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ON THE RELATIONSHIP BETWEEN VERTEBRAL NUMBER AND WATER TEMPERATURE IN COD

by

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An enormous amount of work has been carried out to determine the average number of vertebrae in different stocks of cod (Gadus morhua morhua L.) throughout the North Atlantic, but although the relationship with temperature in the period during and after spawning is often mentioned there seems to be no published attempt to plot the correlation between the two over a wide area. I have taken published data on vertebral numbers of cod stocks from all parts of the North Atlantic and plotted them against surface water temperature during the month of spawning (Figure 1). The data on vertebral count are from Schmidt (1930), Dannevig (1947), Mackenzie and Smith (1955), Thompson (1943), Stanek (1968), Lefranc (1970), Seals Research Division of the Institute of Marine Environmental Research (Plymouth) (unpublished) and some of my own from the Irish Sea and Bristol Channel. The temperature data are from Stefansson (1962), ICNAF (1968), Hydrographic Office, U.S. Navy Dept. (1944), ICES (1962), Clark and Vladykov (1960) and some of my own. In all seventy samples ranging in size from 20 to 4 594 fish and in area from the Western English Channel to Northern Labrador are included (Table 1). In a small number of cases the exact position of the sample and the time of spawning had to be guessed and the average monthly temperature interpolated from contour charts. It seems reasonable to expect that this will increase the variance in the relationship rather than introducing bias.

The equation for the regression line plotted in Figure 1 is as follows:

$$\text{Vertebral count (including urostyle)} = 54.45 - \text{Temperature (in } ^{\circ}\text{C)} \times 0.361$$

The correlation coefficient (r) is - 0.906 for 68 degrees of freedom (probability of $r > 0.302$ is 0.01 for 70 d.f.). The regression accounts for 82% of the variance in vertebral count and an increase in water temperature of 1°C would be expected to give a decrease in average vertebral number of 0.361.

A similar treatment of the relationship between water temperature and vertebral count has been carried out by Clark and Vladykov (1960), but they fitted a curve to their data. In the present case square root and logarithmic transformations of the vertebral count gave such tiny improvements in the correlation coefficient that they are not worth considering. The curves produced by the transformations cannot be plotted on Figure 1 because they are indistinguishable from the straight line.

Clark and Vladykov point out that values which lie away from the regression line may represent fish not spawned on the ground where they were caught. It is of course extremely dangerous to select outlying points for special consideration since this can easily be used to "improve" the correlation spuriously, but perhaps one instance can be cited since it has been raised elsewhere. The values ringed in Figure 1 come from the English Channel and are all higher than might be expected from the water temperature during the spawning period in that area. One of the values comes from the work of Lefranc (1970) and he compares it with values found by other authors and concludes that the low number which he found is due to the relatively warm water in the Straits of Dover. Unfortunately his counts do not include the urostyle whereas those of most other authors in his comparison do. The evidence therefore suggests that the cod sampled in the English Channel may have come from the southern North Sea.

More detailed use of vertebral count data demands more complete information on the position of spawning areas, the time of spawning and the year class of the fish being sampled, since the temperature during and after spawning is likely to fluctuate from year to year. The importance of these year to year fluctuations can be seen from an analysis of variance of vertebral counts of cod from the North Sea (ICES division IVb) sampled at Lowestoft, Grimsby and North Shields by Mr J Prime of the Seals Research Division of the Institute of Marine Environmental Research (Plymouth).

The data are set out in Table 2 and a preliminary analysis shows that for each year class the mean vertebral count is highest at Lowestoft, followed by North Shields and then Grimsby. The order of the mean vertebral counts for each year class is also quite similar for the three ports, with 1963 being consistently highest. The range of values for the different year classes indicates a temperature fluctuation of about 2°C from the warmest to the coldest year. The result of the analysis of variance, which shows significant effects due to Port, Year Class and Port x Year Class interaction, is not surprising in view of what has been said above. The residual (or error) mean square can be used to get some idea of the sample sizes needed to separate stocks, where some hypothesis about difference in water temperature exists

and the year class effect can be allowed for. It is likely that in the present case the port effect is due to a difference in the areas being sampled by the three ports and perhaps also in their seasonal pattern of fishing. Figure 2 shows the "centre of gravity" of the sampling distribution for the three ports.

