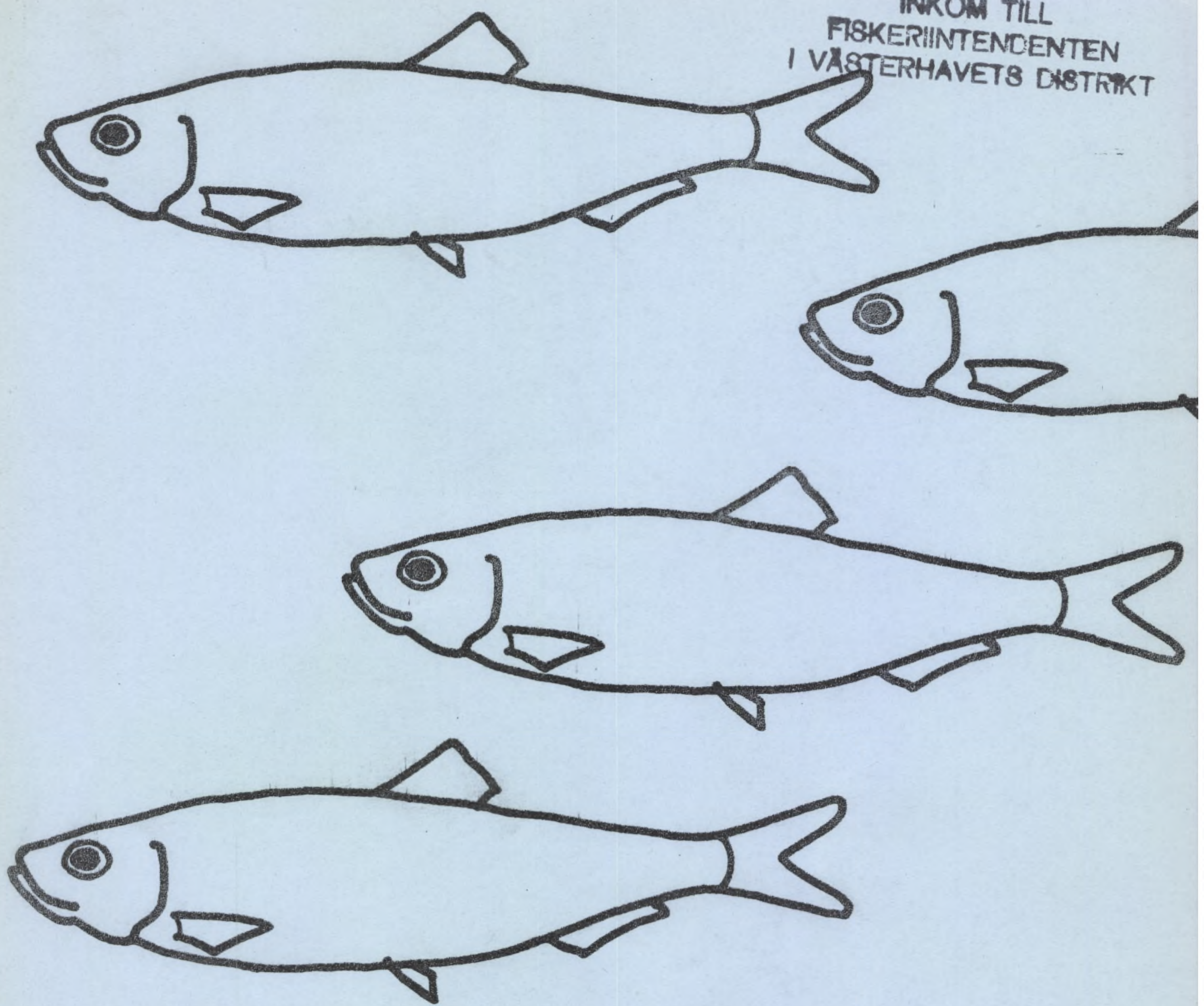

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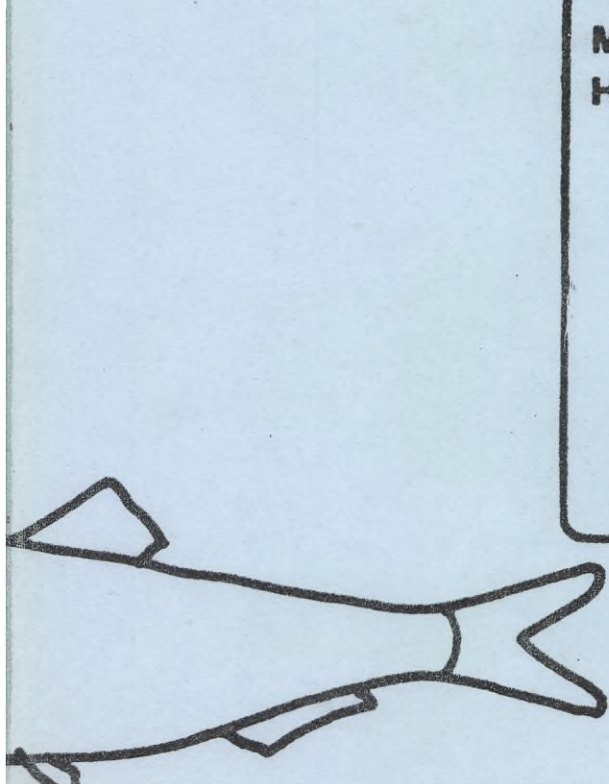
SPRAT SYMPOSIUM, LYSEKIL 1968

Papers

July, 1969



Index

Symposium on the
Life History of the Sprat, *Sprattus sprattus*
22-27 January 1968 at the
Institute of Marine Research (=Havsfiskelaboratoriet)
Lysekil, Sweden

The **purpose** of the symposium has been to give an account of the actual knowledge concerning the sprat. - There have been detailed discussions.

A g e n d a

22 Jan.
10.00
Chairman:
Dr. Thurow

Opening of the meeting

followed by

Sprat stocks and their separation

Taxonomy scientific name *Sprattus sprattus* (L)

Variability

Meristic and morphometric characters, stocks, races,

populations:	VS	% length of head
	RF	serological studies
	K2	shape of the brain (Stojanov)

Varibility of these characters according to the environment, according to year classes. Field observations (and experiments)

23 Jan.
Chairman:
Dr. Jensen

Distribution of the adult sprat during the year

Geographical distribution from the Baltic to the Black Sea

Local distribution

Factors of importance: $T^{o}C$, O_2, stratification of the water, plankton abundance, light, S ‰.

Methods of observation: fishing, echosounding, UV-TV, tagging

24 Jan.
Chairman:
Dr. Lindquist

Long time fluctuations in the sprat fishery and their causes.

Methods of fishing employed in different countries during the course of time

- gill nets
- trap nets
- beach seine
- purse seine
- trawls, pelagic
- trawls, bottom
- with/without artificial light

	Observations of long time fluctuations
	The Baltic, Skagerak, North Sea, other areas.
	Adult history in different regions
Chairman: Dr. Johnson	Age composition of the catch
	Longevity, greatest size and growth
	Food, nutrition and competitors
	Predators as dolphins, mackerel, cod
25 Jan.	The spawning of the sprat and the recruitment to the stock
Chairman: Mr. Dannevig	Maturity (age and size)
	Fecundity
	Spawning
	Seasons in different areas, length of spawning period, maxima in time and space, depth of spawning, number of spawnings per year, induction of spawning
	Drifting of eggs and larvae
	Egg and larval surveys, incubation time. Survival rates of larvae.
26 Jan.	Excursions
	In the morning: visit to the fish auction of Lysekil (sprat)
	After that: visits to canning industries (ABBA-Fyrtornet, Skandiakonserv)
	In the afternoon: visit to the hydrographical station Bornö
27 Jan.	Parasites, diseases
Chairman: Mr. Dannevig	Frequency of *Lernaeenicus*-species in sprat catches; other parasites and or diseases.
	Resumée of the meeting
	A summary of the information available and lacking.
	What to do with the results of the meeting.
	It was decided to mimeograph the papers.

List of Formal Lectures

GUNNAR DANNEVIG: Observations on distribution and behaviour of O-group sprat

" Problems in identification of sprat stocks on the basis of vertebral counts

" Some observations on sprat in an artificial seawater pond

AAGE J.C. JENSEN: Danish Research on the sprat in recent years

ARMIN LINDQUIST: Meristic and morphometric characters in relation to year classes

" Long time fluctuations in the sprat fishery

" The spawning of sprat in the Skagerak-Kattegatt area

" Adult sprat and hydrography

GUNNAR NAEVDAL: Serological studies on sprat from Norwegian waters

OTTO RECHLIN: Some remarks on the winter concentrations of sprat in the Baltic

OLGIERD WRZESIŃSKI and B. KARNICKA: Some observations on the stock of the Baltic sprat (south east Baltic) in the first half of 1967

NEVENKA ZAVODNIK: An account on the sexual cycle and the spawning of the north Adriatic sprat

DUŠAN ZAVODNIK: The distribution and migrations of the sprat from the Adriatic Sea

List of Participants

Arendal	Mr. Gunnar Dannevig Statens Biologiske Stasjon Fløødevigen Arendal Norway	Lowestoft	Mr. A.C. Burd Fisheries Laboratory Lowestoft Suffolk England
Bergen	Mr. G. Naevdal Fiskeridirektoratets Havforskningsinstitutt Bergen Norway		Dr. P.O. Johnson Fisheries Laboratory Lowestoft Suffolk England
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			Mr. Thor Nybakk Skandiakonserv AB 453 00 Lysekil Sweden
Göteborg	Dr. Artur Svansson Havsfiskelaboratoriets hydrografiska avdelning Box 4031 400 40 Göteborg 4 ,Sweden	Rovinj	Dr. Dusan Zavodnik Institut za Biologiju Mora Rovinj Yugoslavia
Hamburg	Dr. G. Rauck Institut für Küsten- und Binnenfischerei Palmaille 9 2000 Hamburg 50 Germany		Mrs. Nevenka Zavodnik Institut za Biologiju Mora Rovinj Yugoslavia
Kiel	Dr. F. Thurow Institut für Küsten- und Binnenfischerei Laboratorium Kiel 2300 Kiel-Seefischmarkt Germany		
Kungshamn	Mr. Jarl Larka Laboratory ABBA-Fyrtornet AB 450 40 Kungshamn Sweden		

Catch of Sprattus sprattus in 1000'metric tons, according to the statistics of ICES, FAO and the different countries.

	1938	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
BALTIC																					
Denmark	–	–	ø	...	...	ø	ø	...	...	...	0.5	0.5	0.2	0.7	1.3	1.8	1.0	0.9	0.3	0.6	
Finland	0.4	0.6	0.5	0.6	0.7	0.5	1.8	1.9	1.7	1.6	1.8	2.3	1.6	1.5	1.6	1.6	1.4	2.1	1.6	2.0	
Germany:	0.3																				
FR		–	2.7	1.6	0.8	0.6	0.5	0.3	0.2	...	0.8	2.3	2.3	0.7	0.4	0.3	ø	0.7	...	...	
GDR							–	–	–	–	–	–	–	–	–	–	8.0	14.7	11.2		
Latvia	0.6																				
Norway												ø	–	–	–	–	–	–	–	–	
Poland	0.1	0.3					2.2	3.1	5.1	0.6	4.3	11.5	15.2	9.8	11.3	13.7	10.7	17.4	16.9	13.6	
Sweden	0.1	...	...	...	...	...	...	ø	0.1	ø	0.1	0.8	0.4	0.3	0.1	0.2	0.1	0.1	ø	ø	
USSR									3.6	4.9	11.3	15.1	20.9	19.6	22.7	43.7	45.8	55.8	52.8	52.4	
					[1] 2.6	1.7	1.9	1.6	2.0	2.5	5.6	7.5									
THE SOUND+BELT																					
Denmark	0.6	0.9	0.8	1.0	1.6	1.7	0.6	1.6	2.4	1.1	1.8	0.9	1.6	1.4	3.2	1.3	1.5	3.0	1.5	1.2	
Germany	0.3		–	–	0.3	0.5	0.2	0.2	0.1	0.2	0.2	0.4	0.3	0.2	0.2	0.3	0.5	0.9	0.5	0.4	
KATTEGATT+ SKAGERAK																					
Denmark	0.1	2.6	3.3	1.7	1.0	1.7	3.5	37.1	33.9	23.2	14.8	5.0	5.3	9.1	8.0	5.9	5.3	4.9	2.1	3.4	
Germany	–		2.3	0.9	0.3	0.3	0.2	0.1	ø	–	...	...	...	...	–	–	–	–	...	–	
Norway	4.7	3.6	2.7	2.0	2.9	2.5	5.6	2.2	2.7	2.0	1.2	2.7	3.4	1.5	4.5	1.2	1.3	0.8	1.2	0.9	
Poland									–	–	–	–	–	–	–	–	–	...	...	–	
Sweden	8.9	11.6	7.8	10.1	9.1	11.2	9.1	10.7	8.3	7.1	3.1	1.5	5.6	4.2	5.3	4.9	3.5	2.6	3.9	3.8	
TOTAL NORTH SEA																					
Belgium	1.2	2.3	2.1	2.3	1.9	1.4	1.9	1.4	1.0	1.6	0.9	1.4	1.2	0.5	0.4	0.8	1.9	6.1	1.2	1.4	
Denmark	0.2	0.4	0.7	1.1	0.3	0.5	0.3	2.9	4.3	1.6	2.0	2.0	1.9	2.1	1.8	3.1	1.6	2.1	1.4	3.0	
England	4.1	0.8	1.0	1.2	1.2	1.2	2.4	3.0	3.6	4.3	1.6	0.9	2.5	2.3	3.0	4.3	5.0	12.8	8.2	6.6	
France	0.9	0.3	ø	0.3	0.2	0.1	0.2	0.1	ø	0.1	ø	...	–	ø	ø	...	0.1	0.1	...	...	
Germany	0.2		0.1	0.1	0.1	0.1	0.1	0.1	4.3	4.9	3.6	7.0	7.5	2.4	6.7	6.2	11.2	11.1	6.0	8.5	
Ireland		0.5	0.5				ø	0.1	0.1	ø	0.8	ø	ø	ø	1.4	0.1	0.4	1.7	1.5	1.6	
Netherlands	0.4	0.5	0.5	0.5	0.4	0.6	0.8	0.5	0.8	1.1	3.4	6.0	7.2	2.0	2.2	2.6	5.1	7.1	3.4	1.5	
N. Ireland															–	ø	ø	1.7	2.9		
Norway	9.9	3.6	6.7	3.6	6.1	4.2	7.7	6.7	3.0	1.9	7.5	2.5	7.6	6.5	4.3	9.4	13.7	9.2	5.4	10.3	
Poland	–								–	0.1	0.1	0.2	0.1	0.1	...	0.1	ø	0.3	0.1	...	
Scotland	0.6	1.8	1.8	0.7	1.5	8.8	8.2	2.7	3.6	2.4	3.3	4.2	4.4	0.6	1.1	4.9	29.1	19.6	46.6	71.1	
ATLANTIC COAST																					
Portugal											ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	
Spain	2.5	0.1				1.0	1.0	0.1	0.1	0.1	0.2	0.4	0.6	0.2	0.1	0.1	ø	0.1	0.4	0.5	
ADRIATIC																					
Yugoslavia	0.3	0.7	0.9	0.8	0.9	0.8	1.3	1.4	2.2	3.0	2.5	1.7	2.0	1.6	2.2	3.1	4.1	5.0	5.7	3.4	
BLACK SEA																					
Bulgaria [2]		2.4	2.1	0.2					0.4	1.5	2.1	2.3	1.8								

1 According to KAZANOVA 1963
2 " " STOJANOV 1960

<0.05 ø
<0.025 ...

