the saury calculated according to Beverton and Holt appeared to be 1.50. Considering that Z = M + F and the fishing mortality (F) on the saury approximates 0, the natural mortality rate (M) of 1.50 was assumed.

The following parameters were taken as initial data for calculations:

$$M = 1.50;\ t_p = t_{p'} = 1.97;\ t_\lambda = 4;\ t_o = -0.874;\ W_\infty = 319.2.$$

The mean mass of the fish from commercial catches was 68 g. The relative recruitment abundance averaged to 59.0% of the commercial population abundance. Hence the recruitment abundance:

$$R = 5\ 300 \text{ thous.ton} = 0.78 \cdot 10^{10} \text{ sp.}$$

The curve of $\frac{Vw}{R}$ on F dependence is of asymptotic character (Fig. 5). Thereby, the possible annual catch increases to 5 300 thous.ton at $R = 0.78 \cdot 10^{10}$ sp. As is evident from the $\frac{Vw}{R}$ on F dependence, the optimum value is within the range of 1.5–2.0 which is in line with $\frac{Vw}{R}$ ranging between 25.64 and 28.49 and with the possible annual catch of 3 400–3 800 thous. ton.

Summary

The vast distribution area of the saury in the Northwest Atlantic is covered by the species in the process of seasonal migrations. Active movement of the fish to the north is related to the beginning of the feeding period. During the spawning-wintering migration the saury occupies the reproduction area. The performance of prolonged migrations results in separation of the feeding and reproduction parts of the area and enables the species to more completely utilize the food resources of the distribution area. Varying migration times of the saury of different age are stipulated by difference in the physiological condition and are, evidently, aimed at weakening of the intraspecific food

competitive relations.

Within the saury distribution area the reproduction and feeding regions, and the region to which the larvae and fry are drifted can be distinguished.

The temperature range of the species occurrence is wide and varies between 8.2 and 24.8°C. The saury is characterized by the high growth rate and belongs to the fish with a short life cycle. The fish of 2 and 3 years old prevails in the catches.

The maximum annual saury catch is 41 thous. ton. The possible annual catch of 3 40 - 3 80 thous. ton may be taken. This is indicative of the fact that the stocks are underexploited. If the catches exceed 5 30 thous. ton the fishery will be economically inexpedient and will adversely affect the stock state of this species.

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Table 1. Age composition of the saury in the commercial catches.

Age (years)	Years			
	I970	I97I	I972	I973
I	2.I6	0.36	0.42	0.04
2	72.56	63.49	52.00	44.74
3	2I.I8	3I.25	35.68	46.7I
4	4.I0	4.90	II.90	8.5I
mean age	2.27	2.4I	2.59	2.64
mean length (cm)	27.70	28.90	30.02	30.27

Table 2. Maturity stages of the saury sexual products during the year, % (summarized data from 1967 to 1973).

Months	Maturity stages					Nos.
	II	III	IV	V	VI–IV	
January	26.4	9.3	34.3	28.6	I.4	I40
February	-	67.6	I6.2	I6.2	-	I79
March	-	2.7	56.8	35.I	5.4	37
April	-	23.9	7I.8	4.3	-	46
May	-	7I.8	24.9	3.3	-	245
June	33.3	64.2	I.I	I.4	-	I56
July	-	I00.0	-	-	-	55
August	97.2	2.8	-	-	-	532
September	75.3	29.6	I.6	-	0.5	3 585
October	54.2	38.5	5.7	I.4	0.2	6 I49
November	60.9	2I.6	I0.6	6.I	0.8	6 890
December	36.2	9.3	3.9	0.3	0.3	2 207

Table 3. Mean length and age of saury from the data of back calculations from the scales.

Age (years)	Length (cm)				Nos.
	I	2	3	4	
I	I7.59	-	-	-	I62
2	I7.38	24.49	-	-	384
3	I6.83	23.79	29.I6	-	42
4	I6.60	23.80	29.60	33.40	5

Table 4. Optimum temperatures of the saury occurrence (by catch depending on the water temperature in the Northwest Atlantic).