So far any possible genetic causes of differences in vertebral count have been ignored, although it has been shown for plaice (Purdom and Wyatt, 1969) and other species that such differences do exist. Since the only way in which such genetic differences can be established is by breeding experiments, the possibility of a genetic cause must always be left as an open hypothesis. This need not be a great handicap when studying stock structure, since a consistent difference in mean vertebral count can be used as evidence of separation regardless of its cause. The absence of a clear difference due to genotype in such a case does not constitute evidence that the stocks are not separate. Only in the case where there is no difference in mean vertebral count between two samples, but breeding experiments show that a genotypic difference exists, does the genetic evidence provide us with extra information on the separation.

REFERENCES

CLARK, J.R. and VLADYKOV, V.D., 1960. Definition of haddock stocks of the Northwestern Atlantic. Fishery Bull. Fish Wild. Serv. U.S., 169 (60)

DANNEVIG, A., 1947. The number of vertebrae and rays of the second dorsal fin of fishes from the Norwegian Skagerak coast. Annls. biol., Copenh., 2 : 131-146.

HYDROGRAPHIC OFFICE, U.S. NAVY Dept., 1944. World atlas of sea surface temperatures. H.O.225, U.S.Navy, Washington D.C., 48 plates.

ICES, 1962. Mean monthly temperature and salinity of the surface layer of the North Sea and adjacent waters from 1905 to 1954. Charlottenlund Slot, ICES Hydrographic Service, 1962, 24 charts.

ICNAF, 1968. Environment Surveys Norwestlant 1-3, Part II, Atlas. Int. Commn. N.W. Atlant. Fish., Spec. Publ. No 7 (2).

LEFRANC, G., 1970. Contribution a la connaissance de la biologie de la morue du sud de la Mer du Nord et de la Manche orientale. Revue Trav. Inst. (scient. tech.) Pech. Marit., 34 (3): 277 - 296.

MACKENZIE, R.A. and SMITH, G.F.M., 1955. Atlantic cod populations along the Southern Canadian mainland as shown by vertebral count studies. J. Fish. Res. Bd Can., 12 (5): 698-705.

PURDOM, C.E. and WYATT, T., 1969. Racial differences in the Irish Sea and North Sea plaice (Pleuronectes platessa). Nature, Lond., 222: 780-781.

SCHMIDT, J., 1930. The Atlantic cod and local races of the same. C.R. Lab. Carlsberg, 18 (6): 1-71.

STANEK, E. 1968. The number of rays in the second dorsal fin and the number of vertebrae in cod from Labrador, Newfoundland and Nova Scotia. Int. Commn. NW Atlant. Fish., Res. Doc. 68/71.

STEFANSSON, U., 1962. North Icelandic waters. Rit Fiskideildar, 3 (1).

THOMPSON, H., 1943. A biological and economic study of cod in the Newfoundland area. Newfld. Res. Bull., 14.

