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FURTHER STUDIES ON BLOOD PROTEIN POLYMORPHISM IN SPRAT

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INTRODUCTION

Polymorphism of hemoglobins and serum transferrins of sprat, *Sprattus sprattus* (L.), has been described on basis of 28 samples from the Norwegian coast (NÆVDAL 1968). Reliability of the type determinations, heredity and choice of characteristic sample parameters were discussed, and significant differences, especially among the samples from western Norway, were noted. The purpose of the present study has been to compare sprat from the Norwegian coast to the sprat population at its potential origin areas (see DANNEVIG 1951 for references).

MATERIAL AND METHODS

Sampling and treatment of hemoglobins and sera, analyses by electrophoresis, staining of proteins, etc. were performed in the same way as described by NÆVDAL (1968). Sampling localities are shown in Fig. 1 and listed in Table I together with sampling dates and numbers of specimens determined for hemoglobin and serum transferrin types. Samples collected at the same place on the same day were taken from different catches. Numbers in brackets indicate unreliable results due to aging or warming of the samples before the analyses. These results have been omitted in the discussion.

The age of the sprat was determined partly from size and partly from growth zones in the otoliths.

RESULTS AND DISCUSSION

Distributions of hemoglobin types in the 1967 and 1968 samples are shown in Table 1 (Norwegian coast) and Table 2 (North Sea and Kattegat). The type HbI-1-3 was not found in these samples. Corresponding distributions of transferrin types are shown in Table 3 and Table 4.

The distributions and the diagram of the 95 per cent limits of confidence (Fig. 2) show good agreement between the results from the samples