	Meristic characters				Morphometric characters	Spawning etc.		Age of first spawning	Growth Length at different ages						Spawning at T°C
	VS	K2	RFC	PF	H	Months	No. of eggs per female x10³		0	1	2	3	4	5-group	
Baltic BELT SEA	46–49	10–13	18–20	16–18	18–21	IV–VII IV–V	10–30	I	9–10	12–13	12–14	12.5–15	13–15	15	7–8°
Kattegatt & Skagerak	46–50	11–12	18–20	16–18	18–21	V–VI		I (0)1)	8–9	12–13 7 2)	13.5–14 10	14.5 12	15 13	15.5	starts 6° 8–12°
North Sea &British Isles	46–49	11–13	18–20	16–18	17–18	(I)II– ←— (B.I.) III(IV) (I)IV– ←— (N.S.) VI(VIII)		(0)I+	6–8 8	8–10 9.5–10	9–12 10.5–11	10.6			starts 6° 8–12°
Atlantic Coasts	46–50				18–23	Ireland II–			7.3	11	12	12.5			7–9°
Mediterranean	46–49	10–12								10	11.2	12.1			
Adriatic	45–49	10–12			16.8–20.9 (majority 17–19)	(XI)– XII–III	ovocytes tot.23–62 maturing ovocytes 6–30	I (0)	6.7–10.4 (mean 8.7)	10.1–12.1 (11.2)	11.6–13.0 (12.4)	12.5–13.9 (13.3)	13.4–14.7 (14.1)	14.8–15.0 (14,9)	9–14° (peak 12–13°)
Black Sea	45–50	9–13			20–23	XII–II	15–25	0 (I)	4.5–7	7.9 7–8.5	9.2 8–8.5	10.2 9.2–9.7	10–11	11–12	

1) Uddevalla fjords 2) Limfjord

Age groups in the Baltic, Kattegatt, Skagerak

egg and larva
↓
x–first growth period ——→ second growth period → third growth period → fourth growth period

Month I V 0-group I V 1-group I V 2-group I V 3-group

Common names of *Sprattus sprattus*

Danish, Norwegian	brisling
Swedish	skarpsill (in the Baltic: vassbuk)
German	der Sprott, die Sprotte, der Breitling
Dutch	sprot
English	sprat
Finnish	kilohaili
Estonian	kilo
Russian	ШПРОТ, КИЛЬКА (in the Black Sea also САРДЕЛЬ, САРДИНКА)
Bulgarian	ТРИЦОНА, ШПРОТ, КОПАРКА, ЦАЦА
Polish	szprot
Serbo-croatian	papalina, srdjelica, srdelica, šarak, melet, sardina papalina, sardelinka, gavica, katarinčica, papalinka, pistač, srdelica oliga
Latvian	brētliņa
Lithuanian	
French	sprat, esprot
Spanish	espadin
Portuguese	espadilha
Calcian	trancho mariquita
Catalonian	sardineta
Romanian	şprot
Italian	papalina, sarda, meletta
Malta	sardina hadra
Greek	papalina
Guipúzcoa	colaguyá
Irish	
Turkish	çaça

Annex

Papers

OBSERVATIONS ON DISTRIBUTION AND BEHAVIOUR OF O-GROUP SPRAT

by

GUNNAR DANNEVIG, Statens Biologiske Stasjon, Flødevigen, Arendal

The Norwegian sprat fishery mainly takes place in the Oslofjord and in the fjords of western Norway, whereas it is of less importance on the interjacent Skagerak coast. Most of the catches consist of immature fish between 1 and 2 years old. In certain districts, especially the Oslofjord, older age groups are of importance too. This age groups, upon which the fishery is based, are not abundant on the Skagerak coast. The O-group sprat, on the other hand, generally occurs here in multitudes during summer and autumn.

In the fall the O-group sprat generally occurs in more or less concentrated shoals, that are easily recorded by an echo sounder. Some years ago, in 1950, I got the opport-unity to carry out an investigation of the distribution and behaviour of the young sprat. The shoals were recorded by an echo sounder, and we used a pelagic trawl to get samples of the fish recorded.

It soon proved that the sprat was very abundant in the open waters just outside the skerries, whereas just a few shoals could be found in between the skerries and in the fjords. These results confirms the general experience of the fishermen, that the O-group sprat preferable occurs on the banks just outside the skerries.

The shoals were found to occur right from the surface and down to a depth of approximately 70 meter. By working day and night within a restricted area, we got conclusive evidence that the young sprat undertook extensive vertical migrations, the light intensity evidently being the governing factor. During the day, when the sun was shining from a clear sky, the sprat was generally found at depths between 50 and 70 meter. Under such conditions, the shoals most frequently were found in depressions in the bottom, as will be seen from the record on ~~this~~ a slide. When it was getting dark in the evening, the shoals become more concentrated, and migrated quickly towards to surface. The next slide, showing the records from 16.30 to 17.00 o'clock, gives quite a good illustration of what was happening at dusk. When it became quite dark, the shoals proved to become less concentrated. The sprat then evidently occured more evenly distributed close to the surface (~~next slide~~). Not until the next morning, the sprat again migrated into deeper waters, after having formed more concentrated shoals.

In cloudy and rainy weather, the sprat might, even in the middle of the day, be found at any depth between the surface and 70meter. It seemed as if the fish, under such intermediate light conditions did not know how to behave.

Having learned how the sprat occured in relation to the bottom configuration, we found in fact shoals of 0-group sprat all along the coast from Arendal to Kristiansand, that is over a distance of about 40 n.m. Well into the winter the sprat disappeared from this part of the coast, and did not reappear. Such an emigration of 0-group sprat from these waters certainly must take place in most years, and we do not know where these quantities of young sprat take their way. It would be most interesting, therefore, making attempts to track down the shoals during late autumn and winter, and study their migrations. At our station we have not yet got the opportunity to do so, as our research vessel must be disposed of for other investigations during that time of the year.

SOME OBSERVATIONS ON SPRAT IN AN ARTIFICIAL SEA WATER POND.

by

GUNNAR DANNEVIG, Statens Biologiske Stasjon, Flødevigen, Arendal

At our station we have an artificial sea water pond with a capacity of approximately 5.000 m^3. The surface area is about 1.600 m^2 and the maximum depth 4,0 m. The pond is situated about 20 m above the sea level, and water has to be pumped up by a means of a centrifugal pump. This pump which has a capacity of 1 m^3 a minute, takes the water from a depth of 19 m in a bay close to the station.

Around November 1st 1966 we transferred a number of about 4.000 O-group sprat to this pond. The purpose was to find out whether it would be possible to keep the sprat there for a longer period, and if the fish could be kept in a good condition. If so, we would later on be in a position to undertake systematic experiments in order to study how the sprat was influenced by various hydrographic factors. In this first experiment, however, we just aimed at seeing what would actually happen when the fish was kept in such a pond.

The sprat was caught by seining in a small bay close to the station. Care was taken not to touch the fish neither by hand nor by any technical equipment. The sprat was removed from the seine by large wash tubs, that were dipped into the seine and filled up with water and the number of fish we managed to catch together with the water. Having filled up the tubs in this way, they were at once carried to the pond and carefully emptied there.

After liberation, the sprat at once formed small shoals and disappeared into the deeper part of the pond. During the following two or three weeks, we every day looked for dead fish, but did not find more than just a few ones. Thus the catch and subsequent handling of the fish did not seem to have caused any severe mortality.

Having stocked our pond in this way, we took care to pump up some new water at certain intervals, so as to keep the oxygen content at an adequate level. Our records show that the water on an average has been completely renewed once in 60 days only. For that reason, the temperature of the pond water has been strongly influenced by the weather conditions, resulting in very high temperatures during summer and low ones during winter. The sprat has, therefore, been exposed to more extreme temperature conditions than those prevailing in Norwegian coastal waters.

During the first week the sprat always kept out of sight of the people attending the experiment. The fish had evidently not yet settled down, and was frightened by the appearance and noise of man. On the 8th day, however, several shoals were observed swimming lively along the brickwork around the pond. Some of these shoals consisted of hundreds of fish, all of which seemed to be quite o good condition.

The supply of animal plankton in the pond was deemed too small to meet the sprat's demand for food during the winter. It was decided, therefore, to start feeding the fish at once, using finely chopped blue mussels as food.

Next morning, when my assistant arrived with the food, not a single sprat was to be seen. By throwning out some of the food, however, he succeeded in collecting quite a number of fish, that at once started feeding voraciously. Later on the sprat always appeared in great numbers whenever food was given.

It was at once evident that the sprat exclusively took food particles that were suspended in the water. Food that had sunk to the bottom, was never touched. For that reason, the feeding has mainly been carried out at definite locations with deep water.

When the sprat was transferred to the pond, the temperature was 9°C at the surface and 12° at a depth of 9 meter. During the month of November the pond water was gradually cooled down. From the 1st of December to the end of February the surface temperature was always below zero, for several weeks even below ÷1°C. The temperature at 1 m or more, was never below 2,8° during the winter. At a depth of 1 m we had in fact temperatures between 2,8 and 4,5° from early December to the 1st of March, from which date we got increasing temperatures at all depths.

On the 29th November the pond was all over covered with thin ice. After having broken and pushed away the ice at the locations selected for feeding, food was thrown out as we used to do. In the record my assistant has noted the he never before had observed so many specimens simultaneously, and that the fish never had been more greedy than on that day. The sprat proved to come up close to the surface, and even touch the surrounding ice with their backs. The surface temperature that day was ÷0,5°C. There was no sign whatever of the fish being embarrassed by this low temperature. Similar observations were made the following day too.

When the ice grew thicher, we had cut holes in it, 60 by 60 cm in square. After having removed the free ice, food was given as usually. It did not last long before the sprat appeared in the holes and took the food, apparently with quite a good appetite.

We continued to feed the sprat through such openings in the ice throughout winter. In cold weather the holes had, of course, to be reopened whenever the fish should be fed. It did not last long before the fish made their appearance as soon as our man started to cut the ice. Thus we got evidence that also the sprat has an ability to learn how to get food. When fed, the sprat come up into the icy water at the surface, and some of them even tried to jump out of the water. One specimen succeeded in doing so, but succumbed after having landed on the ice at the edge of the hole. Even slush of snow at the surface, which frequently occurred when a heavy snowfall, did not seem to embarrass the fish.

The sprat did not lose its good appetite under the severe winter conditions, and continued to eat greedily during the whole winter. The fish did not increase very much in size, however, during these months, and I don't feel quite sure that they have fed frequently enough. Another fact is that the smallest specimens on several occassions were observed to be chased by the bigger ones when the fish was fed. The smallest specimens, therefore, may not have been in a position to get their part of the food. When undisturbed, however, also the small specimens come up close to the surface, and might keep quiet there for quite a longer time.

Early in March the weather turned warmer and we got heavy rain. Owing to the rain and the melting of the snow, we got a thick layer of icy and comparatively fresh water at the surface. It then seemed as if the sprat attempted to keep away from this icy and fresh water. It was further observed that a few specimens that happened to come up into the surface layer, did not manage to swim down again and succumbed. Compared with our observations during the winter, I think it is the low salinity which influenced the fish in this way, or perhaps the combination of a low salinity and low temperature.

On March 20th the ice had melted away, and the temperature of the pond water now increased rapidly. During the spring we also tried other types of of food than blue mussels, which up to that time had been exclusively. It proved that the sprat, without hesitation, took chopped fish, as well as cod eggs and herring eggs. It does not seem difficult, therefore, to find food which the sprat will eat with a good appetite.

My assistant got a little tired, however, of preparing the types of food hitherto used. One morning he asked me, therefore, if we could not find a type of food that was ready for use. Well, I said, I will get you some of the food that is being prepared for raising trout in ponds. This was a dry type of food, and had to be soaked in sea water before given to the fish. The sprat proved to take also this type of food quite normally from the very first day, and since June 1st 1967 trout food has been used exclusively. On certain occassions only, the sprat has got some chopped blue mussels in addition. During the summer the fish proved to grow bigger and fatter on this diet.

In September and October last year, the weather was exceptionally warm for the season, and we had consequently very high temperature in the pond till the end of October. Well into November, however, the weather turned much colder, resulting in a rapid cooling of the pond water. On December 2nd the pond was all over covered by ice. From then on we have, in fact, not seen much to our sprat. Just a few specimens have appeared when the food has been given through holes in the ice, and the food has apparently been of little interest to them. It seems, therefore, as if the rapid cooling of the water has caused the sprat to become far less active than has previously been the case. You will understand that we are now most anxious to see if, and eventually when, the sprat will recover and start feeding normally.

It has to be added, however, that we this winter have encountered some difficulties because of the severe cold. The water pipe conducting sea water to the pond was blocked by ice, with the effect that we were not able to renew the water for several weeks. The oxygen content of the pond water has consequently become lower than previosly. Also this fact may, of course, have had an effect on the sprat. The water supply system will now be reconstructed in order to eliminate such difficulties.

Our observations and experiences up to this time thus seem to indicate that it is really possible to keep sprat for quit a long time in a pond like ours. We have decided, therefore, to start more systematic experiments this year. For one thing we are in a position to alter the temperature conditions simply by pumping up more or less new water from the sea. We may also produce a thinner or thicker surface layer of water with a low salinity. By altering the environmental conditions in this way, it should be possible, I think, to arrive at some conclusions as to how the sprat is being influenced by such factors. And if we are especially lucky, the sprat may become mature and spawn in our pond. That would certanly be most intersting.

PROBLEMS IN IDENTIFICATION OF SPRAT STOCKS ON BASIS OF VERTEBRAL COUNTS

by

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The identification of marine fish stocks has to a great extent been based on vertebral enumeration. In Norway we considered, therefore, to make us of this method also for population studies on the sprat in our waters. Before doing so, however, I found it necessary to carry through some critical studies as to the applicability of the method to this species.
In investigations of morphological characters it is important to know whether the differences observed are inherited or environmental. In the case of the sprat we have no experimental evidence to show the effect of environmentla factors on the number of vertebrae. In several other species it has been clearly demonstrated, however, that the number of vertebrae is strongly under the effect of temperature. I may here refer to works of JOHS. SCHMIDT (1921), VEDEL TÅNING(1944, 1950), ALF DANNEVIG (1950) and MOLANDER & MOLANDER and SWEDMARK (1957). We cannot leave out of account, therefore, that the temperature may have a similar effect in the sprat too.

Another point is that the number of vertebrae cannot be used as a certificate of origin, which makes it possible to distinguish between single specimens from different populations. We always have to compare the mean values, or the frequency distributions, for quite large samples, and find out whether the difference between them are significant or not. Provided a significant difference is found, we may draw the conclusion that the samples have not been drawn from the same population. This fact does not imply, however, that all specimens of the two samples really belong to different populations. The majority of the specimens may very well belong to the same stock, the significant difference between the samples being caused by the admixture of some few specimens from another stock to one of the samples. This is quite an important point, which has to be kept in mind when using frequency distributions for morphological characters in population studies.
In case of the sprat, we have other complications too. Some years ago, it was shown by BJERKAN and ALF DANNEVIG that, within samples of 0-group sprat, the larger individuals might have a higher number of vertebrae than the smaller ones. These authors, as well as MOLANDER, have further reported that a positive correlation between size of fish and number of vertebrae may be found also when comparing samples taken at approximately the same time within a definite district.
These observations were considered to such a degree important, that I found

it necessary to examine the problem on a broad basis. Some of the preliminary results were published in a paper from 1951 (Sprat from Norwegian Waters, an Analysis of Vertebrae Counts). Later on I have worked up another great number of samples, and I shall try to review the total material now at hand. Use has been made mainly of samples of O-group and of I-group sprat, as these age groups generally occur in separate shoals.

In order to study the correlation between size of fish and the vertebral number, each sample has been devided into two subgroups, "large" and "small", according to the average total length of the fish. The mean vertebral number is subsequently calculated separatly for each subgroup, and the difference between the means worked out. In order to review to results, the samples have been classified according to the algebraic value of the difference (D) between large and small fish of the same sample. A positive difference thus indicates that the larger fish on an average have a higher number of vertebrae than the smaller ones.

This table shows the results arrived at on the basis of the material dealt with in the paper previously mentioned. The frequency destribution of the samples according to the difference (D) between small and large fish, is here given separately for O-group and I-group sprat. If the number of vertebrae were independent of the size of the fish, we had to expect about an equal number of samples with positive and with negative differences between the means of the two subgroups. In case of the O-group, there are actually 63 positive differences against 9 negative differences. In addition, the numerical values of the positive differences are on the whole much greater than those of the negative differences. This is a significant deviation from expectation, as P has been calculated to be less than 0,001.

This material as a whole gives, therefore, very strong indications that, within samples of O-group sprat, the larger specimens will generally have a somewhat higher number of vertebrae then the smaller ones. Looking at the I-group sprat, we find that within these samples as well, the larger fish have generally a higher vertebral number than the smaller ones.

Later on I have examined an additional number of 108 samples from Norwegian waters, 40 of the O-group and 68 of the I-group sprat. The results arrived at on the basis of this new material, have in every respect confirmed the conclusions drawn from the material previously published. There can be no doubt, therefore, that we are here dealing with quite a general phenomenon, at least in case of the sprat in Norwegian waters.

The fact that there is generally such a correlation between size of fish and number of vertebrae, will to great extent complicate the use of vertebral counts in population studies. The sprat, as you know, generally occurs in shoals, and it is a fact that fish of approximately the same size tends to keep together and form separate shoals. Such a splitting up of the population, certainly entails definite sampling problems. We may well obtain samples that in every respect are representative of the shoals from which they are taken, but none of the shoals may a priori be considered representative of the total population with regard to the size of the fish. And unless our samples really are representative in this respect, we cannot expect them to be representative as to the number of vertebrae.

It is not surprising, therefore, to find that samples of the same yearclass, taken at approximately the same time and on the very same locality, may differ significantly with respect to mean number of vertebrae. Such observations have, in fact, been made repeatedly. Thus we one year, between August 11th and 16th, got three samples from Floedevigen, for which the averages proved to range from 47.59 to 48.08. This difference proved to be clearly significant. The next year 4 samples were taken within 11 days at the same locality. In this case too, there was a significant difference in vertebral numbers between the samples. These observations clearly demonstrate, therefore, that the population occurring within a restricted area, is not always a completely mixed one, and that a single shoal is not necessarily representative of the total population of a certain yearclass.

As far as I can see, therefore, one has to be very carefull when attempting to identify population units of sprat on the basis of vertebral enumeration. There are evidently many pitfalls to be avoided.

SEROLOGICAL STUDIES ON SPRAT FROM NORWEGIAN WATERS

by

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INTRODUCTION

In addition to morphometric and meristic characeristics and tagging experiments, methods from the field of serology and molecular biology have been introduced in the work of identification of stock units of economical important fishes. Blood types have been used for this purpose for the last ten years, but with variable degree of success. Intra-specific variation in fish hemoglobins were first found by Sick (1961) in whiting and cod by use of a simple agar gel electrophoresis, and distributions of the three common hemoglobin types of cod have been measured from samples from the larger part of the cods geographical range (Sick 1965a, b, Frydenberg et al. 1965). Also in serum proteins and various enzyms intraspecific variations are revealed by electro-phoresis (Møller 1966, Odense, Allen and Leung 1967, Sprague 1967), and most of these variations are found to be genetically determined.