Year, Month, water temperature	September				October					November					December			
	I969	I970	I972	I973	I969	I970	I97I	I972	I973	I969	I970	I97I	I972	I973	I969	I970	I97I	I972
8.I - 9.0													0.3				4I.9	I8.8
9.I - I0.0											0.6	5.5	40.0				25.9	24.4
I0.I - II.0					I.2	0.5				23.2	2.8	68.9	22.7		I.8	3I.6		28.0
II.I - I2.0					2.0	4.5		6.8		50.6	9.8	I9.8	24.2	64.4	75.2	20.I		
I2.I - I3.0					0.4	48.5		I7.2	I0.9	23.I	38.5		5.3	20.4	23.0	48.3	3I.7	
I3.I - I4.0					2.7	4.I	I2.3	2I.7	75.5	3.I	I0.3		I.6	7.I			0.5	
I4.I - I5.0				I3.9	I4.8	I9.9	87.7	4I.I	0.3		38.0		2.4	8.I				
I5.I - I6.0		I.8	I4.0	23.0	53.5	I2.2		6.9	0.8				2.6					8.3
I6.I - I7.0	I00.0	56.5	I8.3	I5.7	25.4	8.4			7.4				0.9					20.5
I7.I - I8.0		4I.0	49.5	28.2		I.9		5.0	5.I			5.8						
I8.I - I9.0		0.7	I8.2	4.3				0.5										
I9.I - 20.0				I0.5				0.8										
Mean weight water temper.	I6.5	I6.9	I7.4	I6.9	I5.4	I3.7	I4.4	I4.0	I3.8	II.7	I3.2	II.0	I0.8	I2.I	II.7	I2.7	I0.I	II.5
Mean temperature for a number of years	I6.9				143					II.8					II.5			

E 2

Table 5. Commercial indices of the Northwest Atlantic Saury fishery by the Soviet fleet, ton (1970-1973).

Periods	Mean catch by a ship per fishing day	Mean catch per haul	Total catch
I970			
September	2.4	0.3	68.2
October	I.2	0.2	I67.7
November	4.3	0.6	684.6
December	5.6	0.8	I57.0
Total for year	3.I	0.5	I 080.0
I97I			
September	-	-	-
October	2.0	0.3	238.5
November	4.2	0.5	845.7
December	4.6	0.8	4I5.3
Total for year	3.7	0.5	I 529.4
I972			
September	0.5	0.2	I3.0
October	0.9	0.3	I78.0
November	5.I	0.8	3 322.0
December	3.0	0.6	550.0
Total for year	3.8	0.7	4 063.0
I973			
September	2.I	0.6	36.0
October	3.4	0.7	830.2
November	5.I	0.9	I50.3
December	-	-	-
Total for year	4.3	0.8	2 369.3