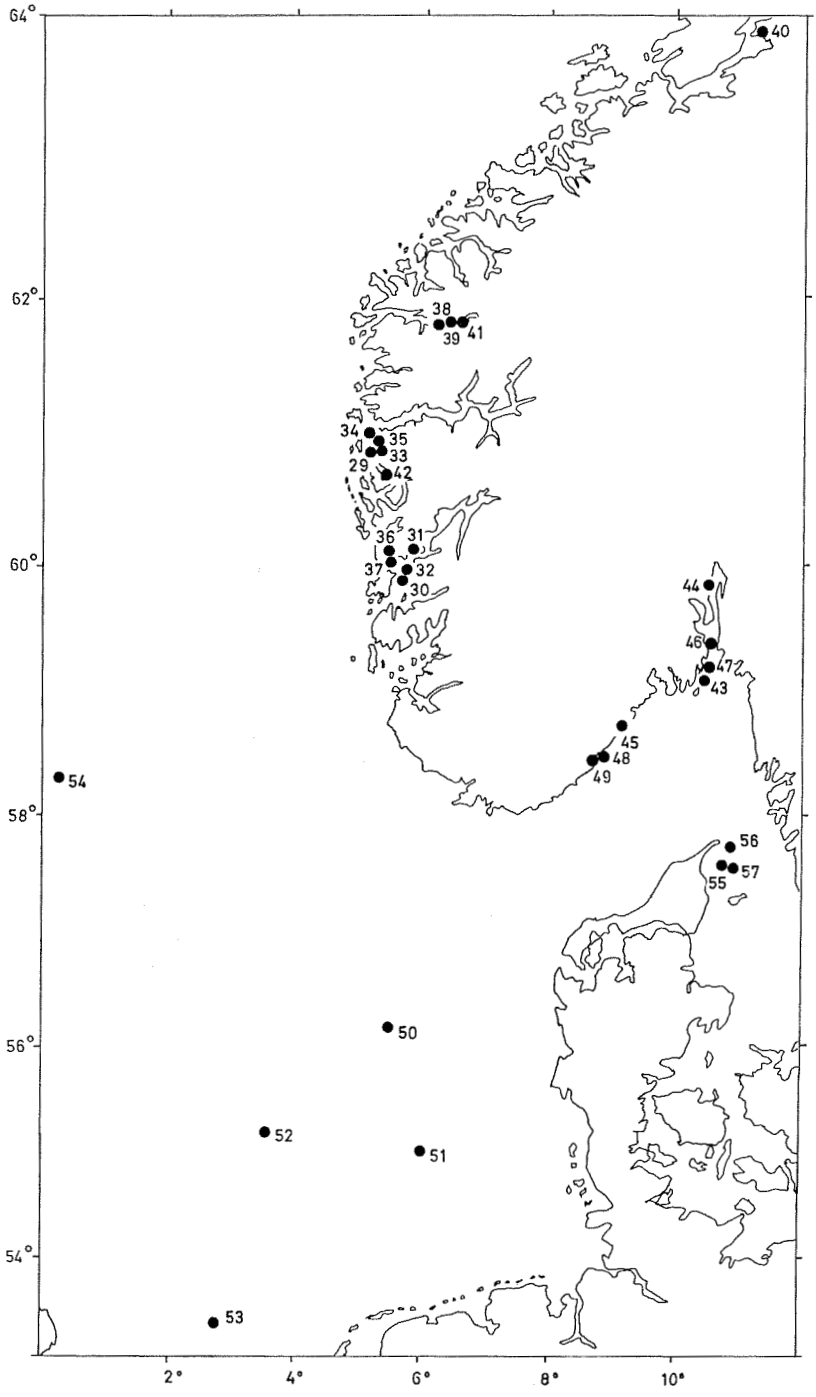

Fig. 1. Sampling localities of blood samples of sprat in 1967 and 1968.

Table 1. Distribution of hemoglobin patterns (phenotypes) in samples of sprat from the Norwegian coast 1967 and 1968.

Sample no.	Hemoglobin patterns					No.	Frequency of pattern HbI-1
	HbI-1	HbI-1-2	HbI-2-3	HbI-3	HbI-2		
29	82	24	1	2	3	110	74.5
30	92	8	—	—	—	100	92.0
31	81	6	—	—	1	88	92.5
32	96	8	—	—	—	104	92.3
33	105	14	—	—	4	123	85.4
34	92	10	—	1	2	105	87.6
35	75	19	2	—	1	97	77.3
36	79	22	—	—	3	104	76.0
37	74	24	4	1	1	104	71.2
38	66	11	—	1	—	78	84.6
39	70	9	—	1	—	80	87.5
40	58	4	—	—	—	62	93.5
41	83	9	—	—	1	93	89.2
42	64	18	1	2	6	91	70.3
43	34	13	—	—	3	50	68.0
44	43	10	—	—	2	55	78.2
45	69	8	—	—	1	78	87.2
47	93	2	—	—	—	95	97.9
48	118	2	—	—	—	120	98.3
49	113	5	—	—	—	118	95.8

collected in 1967 and 1968 from the Norwegian coast and the results from previous years. Great variations were observed among samples, especially among samples from western Norway.

High value of HbI-1 frequencies and intermediate values of q_A characterized the samples from Kattegat. Fig. 2 shows that part of the samples from western Norway, most of the samples from the Skagerak coast and one sample from the Oslo fjord coincided with the Kattegat samples. Most of the samples from the North Sea also showed high value of HbI-1 frequencies while some had higher q_A values than the Kattegat samples. These results were also in accordance with the results of a few of the samples collected at the Norwegian coast. However, a considerable part of the samples collected at the coast had conformity neither with the samples from Kattegat nor with the samples from the North Sea. This is illustrated in Fig. 3 where both the q_A-values and the HbI-1 frequencies for each sample are plotted in a scattering diagram. Samples with less than 50 reliable determinations of specimens have been omitted, but the previous samples (NÆVDAL 1968) are included.

The most likely explanation of the variation among samples is that the samples are collected from populations which differ in their gene pool,