Serological or molecular characteristics to be used for identification of intraspecific variations should satisfy the following claims:

a. They must be easily revealed for great numbers of specimens by use of simple and easily reproducable methods.

b. They must form the basis for proper classification of specimens into well defined groups. Doubtful cases must be rare.

c. They must be genetically controlled and not influenced by ecological or pathological factors. Their mode of inheritance should be so simple that it can be revealed from population data.

d. They must withstand some storage without destructions that make classification unreliable.

Electrophoretic studies on blood proteins of sprat were started in the autumn 1965, and have been carried on in 1966 and 1967. Most attention has been paid to intraspecific variations in hemoglobins and serum proteins, but part of the material have also been analyzed for variations in the enzyme serum esterase.

MATERIAL AND METHODS

Blood was obtained from live sprat by cutting the tail, and collected in small glass tubes which were packed and sent on ice in thermo bottles from the sampling locality to the laboratory. There the blood was centrifuged, and the serum pipetted off.

The erythrocytes were lysed by destilled water and the hemolysate was centrifuged once more before analyses. In the first samples heparin was used as anticoagulant, but as it appeared that hemoglobin solutions should easily be prepared also from partly clotted blood, no anticoagulant was used for the rest of the samples.

The agar gel electrophoresis on microscopic slides, described by Sick (1965a) was applied also for the sprat hemoglobins. The electrophoretic run lasted for 60 minutes. The hemoglobin analyses were usually made within two days after the blood had been collected, but some samples had to be stored (at about 2°C) for somewhat longer time before analysis. The storage did not seem to influence the results seriously, except that weak components tended to become stronger after storage. Some experiments were also carried out with storage of hemoglobin at room temperature.

Sera were subjected to electrophoresis without any initial treatment. Most samples were analyzed fresh, but some were stored frozen for a few days or weeks. Storage did not seem to alter the eletrophoretograms except that the bands tended to become weaker and more diffuse.

Serum proteins were analyzed by combined starch and agar gel electrophoresis (Møller 1966). Runs of 90 minutes were applied for serum proteins and 75 minutes for esterase.

The hemoglobins were stained in Amidoblack 10 B. The serum proteins were best made visible by staining with Nigrosine, but Amidoblack 10 B could also be used. Serum esterase activity was detected by 1-naptylacetate and Fast Blue BB Salt (Grunder, Sartore, and Stormont 1965). Autoradiography according to Giblett, Hickman, and Smithies (1965), modified for this type of electrophoresis by Møller (1966), was carried out for identification of transferrins.

Sample localities are shown in Fig. 1 (1965 and 1966) and Fig. 2 (1967). The hemoglobins of sample no. 20, 24, and 44 were too old when they arrived at the laboratory, and gave unreliable results. The sera in sample no. 47 also were destroyed because of some failures with the staining process when the analyses were carried out.

Length were measured for part of the material, and the age of the bulk of each sample were determined partly from size and partly from growth zones in the otholits.

RESULTS AND DISCUSSION

Hemoglobins

Hemoglobin types of sprat have been described by Wilkins and Iles (1966) and the three hemoglobin patterns revealed by these authors also made up the greater part of the material from Norwegian waters. In a preliminary report (Nævdal 1966) these patterns were called a_1, a_2, and b respectively. Other patterns were called c, d, e, and f. These designations have been retained as "working names", but for a complete description of the sprat hemoglobin variations, a nomenclature similar to that used by Sick (1961, 1965) for cod hemoglobins, has been accepted.

The hemoglobin patterns (phenotypes) revealed by the present investigations are outlined in Fig. 3

Most variations of hemoglobins were found in the slower moving group called Hb I. Three strongfractions were found to belong to this group, and these components were called Hb I-1, Hb I-2, and Hb I-3 in order of increasing cathodic mobility. One or two of these strong components were always present. All the six possible combinations were found, although some of the combinations were very rare.

Weak components were found at the positions where strong fractions were lacking. These weak components varied to some extent, and if these variations were taken into consideration, the specimens could be classified into several more groups. However, the weak components tended to increase in strength upon storing, and because it has not been possible to analyze all samples immediately after sampling, classification according to weak components has been omitted. For the same reason, distinction between "type 1" and "type 2" of Wilkins and Iles (1966), preliminary called a_1 and a_2 respectively (Nævdal 1966), was also omitted since these two patterns differed only in the presence or absence of one weak component at the position of Hb I-2.

The hemoglobin patterns (phenotypes) were named according to which of the three main components they contained: Thus the phenotype Hb I-1 comprises the component Hb I-1 only, phenotype Hb I-1-2 comprises Hb I-1 and Hb I-2, etc. The names of the six phenotypes follow from Fig. 3

A group of hemoglobins of somewhat greater cathodic mobility, were called Hb II. The major part of the specimens contained only one strong component, called Hb II-1, in this group. In a few specimens this component was lacking.

Prolonged storage of the samples in the refrigerator did not result in major changes in the hemoglobin patterns, except that the minor components became stronger. After four or five days the bands became diffuse, and the patterns could not be determined. Heating of the blood, however, resulted in "new" patterns. Among specimens which had been kept at room temperatures (about 20°C) for 20 hours before reanalysis, two "new" patterns, outlined to the right in Fig. 3 were found. One pattern comprised several bands which might vary somewhat in relative intensity, some at positions of normal hemoglobin components, and some with higher cathodic mobility. It could be confused with patterns Hb I-2-3 or Hb I-3, but the weak components clearly distinguish this pattern from the normal ones. The other pattern comprised two bands, none, however, at the positions of any of the normal components.

For the greater part of the material, differences between patterns were clear, and the classification therefore fairly easy. The difference between patterns Hb 1-2 and Hb I-2-3 might be less evident, and the type determination of specimens with one of these patterns might accordingly be unreliable.

The material was separated into age-groups, and the hemoglobin variations were found in samples of the 0-group as well as in samples of older fishes. This supports the conclusion of Wilkins and Iles (1966) that hemoglobin patterns assosiated with age or length are not present in sprat. Genetic control of the hemoglobin types seems more likely. The genetic system still is obscure, but some suggestions may be inferred from the distributions of hemoglobin types. It seems probable that the phenotype Hb I-1-2 with the strong fractions Hb I-1 and Hb I-2 represents a hetsrozygote. Pattern Hb I-1 should then be the phenotypic expression of one of the hemozygotes. The other hemozygote should be expected to show a hemoglobin pattern with Hb I-2 as the only strong component. It may be represented by the type Hb I-2, Hb I-2-3 or Hb I-3 (Hb I-1-3 is found only in one single specimen), or by two or all of them. In the last case, the three types may represent phenotypical modification of the same genotype. Accepting this hypothesis the observed distributions are in pretty good accordance with expected Hardy-Weinberg distributions.

The numbers of the type Hb I-1 in per cent of total specimens in each sample was chosen as characteristic sample parameter. These values were calculated for each sample together with 95 per cent limits of confidence. The variations among samples will be dealt with later.

Serum proteins

Outlines of serum protein electrophoretograms are shown in Fig. 4 Intraspecific variations were observed in several groups of proteins, but the clearest variations and the only ones which could form the basis of proper classification of specimens, were found in the proteins which by autoradiography were found to posess ironbinding capacity, and therefore are called transferrins.

Fig. 5 shows the observed transferrin types. The three bands of greatest anodic mobility, named Tf A_1, Tf A_2, and Tf B_1, were found to bind iron. Sera in which the rare fourth band occurred, were not available when the tracing experiments were done, but as its strength and location conforms with the transferrins, it was interpreted as a rare transferrin band and called Tf B_2.

A total of ten transferrins phenotypes were observed, and one, two or three transferrin components might occur in each specimen. A theory of simple genetical control of the total transferrin types seems unapplicable, and distinction between some of the types, especially those containing Tf A_1 and Tf A_2, sometimes appeared difficult. For these two reasons the phenotypes were lumped together into three main groups as follows from Fig. 5 The three main groups were named Tf AA, Tf AB, and Tf BB.

Two co-dominant alleles may control the three main transferrin types. The alleles are named $\underline{Tf^A}$ and $\underline{Tf^B}$ supposed to control Tf A (Tf A_1 and Tf A_2) and Tf B (Tf B_1 and Tf B_2) respectively. In Table I frequencies of the gene $\underline{Tf^A}$ (called q_A) and expected Hardy-Weinberg distributions, are calculated for four arbitrary chosen samples. Fairly good accordance were found, and similar results were obtained for the rest of the samples. The theory of two co-dominant genes controlling the main transferrin types in sprat therefore seems to be correct. However, only part of the genetic mechanism is revealed by this theory, because the high numbers of phenotypes as well as faint bands which occurred in addition to the strong transferrin bands, indicate a more complex genetic mechanism. But the genetical control of the main types can hardly be doubted and they therefore may be used in segregation studies. As characteristic sample parameters are here chosen the calculated frequencies of the gene $\underline{Tf^A}$, q_A.

Serum esterase

Very complicated variations in serum esterase of sprat were found. Outline of some of the observed phenotypes are shown in Fig. 6 .

Classification of specimens into well defined groups on basis of these variations proved to be difficult, especially because the bands of esterase activity often were diffuse. The two last moving components, named Es S_1 and Es S_2 may constitute a group of esterase controlled by two alleles, and the distributions of the phenotypes (named Es S_1S_1, Es S_1S_2, and Es S_2S_2 respectively) were determined for the samples shown in Table II. The fairly good accordance between observed and expected distributions indicate that the hypothesis may be correct. However, use of esterase phenotypes in segregation studies seems yet unreliable, perhaps except for mere confirmation of results obtained by other methods. (Note the differences in observed frequencies). The results of the esterase analyses are omitted in the following discussion.

Variation among samples

In Fig. 7 a diagram of the 95 per cent limits of confidence are shown for the samples collected in 1965 and 1966. The samples are listed in geographical order. It follows from the figure that great variations among samples were found, and these variations have been further tested by use of t-test (test of frequencies) and χ^2-homogenity tests (test of homogenity of distributions of phenotypes).

χ^2-homogenity test of the total material in Fig. 7 demonstrated that there was very low probability for that all samples have been drawn from one homogenous population with regard to these characteristics. When all samples from Western Norway (including the Trondheim fjord) were compared to the total samples from South-eastern Norway by t-test and χ^2-homogenity tests, it came out that significant differences were found for the transferrins but not for the hemoglobins. The q_A-values were generally higher for the samples from South-eastern Norway, and χ^2-homogenity tests of these samples did not show any significant variations in distributions of transferrin types, while the variations in hemoglobin type distributions were significant. Among the samples from Western Norway the variations were significant in distributions both of hemoglobin and transferrin types.

When the samples from South-eastern Norway were separated into two main groups, namely samples from the Skagerrak coast and the Oslo fjord, significant differences were found in the hemoglobins, but not in the transferrins. Within these two main groups significant variations were only found in distributions of hemoglobin types among the samples from the Skagerrak coast.

Further tests seem unnecessary for the samples from Western Norway. Great variations were observed even among samples from adjacent areas, and no marked geographical trend can be discovered in the variations of sample parameters, except that the samples from Rogaland all showed high percentages og Hb I-1 and intermediate values of q_A.

The results of the samples collected in 1967 are presented in Fig. 8 . The results of the samples collected at the Norwegian coast confirmed the results of the previous years. High values of Hb I-1 frequencies and intermediate values of q_A characterize the samples from the Kattegat. It follows from Fig. 7 and Fig. 8 that part of the samples from the Norwegian coast (but none from the Oslo fjord) gave results which coincided with the Kattegat samples. Most samples from the North Sea also showed high values of Hb I-1 frequencies, but some of them showed higher values of q_A than did the Kattegat samples. These results are also in accordance with the results of a few samples from the Norwegian coast. But a considerable part of the samples collected at the Norwegian coast do not conform neither with the samples from the Kattegat nor with the samples from the North Sea. This is perhaps better illustrated in the scattering diagram in Fig. 9 where both the q_{Λ}-value and the Hb I-1 frequency value have been plotted for each sample. (Samples of less than 50 reliable determinations of specimens have been omitted). It appears from the diagram that a "cloud" of symbols which include the Kattegat samples (and one sample from the North Sea) is found, but a considerable part of the samples are found outside this "cloud".

Attention may here be drawn to the reliability of the type determinations. Uncertain determinations of the transferrin types might be a source of error. The transferrins often occurred as weak bands, and therefore determination of patterns might be difficult in specimens which did not give electrophoretograms of high technical quality. However, doubtful cases were tested by reanalyses, and specimens which gave electrophoretograms of poor quality, were omitted. Consequently, the numbers of specimens for which the transferrin types have not been correctly determined, is low in the present material, and such cases can not explain the observed variations.

Cases of doubt are even fewer for hemoglobin type determinations. However, the possibility do excist that unknown non-inherited factors may influence the hemoglobin types, but genetic factors seem to be responsible for at least the main types. The variations among samples discussed here, are based upon the main types only, and therefore these variations should be highly reliable.

Therefore the most likely explanation of the variations among samples is that the samples have been drawn from populations which differ in their gene pool, that is which are reproductively isolated. The results therefore indicate that a major part of the sprat in Norwegian waters is recruited from spawning grounds in the Kattegat. Recruitment from spawning grounds in the North Sea may also account for part of the Norwegian sprat population. The origin of the sprat from which the rest of the samples have been drawn, is not clear, but local populations in the fjords may be the explanation. It is also possible that the samples from the Kattegat and the North Sea are not representative for these areas, and that other sprat populations excist from which no samples have been drawn.

From the scattering diagram in Fig. 9 it is evident that no co-variance excists between the observed pair of values. This imply that more than two, probably several isolated populations have been sampled, although some of the samples may represent mixture of specimens of different origin. The mechanism which keeps the populations isolated, i.e. which prevent gene flow between the populations, is unknown, but selective mating, a kind of "homing" instinct or physiological adaptions may be guessed.

Although other explanations may be given, the results of the present investigation indicate the following conclusion: The sprat population in Norwegian coastal waters is made up of a major part recruited from spawning areas in the Kattegat and perhaps the North Sea, and minor groups recruited from spawning of local populations in the fjords.

SUMMARY

A total of about 4 500 hemoglobins and sera of sprat have been analyzed by gel electrophoresis. The material comprises 51 samples collected at different localities at the Norwegian coast from the Trondheim fjord to the Oslo fjord, from the North Sea and from the Kattegat. Part of the material have also been analyzed for serum esterase.

Agar gel electrophoresis at pH 7.2 was applied for analyses of hemoglobins, and combined starch and agar gel electrophoresis at pH 9.0 for analyses of serum proteins and esterase. The gels were supported on microscopic slides. A voltage of 65 volts between ends of gel was applied, and the duration of each run was 60, 90, and 75 minutes respectively for hemoglobins, serum proteins and esterase.

The hemoglobins were separated into several weak and strong components. Six main patterns or phenotypes of strong components could be distinguished.

Intraspecific variations were also found in the serum proteins. Most of the variations appeared as presence or absence of weak bands too diffuse to form the basis of proper classification of the specimens. However, among the serum transferrins (identified by Fe^{59} autoradiography) a total of ten different phenotypes were found. In most samples, individual specimens could be classified into only three main types, named Tf AA, Tf AB, and Tf BB.

In serum esterase very complicated intraspecific variations were found, but it appeared difficult to classify the specimens into well defined groups. A classification according to presence of one or both of the two slowest moving components was tried, but as the classification did not appear much reliable, utilization of esterase phenotypes in segregation studies seems doubtful at present.

The hemoglobin types did not demonstrate any relation to length or age. A hypothesis of genetical control involving two allelomorphic genes is suggested, and the observed distributions of phenotypes coincide fairly well with expected distribution according to this theory.

The three main transferrin types seemed to be controlled by two allelomorphic genes, but all the ten types recorded could not be explained by this theory, which accordingly may be a simplified explanation of the total transferrin variation.

Frequencies of the most common hemoglobin type (named type Hb I-1) in per cent of total numbers of specimens in each sample, and frequencies of the gene $\underline{Tf^A}$ supposed to control one of the components in the three main transferrin types, have been selected as characteristic sample parameters.

Significant variations in characteristic sample parameters and in distributions of hemoglobin and transferrin types were found among the samples from the Norwegian coast, but no marked geographical trend could be discovered. The samples from the Kattegat and from the North Sea were characterized by high percentage of the Hb I-1 type and intermediate values of $\underline{Tf^A}$. This coincides with the values obtained from some of the samples from the Norwegian coast. Thus it is implied that among the sprat in Norwegian coastal waters there excist two or probably more populations of different genetic composition, and with a high degree of reproductive isolation. This may be maintained by

spawning of local populations in the fjords beside recruitment from sprat populations in the Kattegat and perhaps the North Sea.

REFERENCES

Frydenberg, O., Møller, D., Nævdal, G., and Sick, K. 1965. Haemoglobin polymorphism in Norwegian cod populations. Hereditas 53:257-271.

Giblett, E.R., Hickman, C.G., and Smithies, O. 1959. Serum transferrins. Nature, Lond. 183:1589-1590.

Grunder, A.A., Sartore, G., and Stormont, C. 1965. Genetic variation in red cell esterase of rabbits. Genetics 52:1345-1353.

Møller, D. 1966. Serum transferrins in cod. FiskDir. Skr. Ser. Hav-Unders. 14:51-61.

Nævdal, G. 1966. Haemoglobins in sprat from Norwegian waters, studied by agar-gel electrophoresis. Coun. Meet. Int. Coun. Explor. Sea 1966 (J : 7): 1-7 (Mimeo.).