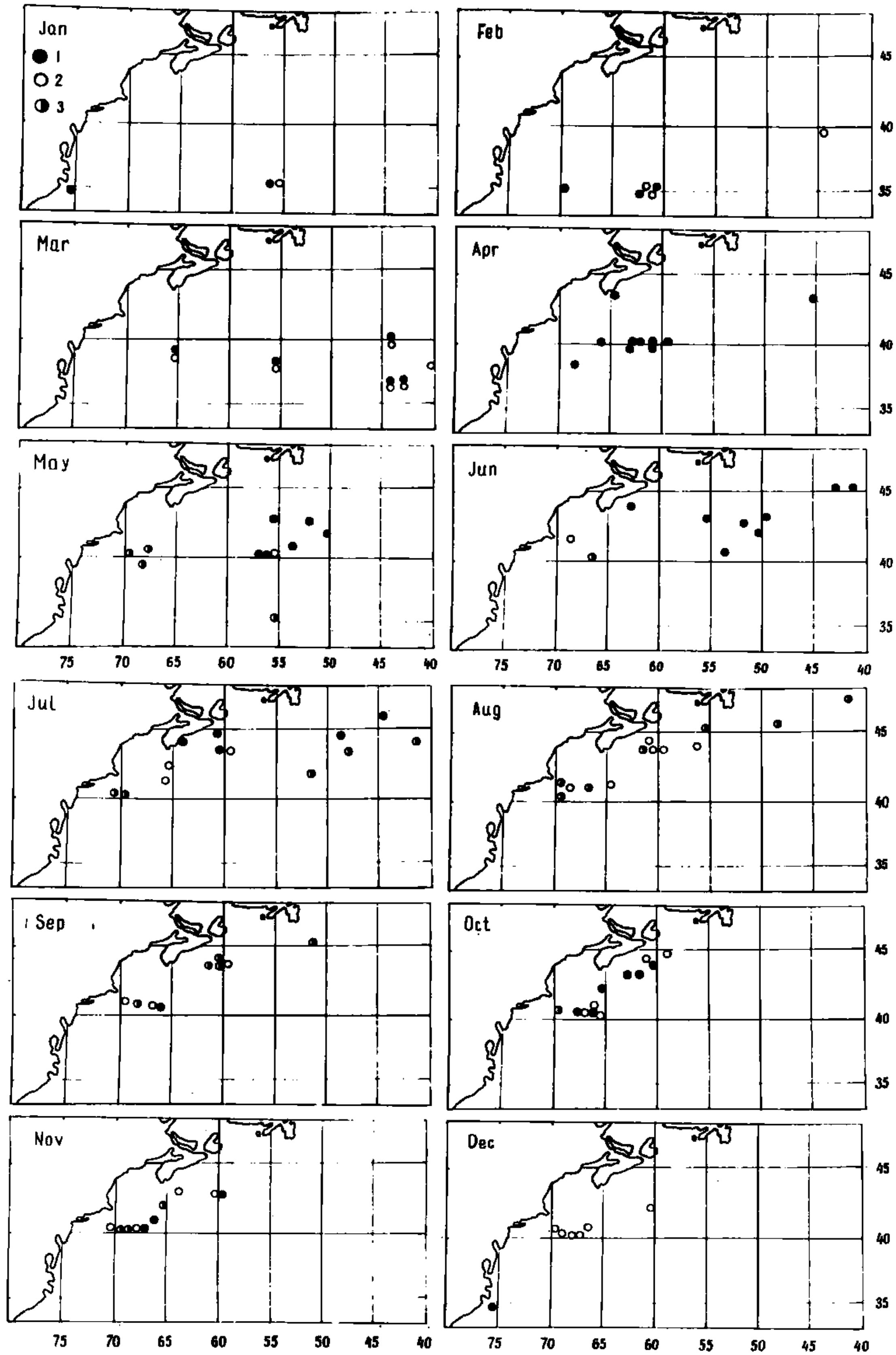

Fig. 1. The saury fishing locations in the Northwest Atlantic by month.
1(2) - large (small) saury occurrence
3 - intermixed aggregation occurrence.

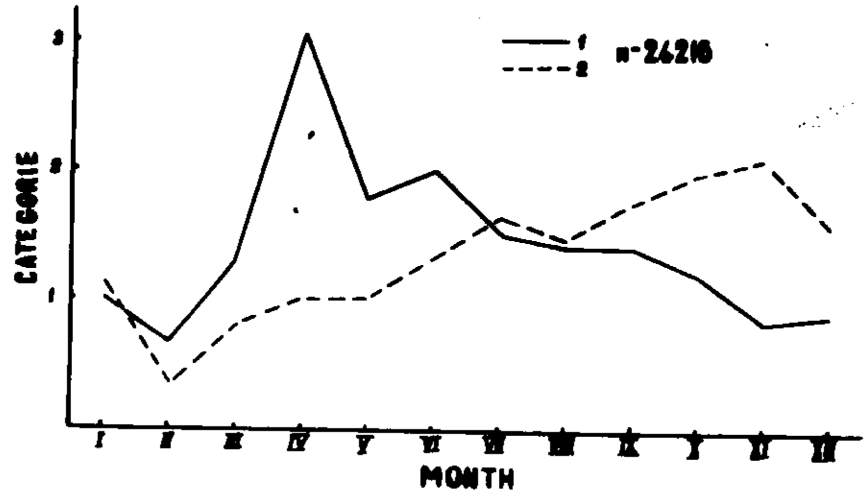

Fig. 2. Size composition of the Georges Bank saury in 1970–1973.