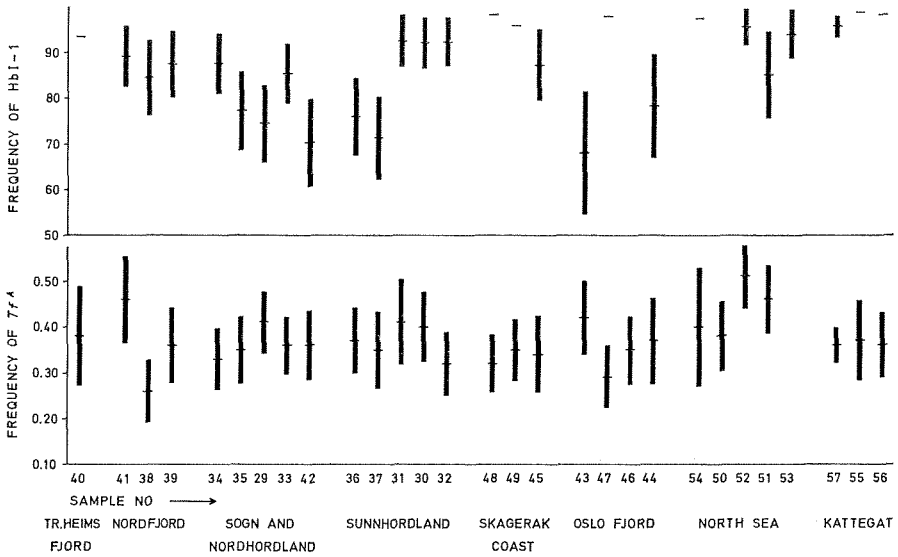

Fig. 2. Confidence intervals for the universal frequencies of HbI-1 and for the gene Tf^A supposed to control the transferrins in the Tf A-group. Horizontal lines mark the observed frequencies, and the vertical bars show the 95% confidence limits. The samples are arranged in geographical order.

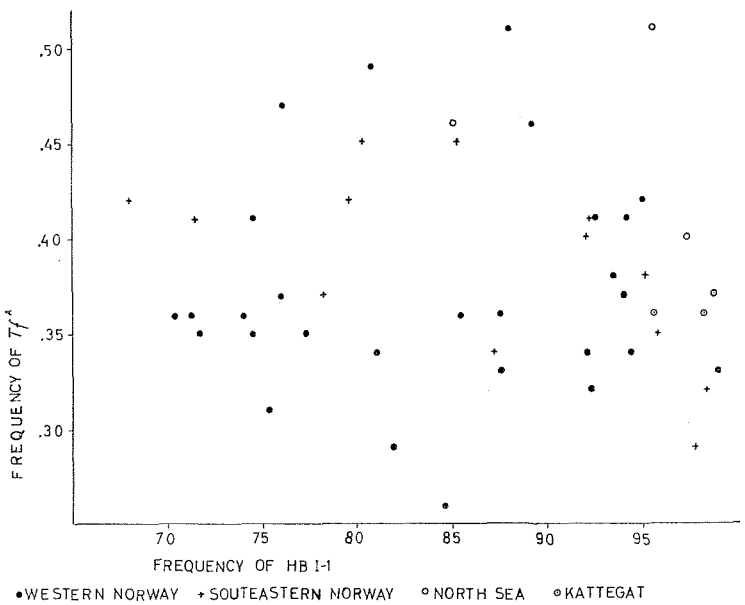

Fig. 3. Relation between frequencies of the hemoglobin type HbI-1 and the transferrin gene Tf^A in sprat samples. Samples of less than 50 specimens are omitted in the diagram.

Table 2. Distributions of hemoglobin pattern in samples of sprat from the North Sea and Kattegat.

Sample no.	Hemoglobin patterns					No.	Frequency of pattern HbI-1
	HbI-1	HbI-1-2	HbI-2-3	HbI-3	HbI-2		
51	51	8	—	—	1	60	85.0
52	106	5	—	—	—	111	95.5
53	77	3	—	—	2	82	93.9
54	109	3	—	—	—	112	97.3
55	74	1	—	—	—	75	98.7
56	112	2	—	—	—	114	98.2
57	307	12	—	—	2	321	95.6

that is populations which are reproductively separated. The results therefore indicate that a major part of the sprat in Norwegian waters may be recruited from spawning grounds in the Kattegat. Recruitement from the North Sea may also account for a part of the Norwegian sprat population. The origin of the sprat from which the rest of the samples have been taken, is not clear, but local populations in the fjords may be one explanation. It is also possible that the samples from Kattegat and the North Sea are not representative for these areas, and that other sprat populations exist from which no samples have been taken.