Odense, P.H., Allen, T.M., and Leung, T.G. 1966. Multiple forms of lactate dehydrogenase and aspartate aminotransferrase in herring (*Clupea harengus harengus* L.). Can. J. Biochem. 51: 291-296.

Sick, K. 1961. Haemoglobin polymorphism in fishes. Nature, Lond. 192:894-896.

— 1965a. Haemoglobin polymorphism of cod in the Baltic and the Danish Belt Sea. Hereditas 54:19-48.

— 1965b. Haemoglobin polymorphism of cod in the North Sea and the North Atlantic Ocean. Hereditas 54:49-73.

Sprague, L.M. 1967. Multiple molecular forms of serum esterase in three tuna species from the Pacific Ocean. Hereditas 57: 198-204.

Wilkins, N.P. and Iles, T.D. 1966. Haemoglobin polymorphism and its ontogeny in herring (*Clupea harengus*) and sprat (*Sprattus sprattus*). Comp. Biochem. Physiol. 17:1141-1158.

Table I. Observed distribution of transferrin types in sprat compared to expected distribution according to the Hardy-Weinberg law.

Sample no., locality and date of sampling		Main transferrin types			Sum	q_A
		TfAA	TfAB	TfBB		
4 Førdespollen, Hordaland 1.IV.66	obs	15	64	60	139	0,34
	exp	16,1	62,4	60,5	139,0	
5 Håvik i Fusa, Hordaland 6.VI.66	obs	12	45	25	82	0,42
	exp	14,5	40,0	27,6	82,1	
6 Frafjord, Rogaland 13.VI.66	obs	11	48	36	95	0,37
	exp	13,0	44,3	37,7	95,0	
9 Simlenes, Sogn 21.VI.66	obs	14	60	61	136	0,33
	exp	14,7	59,7	60,6	135,0	

Table II. Observed distribution of esterase phenotypes in sprat compared to expected distribution according to the Hardy-Weinberg law.

Sample no., lacality and date of sampling		Esterase phenotypes			Sum	q_1	Age
		EsS_1S_1	EsS_1S_2	EsS_2S_2			
27 Kattøya, Langesund-fjorden 3.X.66	obs	15	35	33	83	0,39	1-gr.
	exp	12,6	39,5	30,9			
14 Nå, Hardangerfjorden 14.X.66	obs	19	38	30	87	0,44	1-gr.
	exp	16,8	42,9	27,3			
29 Risnes, Masfjorden 4.VI.67	obs	10	44	30	84	0,38	1-gr.
	exp	12,1	39,6	32,3			
30 Skorpo, Hardangerfjorden 6.VI.67	obs	29	31	8	68	0,65	1-gr.
	exp	28,7	30,9	8,3			
31 Gjermundshamn, Hard-angerfjorden 6.VI.67	obs	22	21	6	49	0,66	1-gr.
	exp	21,3	22,0	5,7			

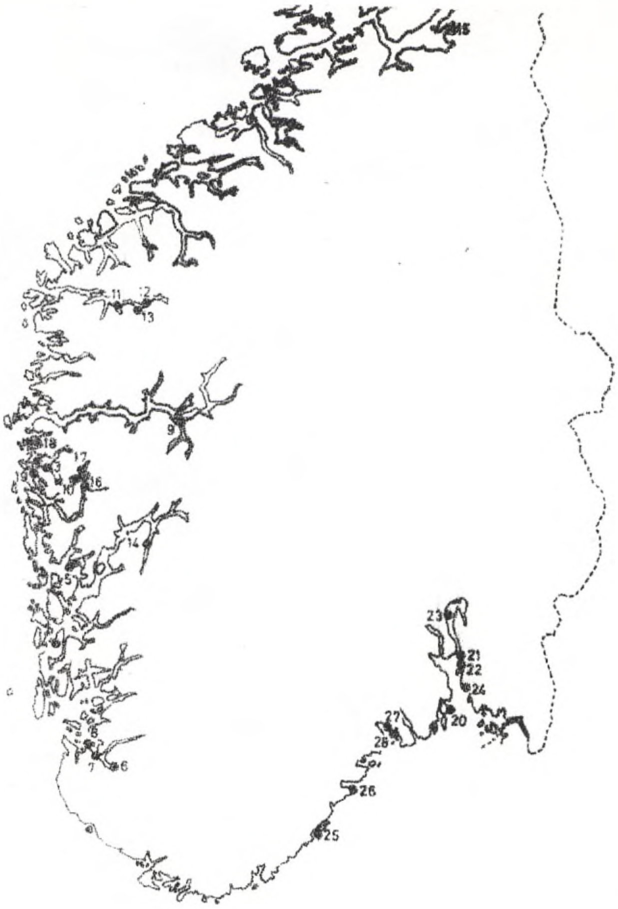

Fig. 1.

Sampling localities of blood samples of sprat in 1965 and 1966.

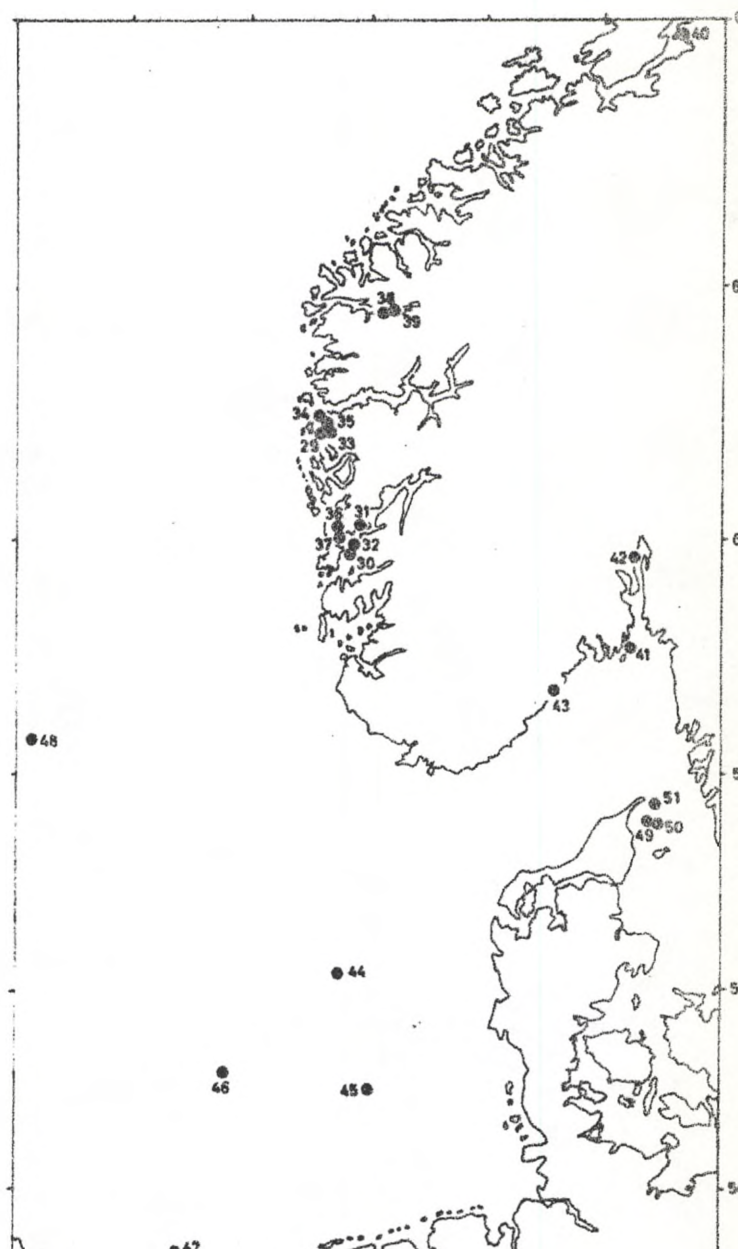

Fig. 2.

Sampling localities of blood samples of sprat in 1967.

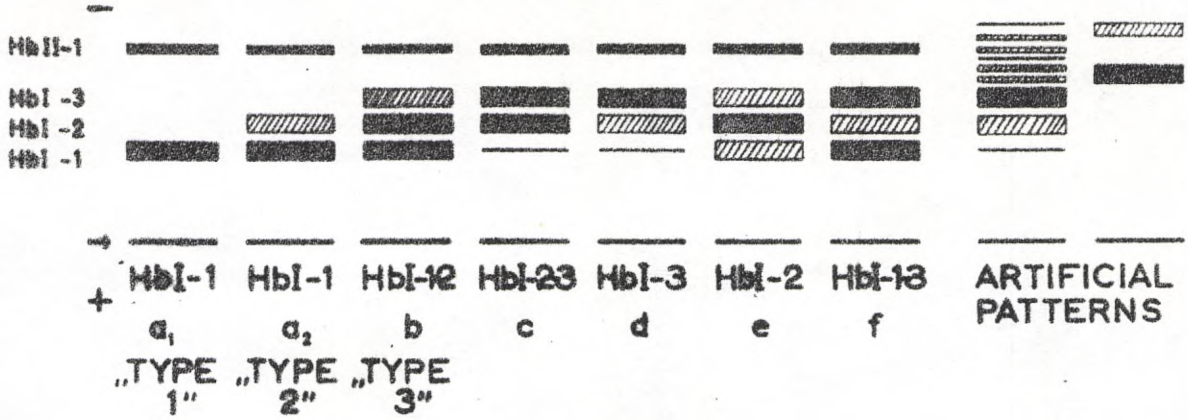

Fig. 3.

Outline of hemoglobin patterns in sprat obtained by agar gel electrophoresis at pH 7.2. The two patterns at right were produced. by heating the blood. Legend: Filled in bars: Strong bands, Hatched bars: Moderately strong bands, Single lines: Faint bands. Arrow indicates the application point.

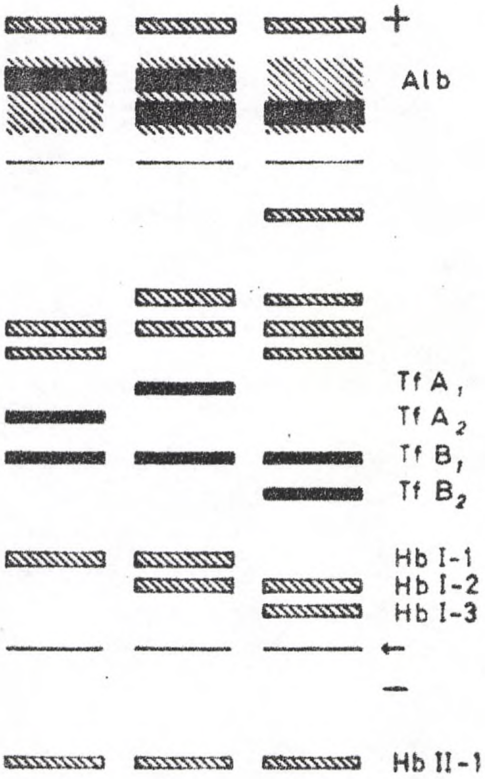

Fig. 4.

Outline of sprat serum protein patterns obtained by combined starch and agar gel electrophoresis at pH 9.0. Legend: Fig. 3.

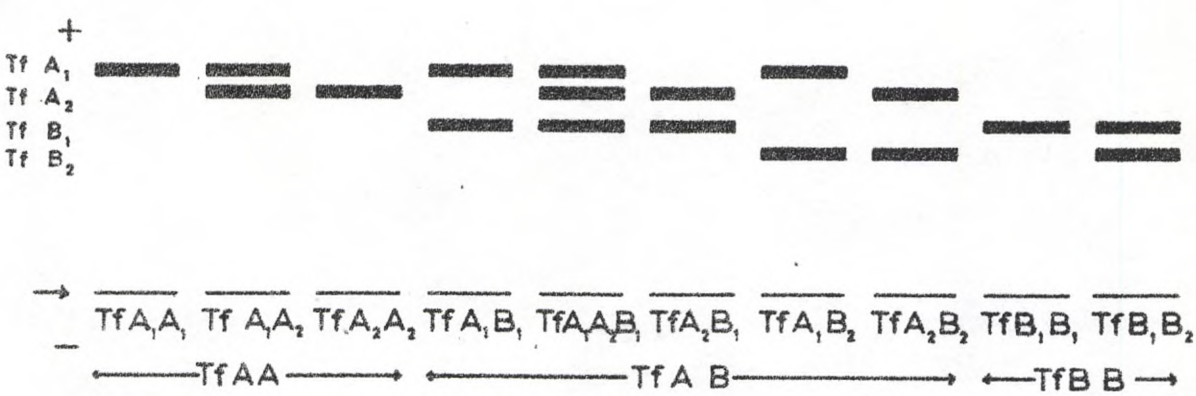

Fig. 5.

Outline of serum transferrin patterns in sprat obtained by combined starch and agar gel electrophoresis. Legend: Fig. 3.

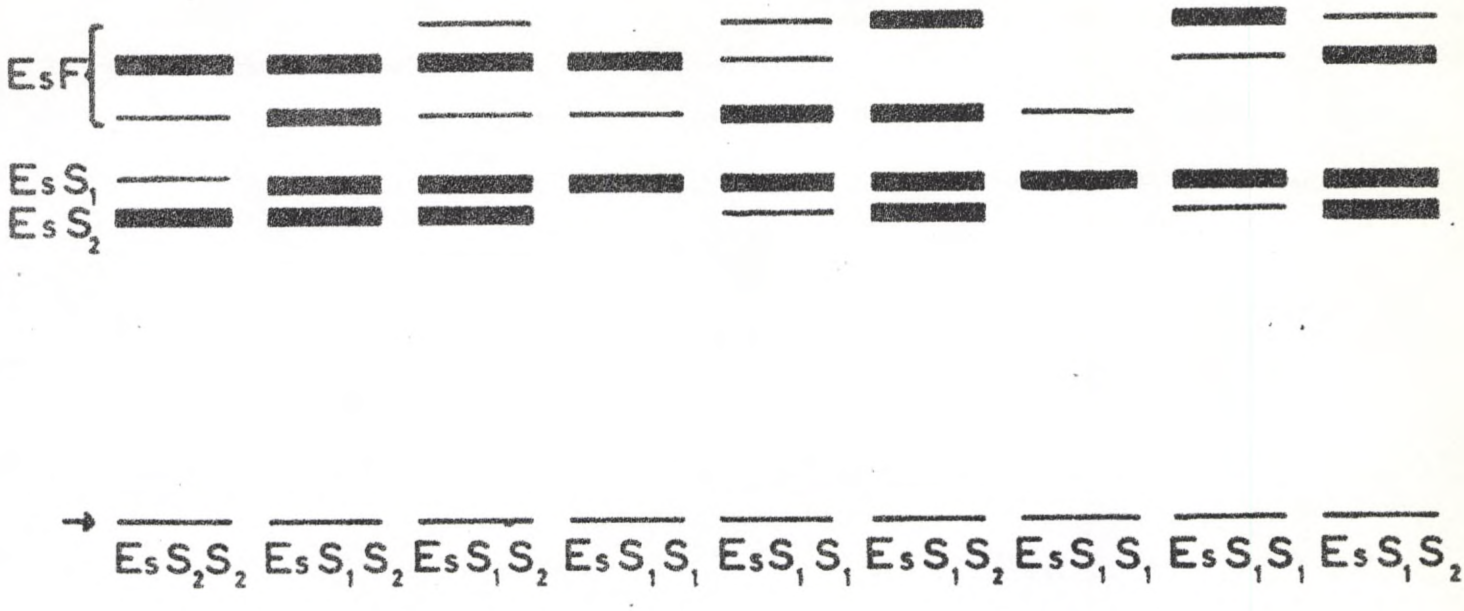

Fig. 6.