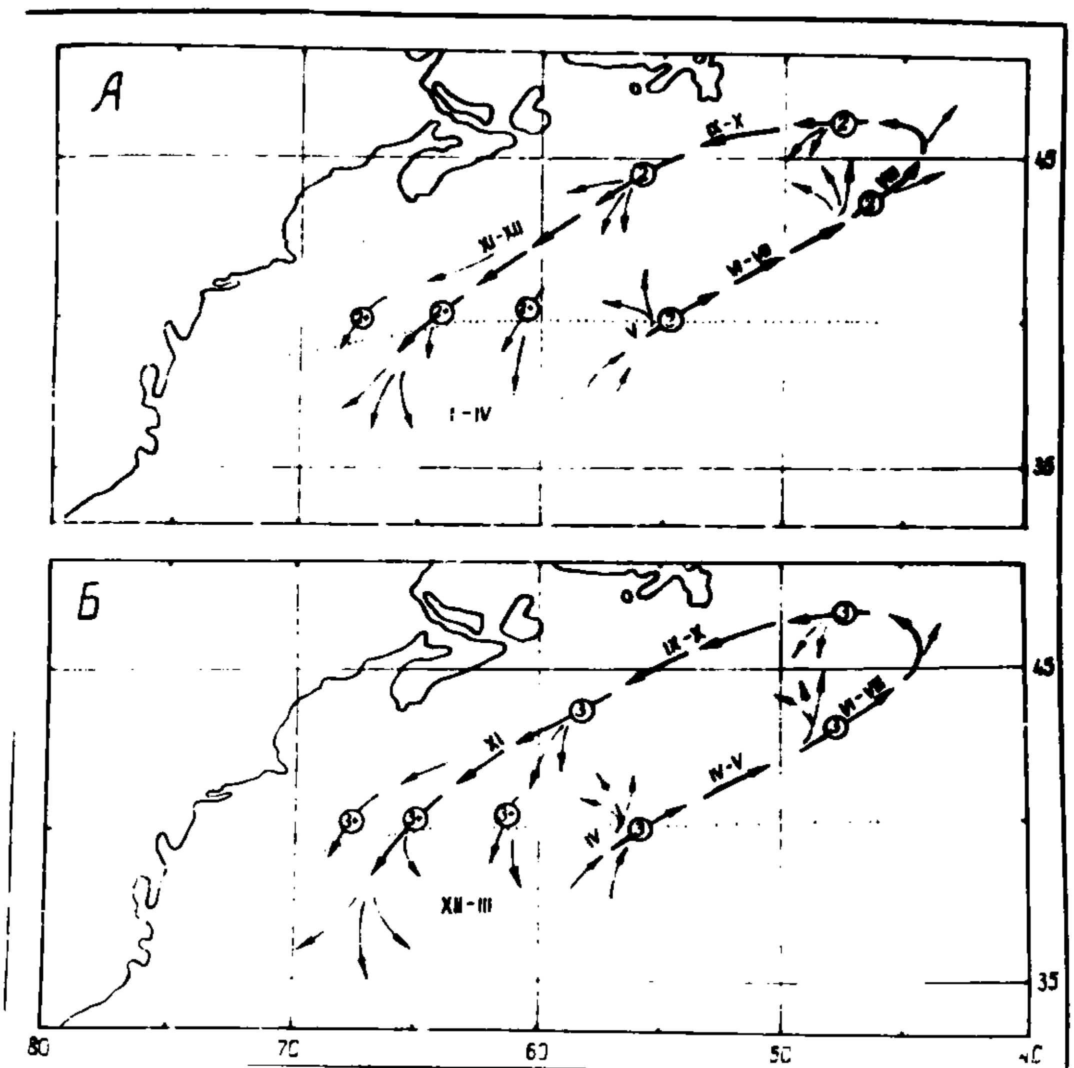

Fig. 3. A model of migration cycle of the Northwest Atlantic saury. The age of migrating fish: A- 2-2+; B- 3-3+. Encircled figures denote the age of the fish, Roman numerals indicate months. A dotted line shows the northern boundary of the saury reproduction area.