It is evident that no covariance exists between the observed pair of values (Fig. 3). This implies that more than two separated populations have been sampled, although some of the samples may represent a mixture of specimens of different origin. The mechanism which prevents gene flow between the populations, is still unknown.

The results of the studies on blood proteins of sprat indicate the following conclusion: the sprat population in Norwegian coastal waters consists of a major group recruited from spawning grounds in the Kattegat and the North Sea and minor groups recruited from local populations in the fjords.

SUMMARY

1. About 3000 specimens comprising 29 samples of sprat have been analysed for hemoglobin and serum protein types. The samples were collected at different localities on the Norwegian coast, in Kattegat and the North Sea.
2. The results of the samples from the coast confirm the results obtained by corresponding studies made before, i.e. great variations among samples, especially among samples from western Norway.

Table 3. Observed distributions of transferrin groups in samples of sprat from the Norwegian coast compared to expected Hardy-Weinberg distributions.

Sample no.		Transferrin groups			No.	q_A	χ^2	Probability of worse fit
		Tf AA	Tf AB	Tf BB				
29	obs	15	57	35	107	0.41		
	exp	18.0	51.8	37.2	107.0		1.15	$0.2<P<0.3$
30	obs	16	35	33	84	0.40		
	exp	13.4	40.3	30.2	83.9		1.46	$0.2<P<0.3$
31	obs	9	27	19	55	0.41		
	exp	9.2	26.6	19.1	54.9		0.01	$0.90<P<0.95$
32	obs	11	38	45	94	0.32		
	exp	9.6	40.9	43.5	94.0		0.46	$0.3<P<0.5$
33	obs	17	55	52	124	0.36		
	exp	16.1	57.1	50.8	124.0		0.16	$0.5<P<0.7$
34	obs	11	44	46	101	0.33		
	exp	11.0	44.7	45.3	101.0		0.02	$0.8<P<0.9$
35	obs	11	38	36	85	0.35		
	exp	10.4	38.7	35.9	85.0		0.05	$0.8<P<0.9$
36	obs	11	46	34	91	0.37		
	exp	12.5	42.4	36.1	91.0		0.61	$0.3<P<0.5$
37	obs	7	33	28	68	0.35		
	exp	8.3	30.9	28.7	67.9		0.36	$0.5<P<0.7$
38	obs	5	33	44	82	0.26		
	exp	5.5	31.6	44.9	81.9		0.13	$0.7<P<0.8$
39	obs	9	33	29	71	0.36		
	exp	9.2	32.7	29.1	71.0		0.01	$0.90<P<0.95$
40	obs	4	22	14	40	0.38		
	exp	5.8	18.8	15.4	40.0		1.23	$0.2<P<0.3$
41	obs	10	32	14	56	0.46		
	exp	11.8	27.8	16.3	55.9		1.22	$0.2<P<0.3$
42	obs	14	31	37	82	0.36		
	exp	10.6	37.8	33.6	82.0		2.65	$0.1<P<0.2$
43	obs	16	34	28	78	0.42		
	exp	13.8	38.0	26.2	78.0		0.90	$0.3<P<0.5$
44	obs	7	25	21	53	0.37		
	exp	7.3	24.7	21.0	53.0		0.01	$0.09<P<0.95$
45	obs	8	29	29	66	0.34		
	exp	7.6	29.6	28.7	65.9		0.03	$0.8<P<0.9$
46	obs	8	42	33	83	0.35		
	exp	10.2	37.8	35.1	83.1		0.84	$0.3<P<0.5$
47	obs	9	37	48	94	0.29		
	exp	7.9	38.7	47.4	94.0		0.23	$0.5<P<0.7$
48	obs	12	46	52	110	0.32		
	exp	11.3	47.9	50.9	110.1		0.14	$0.7<P<0.8$
49	obs	11	50	43	104	0.35		
	exp	12.7	47.3	43.9	103.9		0.41	$0.5<P<0.7$

Table 4. Observed distributions of transferrin groups in samples of sprat from the North Sea and Kattegat compared to expected Hardy-Weinberg distributions