Outline of serum esterase patterns in sprat obtained by combined starch and agar gel electrophoresis. Legend: Fig. 3

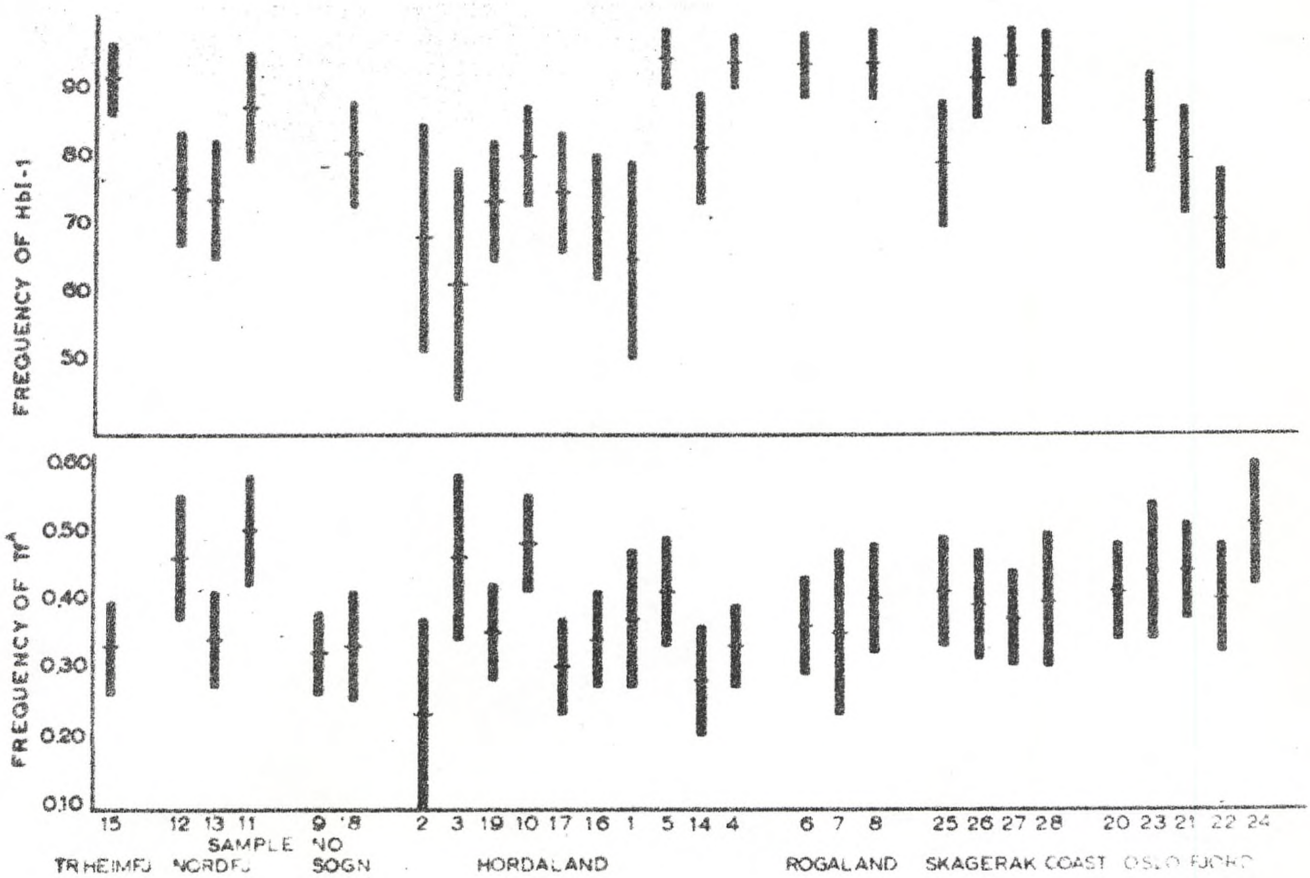

Fig. 7.

Confidence intervals for the universal frequencies of Hb I-1 and for the gene $\underline{Tf^A}$ supposed to control the transferrins in the Tf A - group in sprat samples collected in 1965 and 1966. Horizontal lines mark the observed frequencies, and the vertical bars show the 95 per cent coufidence limits. The samples are arranged in geographical order.

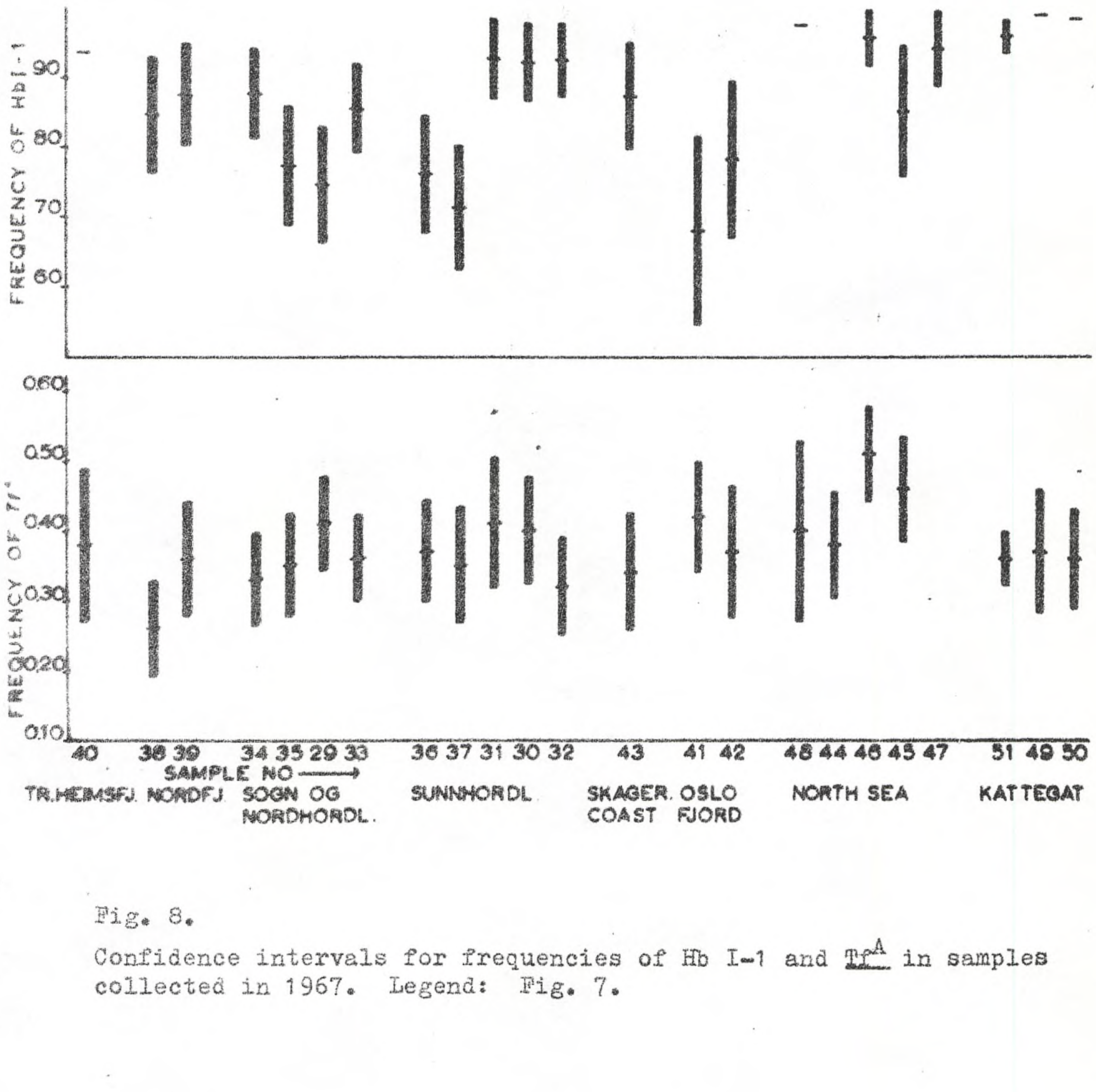

Fig. 8.

Confidence intervals for frequencies of Hb I-1 and $\underline{Tf^A}$ in samples collected in 1967. Legend: Fig. 7.

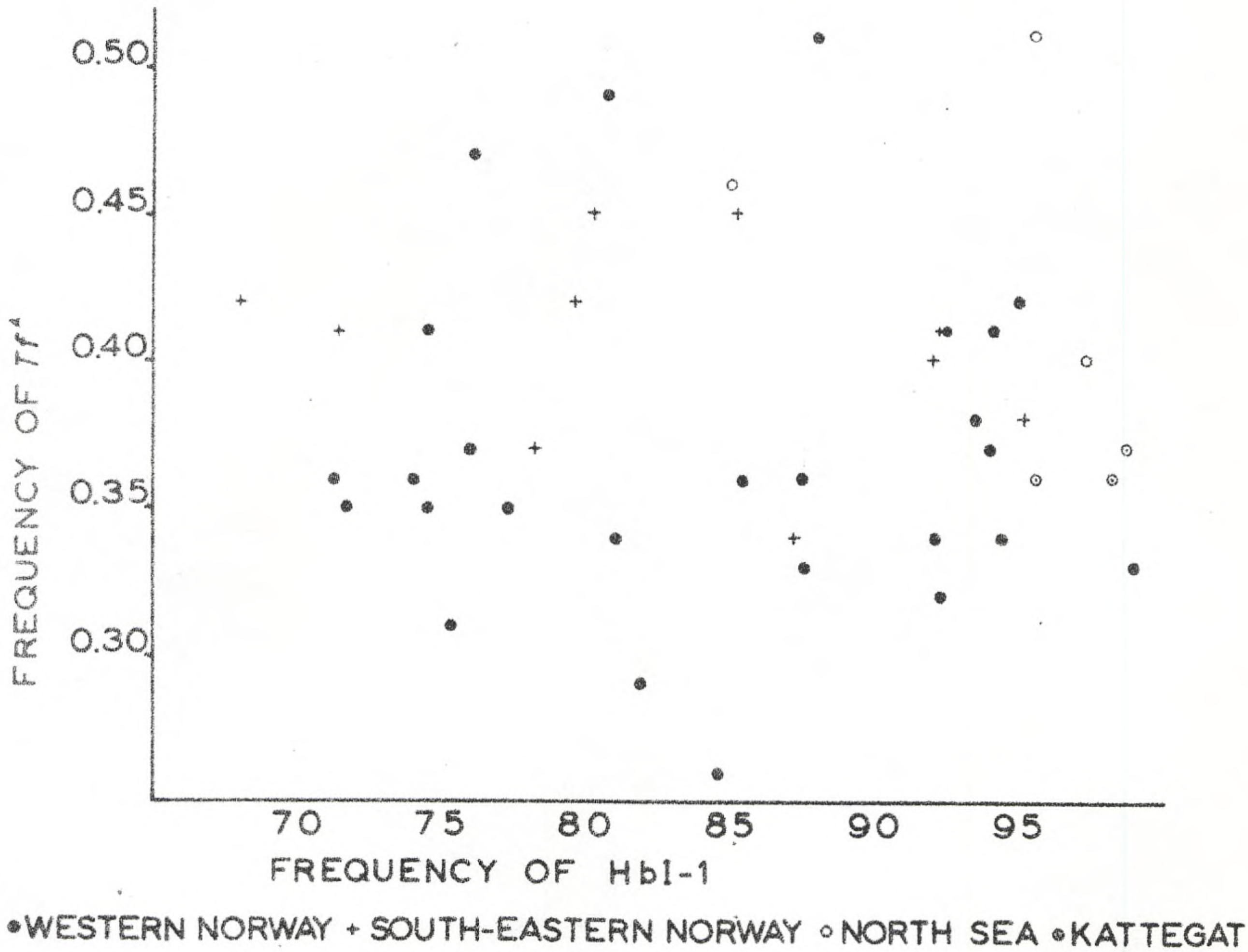

Fig. 9.

Relation between frequencies of the hemoglobin type Hb I-1 and the transferrin gene $\underline{Tf^A}$ in sprat samples. Samples of less than 50 specimens are omitted in this diagram.

SOME REMARKS ON THE WINTERING OF SPRAT IN THE BALTIC

by

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The sprat (Sprattus sprattus L.) is spreaded approximately over the whole Baltic Sea, from the Belt Sea up to the Bothnian Sea. It appears in the range of various salinities and temperatures. At first view it seems that this pelagig fish is only fewly influenced by salinity and temperature.

The sprat is important for the Baltic-fishery for a long time. Up to the end of the fifties mainly the shoals near the coast were fished. The sprat-fishery in the open Baltic Sea began with the development of the pelagic trawls. Now the stocks of the open sea yield a great part of the total sprat catches.

Whereas up to 1966 mainly the prespawning and spawning shoals of sprat were fished from April to June now the winter - sprat - fishery strongly increased. In the Bay of Gdansk a sprat - winter - fishery is known for a longer time. But this fishery beeing a fishery with bottom - trawls the catches have always been relatively small. We have a combined sprat - herring - fishery in the Belt Sea from October to December also with small yields of sprat catches. From about December/January in the basins of the Northern Baltic sprat concentrations are available allowing a profitable pelagic fishery. Already in 1960 ELWERTOWSKI indicated the possibility of such winter concentrations in the deep Baltic basins.

I want to report about my own observations on such winter concentrations and to make my opinion of the causes resulting in these concentrations to the matter for discussion. Already MORAVA and GRAUMAN showed the dependence from the temperature for the formation of spawning concentration and the spawning. ELWERTOWSKI observated the influence of temperature on the wintering of sprat in 1956 and 1963.

In January 1967 our fishery began a true winter fishery on sprat in the area north of Gotland. In that time the sprat shoals were available in the pelagial as "ribbons" 10 to 20 m high. For the whole days they lived in the same depth and moved only insignificantly in vertical direction.

The spreading of the shoals to the surface was limited by the thermocline. In the average the difference of temperature amounted to 1 °C mostly from 4 °C to 3 °C. The sprat shoals predominantly lived in the layer of 4,0 °C. Never they could be observed at a lower temperature than 3.5 °C. On the other hand in the same area herring shoals (Strömling) were moving during the night through the thermocline into the cold surface water. At night-

fall and also at daybreak the sprat shoals approached to the thermocline, too.
A great part of the sprats nearly continuously feeded. In 7 samplings in average 66 % of fishes were feeding. In two samplings deviating from this observation in average only 2.5 % of fishes have feeded. During the day the feeding increased something, the food mainly being copepods.
The determination of maturity is carried out with a scale of eight intervals. 90 % of the sprats are in the stages of maturity I to III. The fishes of stage III reached 51 %.
In the whole area the sprat concentration never lived deeper than 100 to 110 metres in the maximum. Analyses of oxygen content are not available for January 1967. But it is known that a lack of oxygen frequently happens in deeper layers of the Baltic basins. In the pelagic sprat fishery in deep waters frequently flounders (Platychthis flesus) were caught in January 1967. Only the lack of oxygen in deep water layers could have forced so many flounders to this abnormal way of living.
In the same way probably the sprat was prevented to spread into deeper water layers.
In December 1967 we have analysed the oxygen content in the same area and we found that occasionally already at a depth of 80 m a lack of oxygen happened. Between 80 m and 100 m the oxygen content already everywhere decreased so strongly that the occurence of fish is very doubtful.
With these observations the two environmental factors temperature and oxygen content in deep water layers seem to have aninfluence on the formation of winter concentrations of sprat in the Northern Baltic.
This conclusion is intresting, for- the sprat being spreaded so wide in the Baltic- the influence of temperature on it hardly seems possible.

In my opinion the stay in the relatively warm water of the Northern Baltic is connected with the preparation on the spawning time. I said already that MORAWA and GRAUMAN pointed out the dependence of the sprat spawning from the temperature. In my opinion, in the Northern Baltic the temperature also has a decisive influence on the gradual preparation to the spawning during the winter.
In the shallow areas of the Belt Sea the sprat is scattering with the cooling of water in January. In Northern Baltic at the same time he is forming dense concentrations in relatively warm layers of water. These concentrations are feeding nearly coninuously.
The peak of spawning is reached in May and June in the Belt Sea as well as in the Northern Baltic. Whereas in the shallow Belt Sea the warming of water and the enlargement of food supply is arising already in March/April mainly the thermically circumstances in the Northern Baltic are changing

not until June/July. In the Belt Sea the sprat may be feeding intensively before and during the spawning time from March/April and in May. The sprat is spawning.in portions and is feeding during its spawning time relative intensively.

Therefore I assume that the formation of winter concentrations of sprat in the Gotland Sea is an adaption to its environmental circumstances. The shoals are concentrated in those water layers where there is food at this time, and here is a temperature enableing them to utilize this food. Therefore I have called these concentrations wintering shoals but not pre-spawning shoals.

In this connection it seems interesting to tell that in August/September 1967 we observed fish concentrations in the Northern Baltic nearly exclusively in the thermocline in the range between $6^{o}C$ and $13^{o}C$. In the same area the sprat predominantely lived in December 1967 above the thermocline in the range between $5^{o}C$ and $8^{o}C$.

SOME OBSERVATIONS ON THE STOCK OF BALTIC SPRAT (South east Baltic) IN THE FIRST HALF OF THE YEAR 1967

by

OLGIERD WRZESINSKI and BARBARA KARNICKA , Morski Instytut Rybacki, Gdynia

Introduction

The investigations on the stock of sprat from Gdansk Basin and Gotland Basin were based on the materials collected from commercial and experimental catches, carreid out in the first half of the year 1967. The research included mass measurements, the determination of the stage of development of gonads, the sex and the degree of filling of stomachs. The age was read from otoliths.

1. Length composition.

The sprats for investigations were captured by means of pelagic pair-trawls and bottom trawls. The length of fish caught in Gdansk Basin ranged from 7 to 15 cm., whereas most abundant lengths were 12 and 13 cm., particulary from the fishing grounds of the open sea. In the coastal fishing grounds of Gdansk Basin and the region adjacent to Vistula mouth the participation of juvenile fish of the lengths 7, 8 and 9 cm. was considerably higher than in the open sea and sometimes exceeded 50% of the total mass of landings. Such length composition is most probably the result of favourable feeding conditions prevailing in coastal waters, particularly in those internal waters of Gdansk Bay which are sheltered against the activity of waves (Puck Bay). In Gotland Basin there were captured less fish of the length 7, 8 and 9 cm., whereas more of the fish of the lengths 13, 14 and 15 cm. The largest specimen caught here was 15.4 cm. long. The fish of the length above 15 cm. were very seldom found in the catches in both these regions. The mean length of fish from Gdansk Basin was 11.57 cm., with mean weight of 10.47 g. These values for the fish from Gotland Basin were higher, being respectively 12.30cm and 12.56 g.

2. Age composition.

In both of the above regions the main mass of catches was composed of fish of the populations of mean abundance,born in 1963 and 1964. The participation of the year-class 1965 in the catches was insignificant.