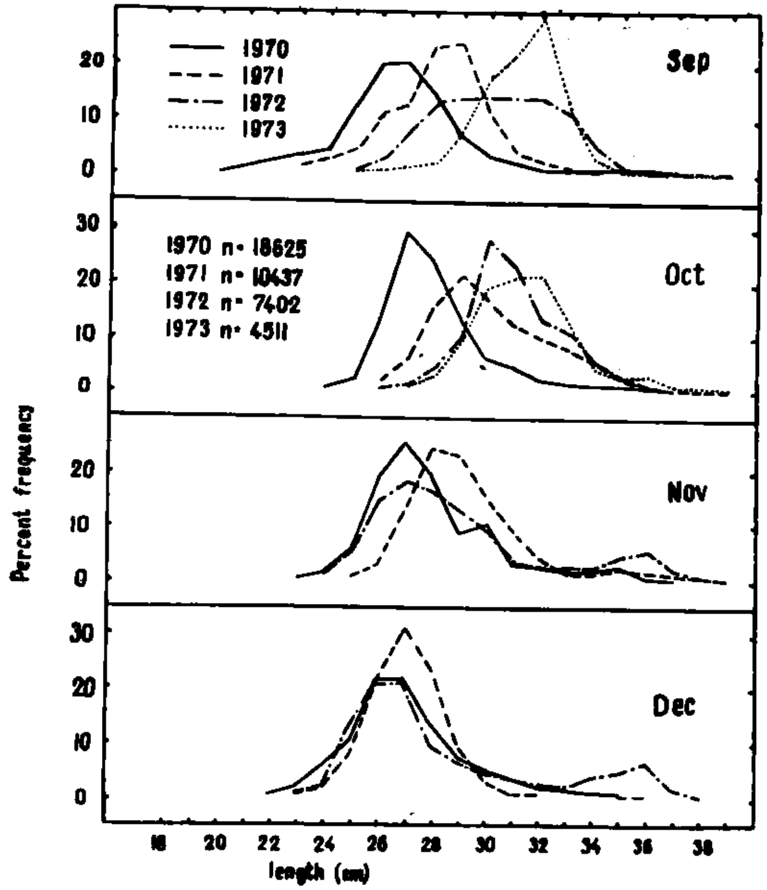

Fig. 4. The variation of the stomach filling degree (1) and the intestine steatosis degree (2) in the Northwest Atlantic saury, 1968-1973.

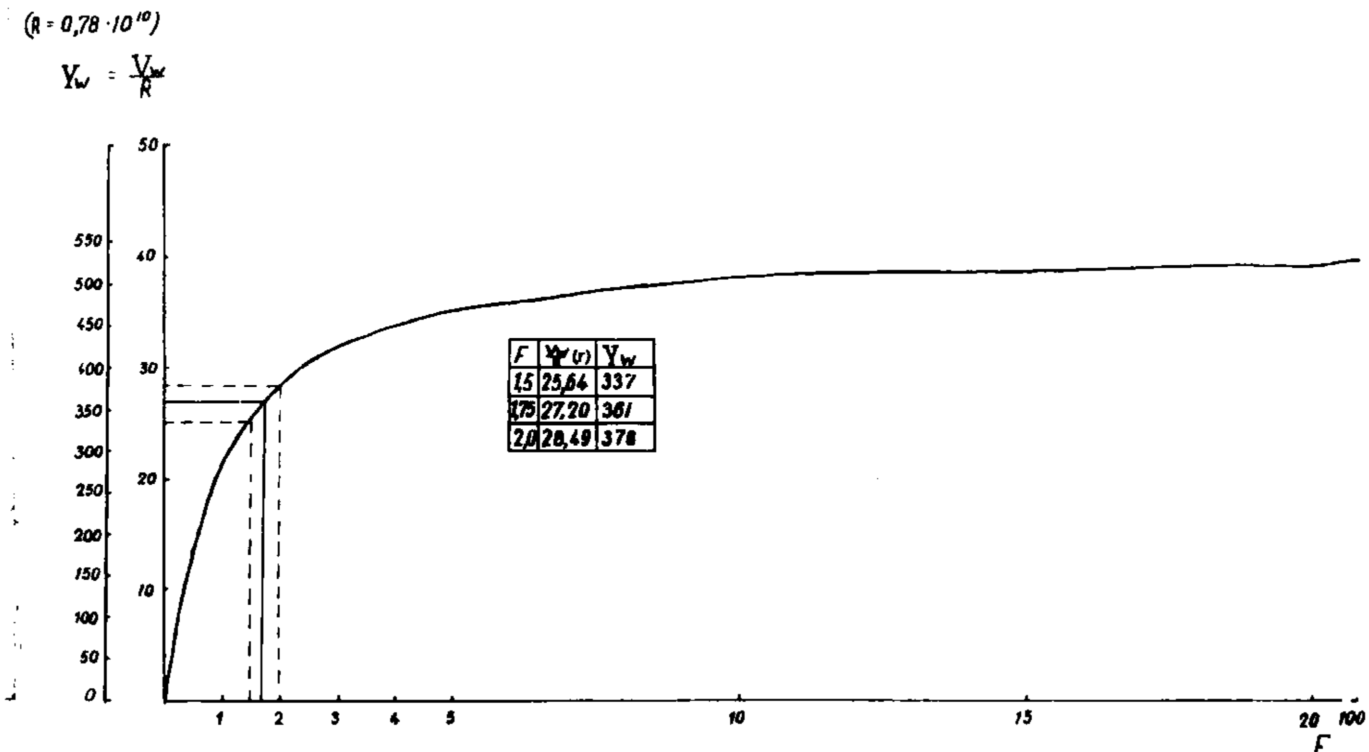

Fig. 5. A dependence of the possible catch index ($\frac{Vw}{R}$, r) and of the possible catch at R = 0.78 × 10^{10} sp. on the fishing mortality rate, F.