Sample no.		Trasferrin groups			No.	q_A	χ^2	Probability of worse fit
		Tf AA	Tf AB	Tf BB				
50	obs	15	35	35	85	0.38		
	exp	12.3	40.1	32.7	85.1		1.40	$0.2<P<0.3$
51	obs	20	42	27	89	0.46		
	exp	18.8	44.2	26.0	89.0		0.23	$0.5<P<0.7$
52	obs	32	48	30	110	0.51		
	exp	28.6	55.0	26.4	110.0		1.79	$0.1<P<0.2$
54	obs	6	12	12	30	0.40		
	exp	4.8	14.4	10.8	30.0		0.83	$0.3<P<0.5$
55	obs	7	32	24	63	0.37		
	exp	8.6	29.4	25.0	63.0		0.57	$0.3<P<0.5$
56	obs	10	48	37	95	0.36		
	exp	12.3	43.8	38.9	95.0		0.92	$0.3<P<0.5$
57	obs	40	49	133	322	0.36		
	exp	41.7	48.4	131.9	322.0		0.08	$0.7<P<0.8$

3. The Kattegat samples coincided with part of the samples from western Norway, with most of the samples from the Skagerak coast and with one sample from the Oslo fjord. The samples from the North Sea also showed accordance with some of the samples from the Norwegian coast.
4. The present and previous analyses indicate that the sprat population in Norwegian waters consists of one major component recruited from Kattegat and the North Sea, and minor components recruited from local spawning in the fjords.

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Table I. Number of specimens analysed for hemoglobin and transferrin types in blood samples of sprat from western Norway (29—42), southeastern Norway (43—49), North Sea (50—54) and Kattegat (55—57).

Sample no.	Locality	Date	Hemoglobin	Transferrin	Age
29	Risnes, Masfj Hordaland	4 June 67	110	107	1-group
30	Skorpo, Hardangerfj, Hordaland	6 June 67	100	84	1-group
31	Gjermundshamn, Hordaland	6 June 67	88	55	1-group
32	Skorpo, Hardangerfj, Hordaland	6 June 67	104	94	1-group
33	Duesund, Masfj, Hordaland	12 June 67	123	124	1-group
34	Haveland, Sogn	19 June 67	105	101	1-group
35	Oppedalsøyra, Sogn	19 June 67	97	85	1-group
36	Lygrespollen, Hordaland	26 June 67	104	91	1-group
37	Lygrespollen, Hordaland	26 June 67	104	68	1-group
38	Tistam, Nordfjord	14 Oct. 67	78	82	1+2-group
39	Tistam, Nordfjord	14 Oct. 67	80	71	1+2-group
40	Borgenfjorden, Trøndelag	26 Oct. 67	62	40	0+1+2-group
41	Innvik, Nordfjord	26 June 68	93	56	1-group
42	Asgard, Austfj, Hordaland	12 Oct. 68	91	82	0-group
43	Bolærne, Oslofjorden	9 Sept. 68	50	78	1+2-group
44	Vollen, Oslofjorden	13 Sept. 68	55	53	1-group
45	Sandnesfj, Aust-Agder	29 Sept. 67	78	66	0-group
46	Bastøy Oslofjorden	30 Aug. 68	(91)	83	1+2-group
47	Husvik, Tønsberg Oslofjorden	30 Aug. 68	95	94	1+2-group
48	Flødevigen Aust-Agder	23 Oct. 68	120	110	0-group
49	Flødevigen Aust-Agder	25 Oct. 68	118	104	0-group
50	56°10′N, 05°25′E North Sea	24 Aug. 67	(120)	85	2-group
51	55°00′N, 06°00′E North Sea	28 Aug. 67	60	89	2-group
52	55°08′N, 03°32′E North Sea	29 Aug. 67	111	110	2-group

Table I (cont.)

Sample no.	Locality	Date	Hemoglobin	Transferrin	Age
53	53°19′N, 02°45′E North Sea	16 Sept. 67	82	—	2-group
54	58°21′N, 00°45′E North Sea	20 Sept. 67	112	30	2-group
55	57°35′N, 10°55′E Kattegat	8 Nov. 67	75	63	2-group
56	57°35′N, 10°55′E	8 Nov. 67	114	95	1-group
57	57°43′N, 10°50′E Kattegat	10 Nov. 67	321	322	2-group