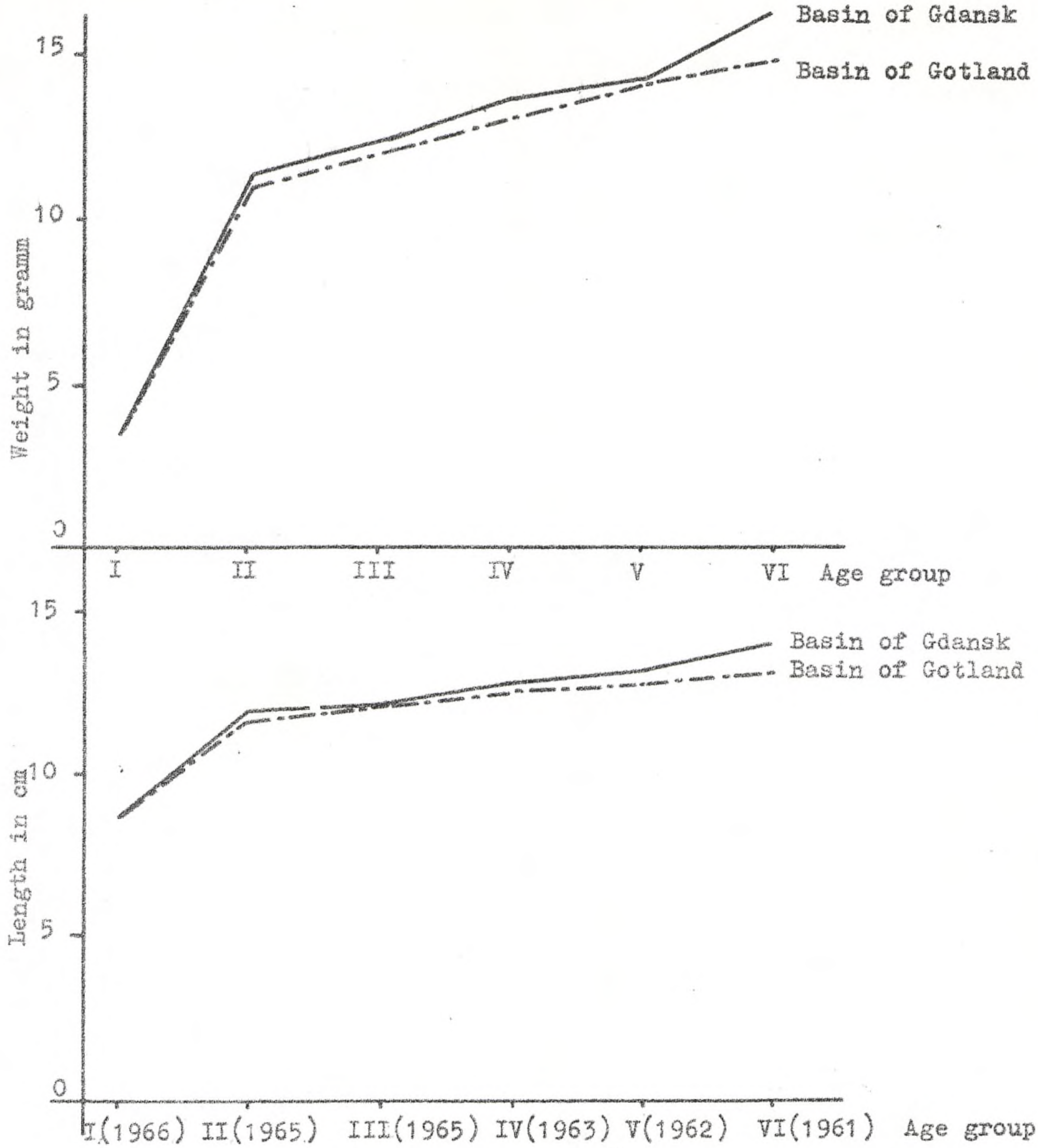

Fig. 1. The rate of growth of sprat (Gotland Basin and Gdansk Basin compared).

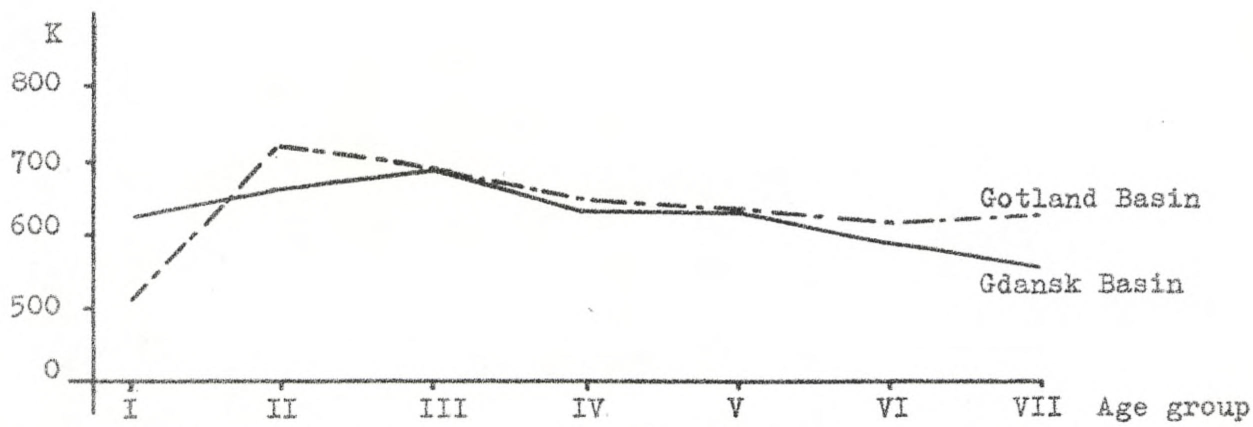

Fig. 2. The length-weight coefficient of sprat (Gotland Basin and Gdansk Basin compared).

(OLGIERD WRZESINSKI and BARBARA KARNICKA: Some observations on the stock of Baltic Sprat)

Table 1

Age composition of the catches from Gdansk Basin and Gotland Basin - in % according to age - length key

Month	I(1966)	II(1965)	III(1964)	IV(1963)	V(1962)	VI(1961) and older
			Basin of Gdansk			
I - III	331	92	299	178	81	15
III- V	267	23	337	187	80	92
			Basin of Gotland			
I - III	45	41	345	278	165	123
III- IV	48	28	306	200	248	180

It appears from this Table that in 1966 was born strong population in Gdansk Bay. The fish of this age group were particularly abundant in the catches carried out in coastal fishing grounds, in which they sometimes amounted to 27% of the total mass of landings whereas in Gotland fishing grounds there were represented older fish in the catches, those born in the years 1960 to 1964.

3. The rate of growth.

As it may be seen from the Figure 1 it is possible to observe some common feature in the growth of fish in both the regions, though stronger and quicker increase of weight and length is noted in fish from Gdansk Basin, particularly in young specimens in their I and II year of life. Each section of the curve for sprat from Gdansk Basin, pointing to the fast rate of growth of this species in its VIth year of life, has been plotted on the basis of a small number of observations and therefore is not representative for the true rate of growth of this age group. In general, we see, as it has been already observed by MORAVA (8), that the growth of sprat from Eastern and North - eastern Baltic is slower than the growth of sprat from the Southern and Western parts of this sea. Similar relation has been observed by MOLANDER (6) in sprat from the region of western and eastern coasts of Sweden. In juvenile fish, belonging to the age group I, the weight increase in its first year of life amounted to 7 g. and length increase to ab.t. 3 - 3.5 cm. (expressed in mean values). On reaching the length of 12 cm. and the weight of an individual within the limits from 11.5 to 12.0 g. the rate of growth decreases untill it is completely retarded when the fish reach their total length of 15 cm. and the

age of 6 or more years.
The observations on the rate of growth included also the relation between length and weight (according to FULTON's formula) for particular age groups of fish from both of the above regions (Figure 2). It has been found that the length - age coefficient (K) is slightly higher for fish from Gotland Basin, for which the value is generally 0.672. For fish captured in Gdansk Basin the value of this coefficient is 0.655. The maxium value of the coefficient K is reached in sprat in both regions in its second and third year of life.

4. Development of gonads and the sex.

In the catches carried out in both of the above regions the number of females predominated over the number of males; average relation being 55% of females and 45% of males. In the fishing grounds of the open sea the number of females reached even 65%. In this respect our observations are in accordance with the observations carried out by HESSLE (4) on the sprat caught at the coasts of Sweden. It has also been established that the relation between the number of both sexes depends on age composition. The more of adult individuals, i.e. the older age groups, are in the stock the less is the number of males in it. In the stock composed of young fish the number of males is as a rule higher. HESSLE (4) assumes the life cycle of males to be shorter than the life cycle of females. We may consider this assumption to be applicable also to the sprat from South-east Baltic.

The development of gonads in fish in both regions took more or less similar course, though in Gdansk Basin in the first quarter of the year 1967 most of the catches were composed of fish with gonads in I and II stage of maturity (according to MAIER's scale). However, on comparison of individuals of the same age it was found that the development of gonads of gonads of sprat from Gotland fishing grounds was slightly retarded in relation to the gonads of sprat from Gdansk Basin. Hence probably arises some retardation of the beginning of spawning of the sprat from Gotland Basin. It was not possible to determine an accurate time of the beginning of spawning both in the region of Gotland and in the region of Gdansk, since in both these regions the first females with running gonads were simultaneously noted in the month of February. No males with running gonads were found there at the same time.

5. Feeding intensity.

During our observations we noted that the sprat in the open sea feeds with less intensity than in the coastal regions. The filled stomachs of fish in the Gotland Basin were smaller in consecutive months of the first half of the year 1967 than they were in fish in Gdansk Basin. Moreover, the percentage of fish with emty stomacs (0 - according 5-degree scale) was in that region higher than in Gdansk Basin. The results of investigations on the filling of stomachs are given in the Table II.

Table II

Mean values for filling of stomachs (in %) in sprat (♀ ♂) in the first quarter of 1967

Region	The degree of filling of stomachs				
	0	1	2	3	4
Gdansk Basin	40.3	9.1	12.2	20.6	17.1
Gotland Basin	58.7	15.1	9.2	11.4	5.3

No intensive feeding was noted in sprat during its spring migrations in both of the above regions. This seems to be closely connected with sexual maturation of this fish, since developing gonads increase their weight and size, thus impeding the takning of food (MORAVA (8), MAŃKOWSKI (5)). During the investigations it has been several times found that the stomachs of sprat were tightly filled in spit of their gonads being partly spent or running (VII and VI stage of maturity according to MAIER's scale). It seems that the sprat sometimes feeds during spawning in order to regenerate the gonads before each next shedding of sex products.

6. Migrations of sprat in South-east Baltic.

The sprat caught in the fishing grounds of Gotland is, as it seems, a separate stock, doing its annual cyclic migrations. An attempt was made to detect the direction of these migrations. On the basis of our own observations and the fishing results of cutters operating in this region it may be concluded that those sprat shoals shift southwards from their wintering grounds, probably situated off the entrance to the Gulf of Finland and the Gulf of Bothnia. These migrations become particularly intensive during the months March-April when the shoals move rapidly towards their spawning grounds, situated at the south edge of Gotland Deep. The migration of shoals towards the south is finally stopped in May when the concentrations reach their highest density and when the maximum intensity of spawning approaches.

According to the course of these migrations and the concentration of sprat shoals we find that the most advantageous conditions for Polish cutter fisheries in this region prevail in the period of April - May.

The stock from Gdansk Basin does not undertake so distant migrations (ELWERTOWSKI (3), DEMEL (1)). It usually shifts before the approach of spawning from its wintering grounds, most often situated in the bottom layers of Gdansk Deep, towards spawning grounds in the open part of Gdansk Bay and towards the Furrow of Słupsk. These migrations are of short duration and they stop as soon as the spawning starts. Besides more or less intensive horizontal migrations the shoals of sprat also make regular, characteristic, vertical daily migrations. From echo - sounder records it appears that in the afternoon the sprat migrates upwards into higher water layers, making at first small, dense shoals, which gradually disperse. This dispersion lasts until early morning hours when again the sprat gathers into small shoals and shifts downwards into bottom layers. In the late morning hours the sprat is gathered into dense concentrations at the bottom or slightly above it, which remain in this state until small afternoon hours. According to ELWERTOWSKI (2) these migrations are caused by changing daily intensity of sun irradiation, not by thermic conditions.

7. Some technological data for sprat in Southern Baltic.

The Table II contains some data characterizing the sprat caught in Gdansk Bay and in the fishing grounds of the open sea, situated to the east of the Furrow of Słupsk. In the annual cycle of fat metabolism there are to be distinguished two phases according to MACIEJCZYK and ELWERTOWSIK (6):

1. the phase of reduction, commencing in winter and lasting until the middle of summer,
2. the phase of accumulation, covering the period from summer to winter.

Table III

Date of catch	Fat contents in %	Mean weight 12 cm.	13cm.	14cm.	State of gonads	Filling of stomachs
		B a y o f	G d a n s k			
13.I.67	17.3	12.2	13.6	18.7	III-IV	1
16.I.67	18.8	11.2	12.5	18.0	II-III-IV	2
12.III.67	13.6	11.8	12.5	15.0	III-IV-V	2
21.III.67	14.1	11.9	13.9	20.0	I - IV	3
21.IV.67	10.5	10.9	14.1	18.0	IV-V-VI	2
27.IV.67	8.9	10.8	12.7	15.4	III - V	1
28.IV.67	8.6	11.2	11.7	-	IV-V-VI	2
2.V.67.	8.4	12.3	14.2	17.1	IV-V-VI	3
8.V.67	8.4	11.4	13.3	-	IV-V-VI	1
30.V.67	6.1	11.2	13.6	16.0	IV-VI-VIII	1
		East from Furrow of Słupsk				
20.I.67	15.6	11.3	13.5	15.0	II-III-IV	
9.II.67	15.3	11.3	11.9	13.3	III-IV	
16.II.67	16.4	12.0	13.9	16.8	III-IV-V	
24.II.67	15.5	12.1	14.3	20.0	III - IV	

Date of catch	Fat contents in %	Mean weight 12 cm	13 cm	14 cm	State of gonads	Filling of stomachs
		East from Furrow of Słupsk				
26.II.67	15.9	12.2	13.7	20.0	III-IV-V	
7.III.67	14.2	11.6	13.2	15.0	III-IV-V	
18.III.67	12.0	11.1	13.3	14.4	III-IV-V	
21.III.67	12.6	12.1	14.0	16.7	III-IV-V	
3.IV.67	12.2	11.2	13.1	14.5	V - VI	
5.IV.67	13.5	11.9	13.9	16.1	IV - VI	
12.IV.67	10.6	10.8	12.8	14.0	V - VI	

Our observations therefore deal with the phase of fat reduction, which is accompanied by steady development of maturity of gonads. The lowest fat contents in sprat is noted in the months of fullsspawning intensity when this species sheds the portions of sex products and starts intensive feeding.

The qualitative analysis of fat contents in sprat of total length above 10 cm. has been made by the BULL's method; the degree of gonads maturity determined according to MAIER's scale and the filling of stomachs according to the following 5-degree scale:

0 - empty stomachs
1 - 25% filling
2 - 50% "
3 - 75% "
4 - full stomachs

In view of the lack of synchronized data no comparison has been made of the results of analyses of fat contents in sprat from the fishing grounds of Gotland and Gdansk, caught in the same period.

References:

1. DEMEL, K., 1938: Ruchy ławic szprota u naszych bregów w świetle czynników hydrograficznych. - Arch. Hydrob. i Ryb. 11: 229-253
Pl (Les migrations du sprat dans les eaux côtières polonaises et les conditions hydrographiques locales)

2. ELWERTOWSKI, JAN, 1960: Biologishe Grundlagen der Sprottenfischerei in der östlichen und mittleren Ostsee. - Fischereiforshung-Informationen für die Praxis 3 (4): 1-19

3. - " - 1957: Biologiczna charakteryskyka polskich połowow szprota w Bałtyku poludniowym w latach 1950-1954. - Prace MIR Gdynia 9: 175-219.
Pl (Biological characteristics of Polish sprat catches in southern Baltic in 1950-1954

4. HESSLE, CHR., 1927: Sprat and sprat-fishery on the Baltic coast of Sweden. - Medd: K. Lantbruksstyrelsen Nr. 262, 29 pp, Stockholm

5.MAŃKOWSKI, W., 1947: Odyywianie sie pokarm szprote (Clupea sprattus L.) Bałtyku Środkowego. - Arch. Hydrob. i Ryb. 13: 37-90 Pl (Feeding and food of the sprat in the middle Baltic)

6.ELWERTOWSKI, JAN,& JERZY MACIEJCZYK, 1959: Wahania Zawartości tłuszczu w szprocie zatoki Gdanskiej w zależności od waruków hydrograficznych i biologicznych. - Prace MIR Gdynia 10/A: 375-382. Pl (Changes of the fat content in the sprat of the Gdansk Bay in relation to the hydrologic and biologic factors)

7.MOLANDER, ARVID, R., 1952: The sprat fishery and the sprat of the west coast of Sweden. - Inst. Mar. Res. Lysekil, Ser. Biol., Rep. No. 2, 67 pp.

8.MORAWA, F.W. FRITHJOF, 1955: Wachstum, Wachtumsbedingungen und Aufwuchsplätze des Sprottes (Clupea sprattus L.) in der Ostsee. - Z.f. Fischerei 4(1/2): 101-136

THE DISTRIBUTION AND MIGRATIONS OF SPRAT (Sprattus sprattus L.) WITHIN THE ADRIATIC SEA

by

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FAGE (1920) and FURNESTIN (1948, 1952) produced comprehensive reports on the ecology and distribution of the Sprat in the Mediterranean Sea. It was stated that the sprat occurs almost exclusively in the northern coastal regions of the Mediterranean basin (Gulf of Lion, Northern Adriatic) and Black Sea, where there is lower salinity due to fresh water influx, and lower temperatures in winter caused by strong cold northerly winds. STOJANOV (1953) and Russian authors (ASLANOVA 1954, PAVLOVSKAJA 1954) later showed that the sprat occurs over the greater part of the Black Sea, both in coastal areas and the open sea.

A similar distribution was found for the Adriatic sprat, which is found along the Yugoslav coast as far south as Dubrovnik and offshore within the Bay of Venice (Figure 1.). The salinity within these regions can be very low locally, particularly in the north west part where great rivers such as the Isonzo and Po outflow, and along the eastern coastline where strong underwater springs of fresh water occur. Surface temperatures are also particularly low in winter due to the strong cold north-western wind ("bora").

Homothermal winter conditions are characteristic of the Bay of Venice, this being due to complete mixing of the water layers from surface to bottom over depths of about 35-40 metres. Unfortunately, practically no permanent data are available concerning environmental conditions in other regions where the sprat appears in greater quantities such as Quarner Bay, the North Dalmatian channels and the Novigrad Sea.

Up to a few years ago more was known about the sprat from the Italian Adriatic coast (BONAPARTE 1832-41, FAGE 1920, PAOLUCCI 1908, SOMMANI 1946, and others) in spite of the fact that enormous quantities of this fish appear in Quarner Bay over the winter period. Furthermore, maximum landings of Adriatic Sprat are recorded from this region, these accounting for more than one tenth of the total annual catch of marine fish in Yugoslavia. Investigations into the sprat stocks inhabiting the north-eastern coastal and offshore waters of the Adriatic were thus initiated some years ago.

One result arising from these studies has been evidense for the existence of two sprat populations inhabiting this region (ZAVODNIK & ZAVODNIK, 1967). The first group, living mainly in the western part of the north Adriatic and along the Italian coast, is characterised by having a scutellae count lower than 31.90 and head length of about 20% of the total fish length, whilst the second group, from the Istrian coast and Quarner Bay, have a scutellar count greater than 31.90 and head length only 18% of the total length. Unfortunately samples so far available from other parts of the Adriatic have been too few in number to yield any reliable quantitative estimates of these characters.

For many years the sprat was caught along the eastern Adriatic coasts exclusively in winter times, disappearing from this area at the beginning of spring, this being a clear indication that the north Adriatic sprat is a migratiny species. No evidence concerning the summer distribution of these fish was forthcoming until 1962, when great quantities of sprat shoals were located in the open waters of the Bay of Venice (GAMULIN 1964). This discovery posed questions concerning the migration routes, when and how extensive are these movements. The presence of fish shoals may be detected by several methods, such as catching the fish, presence of the eggs in plankton samples and echo-sounding. Work carried out using echosounding and fishing indicated that the sprat shoals migrate at the end of autumn towards Quarner Bay over two main migration routes (Figure 2.). One section of the population moves towards the western coast of the Istrian peninsula, reaching there in quantity usually by early December, then turning immediately southwards and travelling along the coast reach after some days the southernmost point of the Istrian peninsula (Cape Kamenjak), after which they enter Quarner Bay. Here join other shoals which have migrated directly from summer grounds to the entrance of Quarner Bay. Subsequent migrations of the sprat are not yet known, but it is a fact that during winter this fish can be caught over the entire Quarner region and around the Quarner Islands.

It is interesting to note that the first fish to arrive and enter Quarner Bay are usually the youngest fish of 0 age group, whilst the shoals of older adult fish arrive later.

Whilst migrating southwards the sprat is spawning, and large numbers of its eggs (up to more than 400 eggs per square metre) have been found in plankton samples taken in the vicinity of the west Istrian coast during December. Later on the quantities of eggs diminish considerably but are present in smaller amounts until April. The spawning intensity indicates that a small portion of the sprat population remains in the open and coastal waters of the Bay of Venice while the majority of fish move out of this region and migrate southwards to Quarner region.

During the winter period sprat is often caught together with smaller quantities of mature sardines and it is possible that the spawning areas of sprat and sardine overlap to some extent. There is, however, no planktonic evidence available from the Quarner region during winter and the extent of spawning there at this time is unknown. But the presence of mature sprats with the gonads in V. and VI. stages indicates that the spawning surely takes place in Quarner Bay and maybe also in the Gulf of Rijeka.

In spring the sprat gradually disappears from Quarner region - at first adult fishes and after them the young ones. Up to date, the exact migration routes towards the summer grounds are not known in detail. However, it is supposed that the main lines do not touch the coastal regions (Figure 3). The evidence for this supposition is the absence of sprat eggs in plankton samples taken at coastal stations, while the samples taken offshore may be positive. Furthermore, the sprat is usually not caught in this time by fishermen. It is true that smaller part of sprat population remains in the depths of Quarner Bay and within the Dalmatian Channels during the summer, when small quantities can be caught by bottom trawls. It is supposed that the fish remain in the depths of these regions because of special hydrographic conditions in them, prevalently because of the low summer temperatures in bottom layers.

It is observed that the morfometrical ~~and~~ numerical characteristics of the sprat in the coastal region of Istria and in the Quarner Bay vary insignificantly. Consequently, the long headed population with the scutellar count less than 31.90 does not arrive Yugoslav waters. It can be concluded that it remains during winter in the vicinity of Italian coast. According to the bibliographical data, this sprat does not migrate at the beginning of winter, or it migrates only to a small extent southwards as south as to Rimini (Figure 4.). Therefore this population is considered by us as "stationary" population which ecologically somewhat differs from the Yugoslav "migratory" population.

To our regret, no valuable data exist on the livning manners of sprat from other regions of the Adriatic. However, some quantities of sprat can be observed irregularly in summer time in small Novigrad Sea, where the salinity is lowered due to the influx of river Zrmanja and which is connected with the great depths of the Velebit Channel. Unfortunately, it is not known if the fish observed depends to the autochthone population or the summer occuring is an indication of eventual summer migrations of the sprat.

The migrations of the North Adriatic sprat can be explained by the analysis of ecological conditions in its distribution area. The depths of the northern part of the Adriatic rarely exceed 50 m and they are usually less than 35 m. The bottom currents arriving from the southern regions of the Adriatic, turn at this barrier westwards. On the other hand, the influx of great water quantities of River Po prevents the flowing of cold sea water southwards. The result of this is an accumulation of cold water masses in the open sea within Bay of Venice, where summer grounds of sprat are situated. In summer time the thermocline in the depths of 10-20 metres is very sharp; the sea water temperature can be lowered for more than 5°C in a water layer of only 2m! At this time, the influx of river Po usually lessens considerably, and at the end of autumn the surface layers grow cool. Shortly the homothermal conditions in the entire Bay of Venice establish. Approximately at the same time the sprat appears at the sea surface and begins to migrate. Very soon it expands from summer grounds throughout the entire area. Simultaneously, it begins to spawn. In spring, the sprat returns to summer grounds still in the course of homothermal conditions, before the thermocline is established. The analysis of salinity conditions showed, that the salinity may influence the migrations locally but not to such extent as the temperature conditions.

It is clear that Adriatic sprat is to be treated as a special population which lives in an ecologically most interesting area. To our regret, because of various reasons, this fish species is very bad known in some regions which are geographically almost isolated; it is our duty to solve these problems in the nearest future.

References:

ASLANOVA, N.E., 1954: Sprot Cernogo morja. - Trudy VNIRO 28 : 75-101

BONAPARTE, C.L., 1832-41: Iconografia della Fauna italica III.: Pesci. Roma.

FAGE, L., 1920: Engraulidae, Clupeidae. - Rep. Danish Ocean Exped. 1908/10 to the Mediterranean & adj. seas. No. 6, Vol. 2 (Biology). A.9.

FURNESTIN, J., 1948: Observations sur le sprat (Clupea sprattus L.) des cotes méridionales de France (Atlantique et Méditerranée). - Rev. Trav. Office de Peches Marit. 14 (1-4): 39-69

- " - 1952: Biologie des clupéidés méditerranéens "Vie et Milieu" Bull. lab. Arago, Banyuls, suppl. No. 2: 97-117

GAMULIN, T., 1964: Znacenje sjevernog plitkog Jadrana za bolje poznavanje pelagickih riba. Acta Adriat., 11 (11) : 91-96

PAOLUCCI, C., 1908: Sulla ittiofauna adriatica e particolarmente sulla "Clupea papalina Bp.". Ancona.

PAVLOVSKAYA, P.M., 1954: Razmnozhenie shprota, stavrida i barabuli v Tchernom more. - Trudy VNIRO 28: 126-135
Ru (Spawning of the sprat - and 2 other fishes, stavrid and barabul - in the Black Sea)

SOMMANI, E., 1946: La Clupea papalina Bp. dell'Adriatico (breve studio biometrico). Boll.Pesca Piscicolt. Idrobiol., N.S., 1 (1): 47-53

ZAVODNIK D. & ZAVODNIK N., 1967: Observations on the biometry and numerical characteristics in Sprat (Sprattus sprattus L.) in the Northern Adriatic. Thalassia Jugosl., (1-6) : 183-194

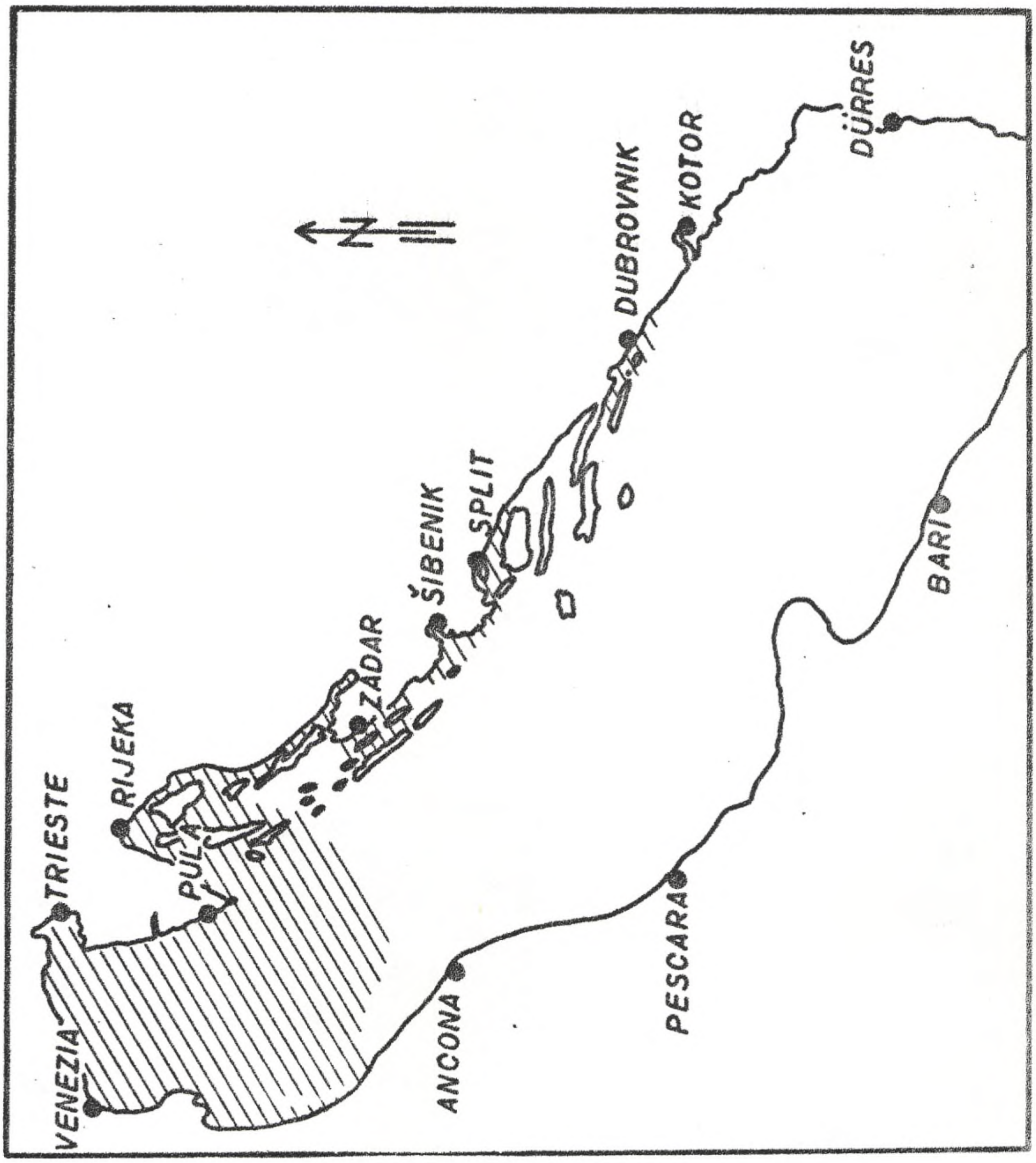

Fig. 1. Distribution of the sprat within the Adriatic Sea.
(D. ZAVODNIK: The Distribution and Migrations of the Sprat...)

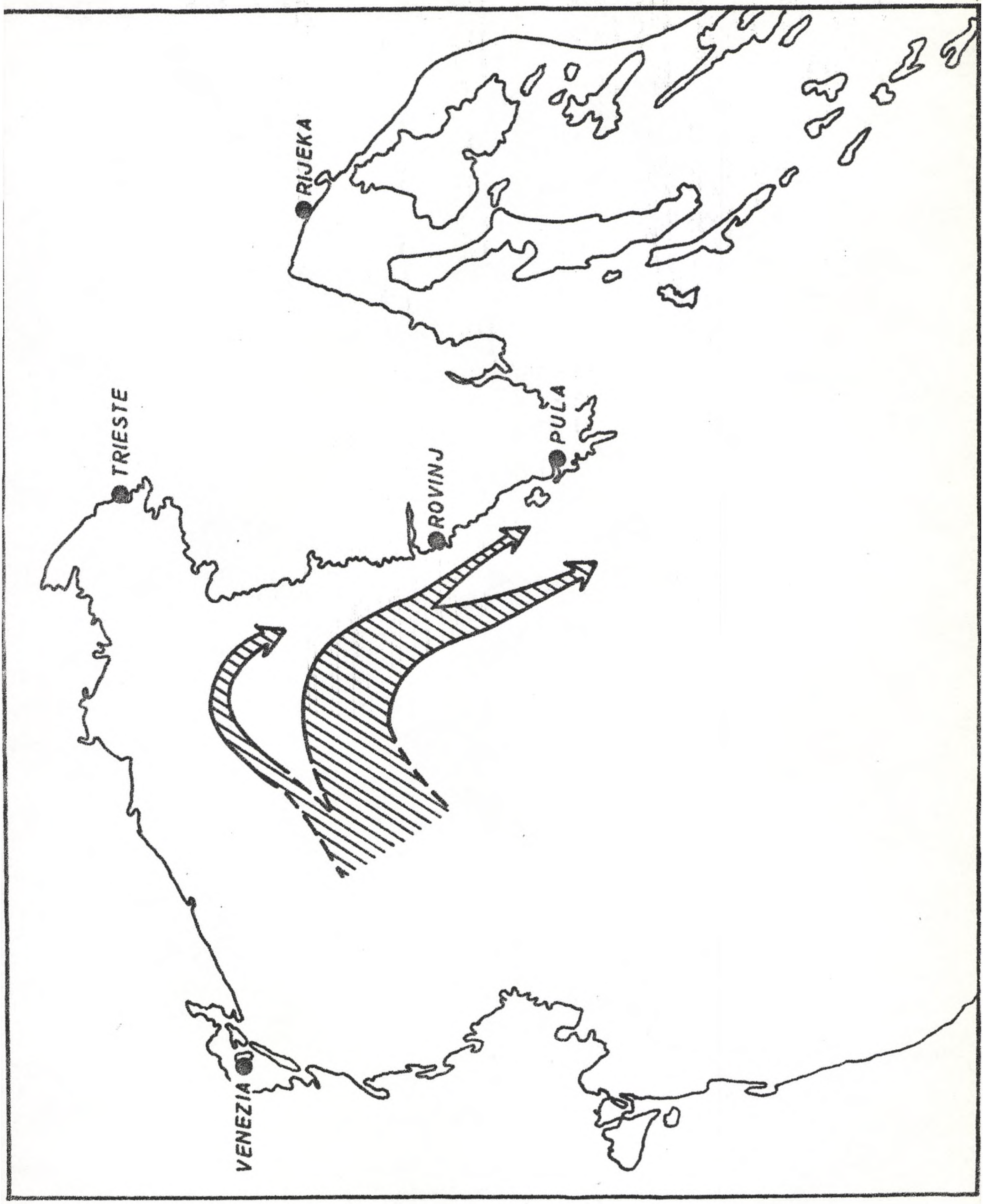

Fig. 2. The main autumnal migration routes of the North Adriatic sprat.
(D. ZAVODNIK: The Distribution and Migrations of the Sprat...)

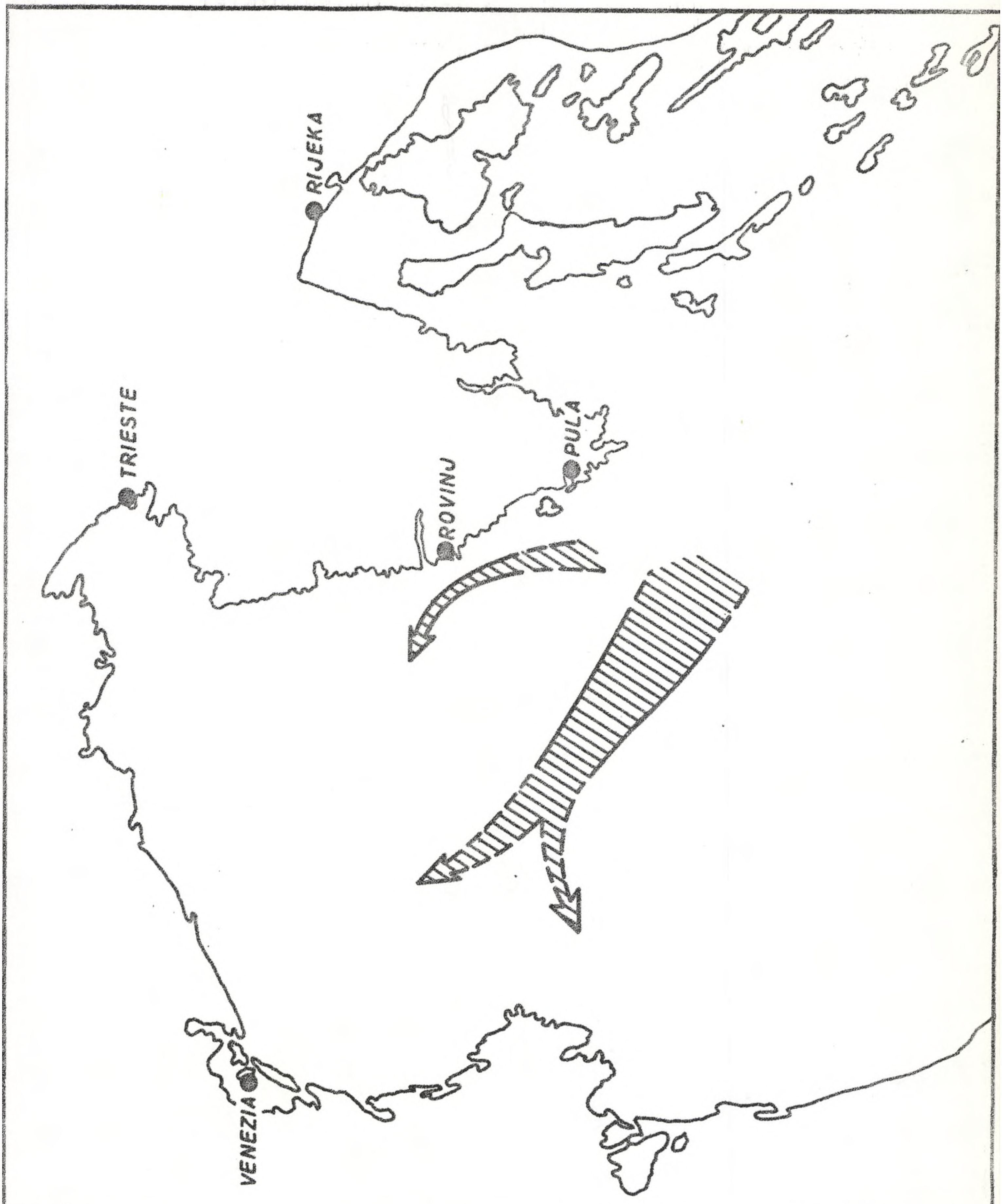

Fig.3. Hypothetical spring migration route of the North Adriatic sprat.

(D. ZAVODNIK: The Distribution and Migrations of the Sprat...)

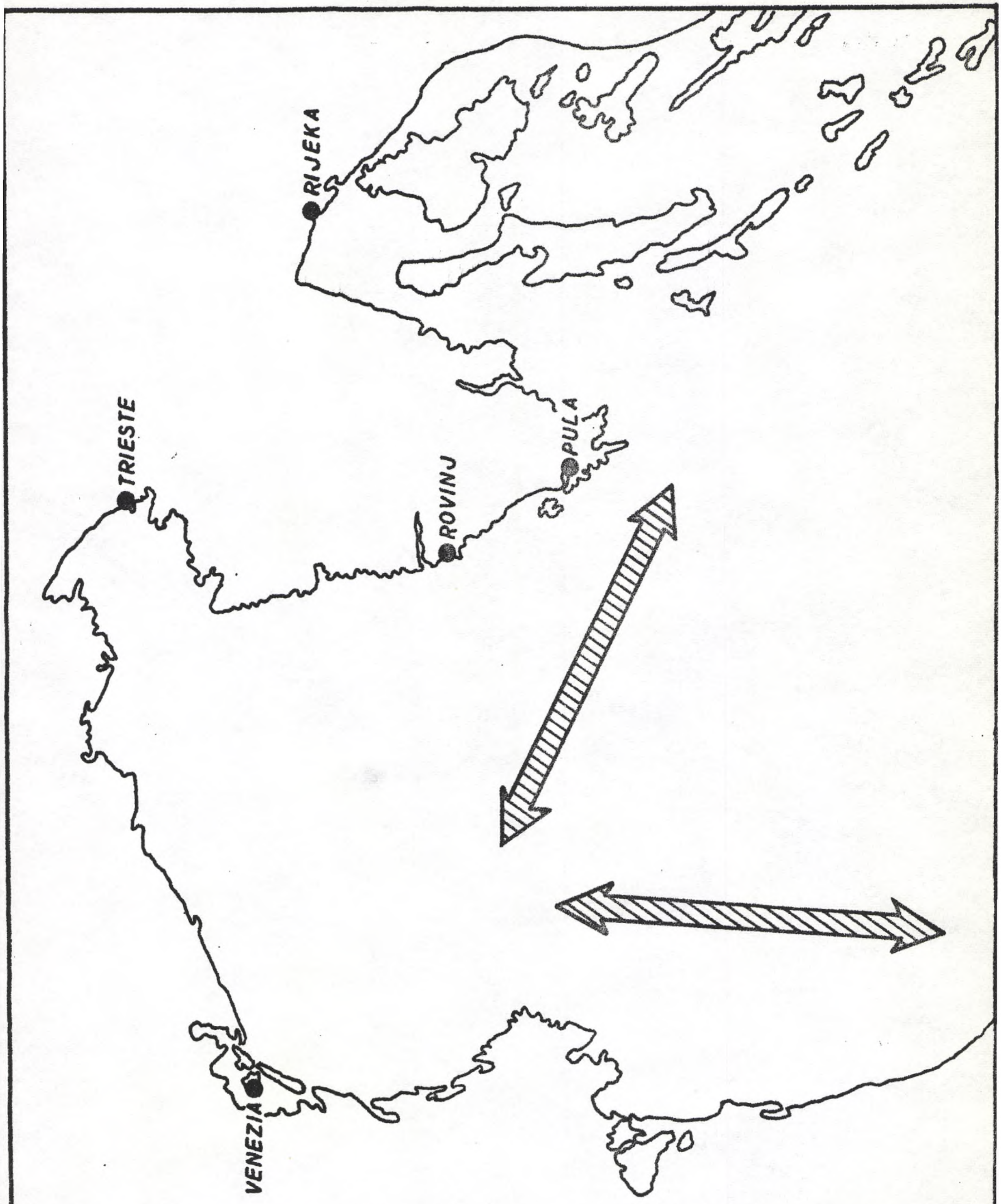

Fig. 4. The main migration directions of the northern stock of sprat.
(D. ZAVODNIK: The Distribution and Migrations of the Sprat...)

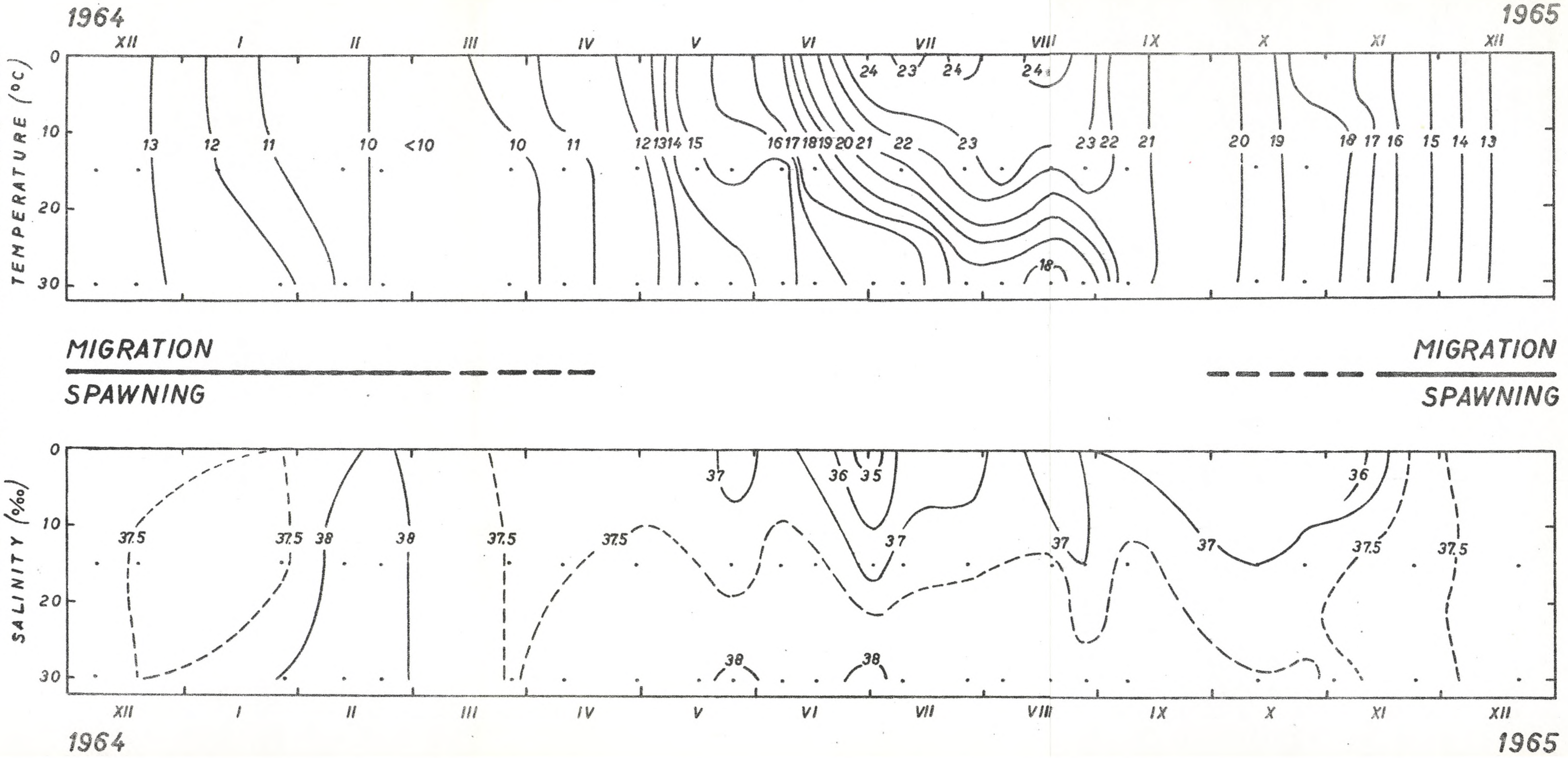

Fig. 5. Environmental conditions at the Station "Banjole" near Rovinj in 1964-1965

(D. ZAVODNIK: The Distribution and Migrations of the Sprat...)

AN ACCOUNT ON THE SEXUAL CYCLE AND THE SPAWNING OF THE NORTH ADRIATIC SPRAT (Sprattus sprattus L.)

by

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In the northern Adriatic, the fecundity and the spawning cycle of the sprat, and especially its spawning places are very bad known. However, it was reported earlier (GRAEFFE 1888, FAGE 1920) that the sprat spawns in winter months in northern Adriatic, but where its principal spawning places are situated was not known till some years ago.

For obtaining the informations on the spawning cycle and the fecundity of North Adriatic sprat, histological sections of ovaries of 90 specimens were made, which derived from commercial catches made in winter time of 1963-1966 offshore in the Bay of Venice. The measurements of the ovocytes were fulfilled on 20 fishes, whose gonads were weighed to an accuracy of 0.0001 gram and afterwards kept in GILSON's solution till analysis begun. Counting and measurements of the ovocytes were made from 0.1 gram of ovaries; later the results were corrected to a total weight of the gonads.

It was stated that in the ovaries of pre-spawning fishes at least three stocks of ovocytes can be identified (ZAVODNIK N., 1968). The most numerous are the ovocytes of the "reserve" stock. The diameter of these ovocytes was found to be from 0.03 to 0.12 mm. The greater ovocytes of the diameters of 0.13 to 0.30 mm belong to the stock of "half-mature" ovocytes, which are characteristic for the ovaries in the second and the third stadies of sexual maturity. The most developped "maturing" ovocytes in the ovaries of fourth and fifth stages of maturity measured 0.34 to 0.50 mm in diameter. Consequently, to the stock of "mature" ovocytes all ovocytes were summed up, whose diameter exceeds 0.50 mm. It is the matter of fact that because of the intraovarial pressure the "mature" ovocytes are always smaller than are the ripe planctonic eggs, whose diameter is about 1 mm. The ripe eggs are thrown out in batches, but it is not known in what intervals.

After the first spawning, usually two stocks of ovocytes remain in the ovaries, and frequently after the third spawning in the ovaries only reserve ovocytes can be found. Therefore it is supposed that the North Adriatic sprat spawns at least three times in a spawning season. To our regret, from the data available no conclusion can be made on the number of spawnings in relationship to the age of the fish. However, it is stated that some specimens mature already in the first year of live, but a great majority of them spawns for the first time in the second year, when they reach about 11,5 - 12,5 cms of total length.

Observations on fecundity were made on twenty specimens. Consequently, a significant correlation between the fecundity and the length of the fish was not obtained, as the fishes studied had previously spawned for one or maybe two times in the breeding season (ZAVODNIK N., 1968). Meanwhile, the correlation between the fecundity and the weight of the ovary is more evident. Obviously, the number of the ovocytes in the ovaries of the same weight can vary considerably. In the mature ovaries studied by us 23.000 to 62.000 ovocytes were encountered, of which on an average about 57 percent belong to the reserve stock. The mean weight of mature ovaries is found to be about 6 % of the weight of the fish (extreme minimal value is 3 % and the maximal is 9 %), while in the period of recuperation the mean weight of the ovaries is only about 0.5 percent of the total fish weight.
According to the appearance and the structure of the ovaries the North Adriatic sprat matures in October-November and at the end of this period the first batch of ova is thrown out. To confirm this supposition plankton investigations were organised from December 1964 on. In this time, planktonic sprat eggs were encountered in the entire area of the most northern part of the Adriatic (Bay of Venice), except in the immediate vicinity of the west Istrian coast (ZAVODNIK D.,1968). But already at a distance of six nautical miles westwards, the maximal concentrations of sprat eggs were registered - up to 441 specimens per square metre. The quantities of eggs inreased gradually from the coast towards the open sea. In January 1965, the eggs were few in number in Rovinj region, nut nearly uniformly distributed in the area, except for some coastal stations, which were negative. In the middle of March some sprat eggs were encountered still, but from April till October no sprat egg was found in our samples. From November 1965 no plankton sample is available . However, in December significant quantities of eggs were encountered in the entire area, especially in offshore waters. When the sprat eggs were present in plankton samples, the temperature range is registered to be 9-14°C. It is supposed that principal spawning places of the North Adriatic sprat are situated in the open waters of the Bay of Venice and very probably also in the Quarner region (ZAVODNIK D ., 1968).
Obviously, the majority of specimens breed in early winter (respectively December); probably in this time already the second or even third batch of ova are thrown out, and this matter can be of a greatest influence to the quantities of eggs present in plankton. It is true that the first batch of mature ovocytes is less in number than is the second and the third batch. Our results are similar to those obtained by HEIDRICH (1925) and ASLANOVA (1954).
The histological analyses of the ovaries indicate that spawning of the North Adriatic sprat ceased in March when the last batch of ova is thrown out.

It is in fully concordance with the results of the planktological investigations. But it is supposed that only a limited number of mature sprats spawns in this time, while the majority of the population ceased with the spawning earlier. While in resting phase, in the ovaries only the reserve stock of the ovocytes can be found together with some resorbing residuals of the previous stocks.

Bibliography

ANDREU, B.M., 1966: Fecundidad del espadín atlantico (Sprattus sprattus) del No España. - Invest.pesq. 30 : 589-602

ASLANOVA, N.E., 1954: Šprot Čornogo morja. - Trudy VNIRO 28 : 75-101

FAGE, L., 1920: Engraulidae, Clupeidae. - Rep. Dan. Oc. Exped. "Thor" 2 (A. 9) : 140 pp.

GRAEFFE, E., 1888: Übersicht der Seethierfauna des Golfes von Triest -IV. - Arb. Zool. Inst. Wien 7 (3) : 445-470

HEIDRICH, H., 1925: Über die Fortpflanzung von Clupea sprattus in der Kieler Bucht. - Wiss. Meeresunters., N.F., Kiel 20 (1) : 1-45

ZAVODNIK, D., 1968: Studies on the life history of Adriatic sprat - II. : Contribution to the spawning of the sprat (Sprattus sprattus L.) off the west coast of Istria (Northern Adriatic). Stud. Rev. gen. Fish. Coun. Medit. (in print)

ZAVODNIK, N., 1968: Studies on the life history of Adriatic sprat - I. : Contribution to knowledge of the spawning cycle of North Adriatic sprat (Sprattus sprattus L.). Stud. Rev. gen. Fish. Coun. Medit. (in print)