Table 1 Mean vertebral counts of cod (including urostyle) in the North Atlantic

Source	Area of sampling	Number of fish	Mean number of vertebrae	Standard deviation	Temperature at spawning (°C)
Schmidt (1930)	66°53'N20°42'W	120	52.96	0.65	3.5
	66°01'N17°30'W	287	52.96	0.71	3.0
	65°40'N14°10'W	370	53.23	0.64	3.5
	65°17'N13°59'W	1 290	52.85	0.69	3.8
	64°35'N13°15'W	73	53.26	0.71	4.0
	63°44'N22°57'W	186	52.73	0.71	5.5
	Faroe Plateau	4 594	52.28		6.5
Schmidt (1930)	63°08'N7°30'E	79	53.76	0.62	4.5
	68°00'N14°00'E	148	53.67	0.71	4.5
	69°38'N33°12'E	66	53.82	0.68	1.5
	70°15'N19°30'E	76	52.95	0.76	3.0
	70°24'N32°00'E	81	53.42	0.77	1.5
Dannevig (1947)	59°33'N10°27'E	3 242	51.94	0.71-0.88	7.7
Schmidt (1930)	41°18'N70°02'W	70	52.90	0.68	4.5
	43°59'N68°08'W	58	53.97	0.88	3.0
	43°36'N62°18'W	93	54.29	0.80	2.0
	46°00'N61°35'W	72	53.86	0.92	0.0
	47°35'N59°10'W	49	54.16	0.85	0.0
	47°34'N52°42'W	65	54.91	1.07	0.8
	65°23'N52°54'W	183	53.60	0.80	0.8
	61°00'N47°00'W	200	53.42	0.69	0.8
	65°40'N37°10'W	183	53.14	0.67	1.5
Mackenzie and Smith (1955)	Ingonish	2 172	53.96	)	0.0
	Canso	915	54.13	)	0.8
	Quereau	3 481	54.22	)	0.6
	Sable Island	7 031	54.04	)0.77	1.8
	St. Margaret	2 863	53.86	)	1.1
	Browns	4 388	53.80	)	2.4
	Digby	1 730	53.51	)	2.8
Thompson (1943)	Banquereau	82	53.99	0.65	0.6
	44°30'N51°00'W	60	53.38	0.95	4.5
	48°40'N53°00'W	99	55.43	0.87	0.8
	52°00'N53°30'W	90	55.20	1.01	0.2
	53°00'N55°00'W	60	55.17	0.81	-1.0
	53°30'N55°00'W	91	55.07	0.97	-1.0
	54°30'N57°00'W	29	54.86	0.86	-1.0
Stanek (1968)	52°30'N52°00'W		55.26		0.0
	51°20'N51°30'W		55.34		-0.5
	50°30'N52°30'W		54.83		0.0
Schmidt (1930)	60°52'N 8°12'W	120	51.77	0.64	8.0
	57°00'N14°00'W	91	51.47	0.62	8.7
	53°24'N 2°58'W	193	51.69	0.64	7.0
	55°25'N 5°30'W	75	51.67	0.62	7.0
	58°14'N 6°18'W	272	51.87	0.55	7.5
	58°59'N 2°53'W	200	51.91	0.61	6.8
	56°01'N 3°22'W	84	52.24	0.61	5.5
	54°46'N 0°28'E	165	52.04	0.64	5.8
	53°03'N 2°07'E	94	52.09	0.74	5.3
	53°00'N 4°45'E	97	52.19	0.63	5.0
	54°12'N 7°53'E	205	52.30	0.63	4.0
	56°39'N 7°58'E	150	52.06	0.65	4.3
	55°28'N 7°55'E	200	52.28	0.55	4.0
	60°23'N 5°20'E	197	52.43	0.67	4.0
	59°24'N 5°17'E	93	52.44	0.74	4.0
Seals Research Division of the Institute of Marine Environmental Research (Plymouth)	Flamborough	465	52.23	0.70	5.5
	Gt. Fisher	600	52.30	0.72	5.5
	Dogger	531	52.44	0.70	5.2
	Southern N. Sea	531	52.30	0.67	6.0
	off Hastings	20	52.25	0.64	7.5
	off Brixham	38	52.13	0.84	9.2
	Southern Irish Sea	473	51.72	0.68	8.0
	N.E. Irish Sea	147	51.56	0.70	6.0
	North Channel	283	51.72	0.78	7.2
	West of Scotland	535	51.70	0.69	8.3
	off Southend	36	52.47	0.61	6.0
Lefranc (1970)	E. Channel	488	52.33		7.5
Present study	Bristol Channel	209	51.58	0.72	8.3
	County Down	469	51.80	0.69	7.0
	N.E. Irish Sea	363	51.60	0.87	6.0
	S. Irish Sea	52	51.67	0.65	7.5

Table 2 Analysis of variance on vertebral counts of cod from the North Sea (ICES Division IVb) sampled at Lowestoft, Grimsby and North Shields

Deviation from 50 vertebrae (including urostyle)	Port														
	Lowestoft					Grimsby					North Shields				
	Year-class														
	1963	1964	1965	1966	1967	1963	1964	1965	1966	1967	1963	1964	1965	1966	1967
0	1		1	1					1	2		1			
1	5	2	5	18	2		3	6	37	18	2	10	15	27	15
2	23	26	54	90	31	4	12	28	117	73	10	33	58	127	58
3	36	25	41	72	30	5	3	23	76	49	15	12	59	88	33
4	9	4	3	3				2	2	1	2	1	11	3	2
Number of fish	74	57	104	184	63	9	18	59	233	143	29	57	143	245	108
Mean number of vertebrae	52.64	52.54	52.38	52.32	52.44	52.56	52.00	52.36	52.18	52.20	52.59	52.04	52.46	52.24	52.20

Source

	Sum of squares	d.f.	M.S.	F
Port	11.372651	2	5.6863	10.81**
Year-class	18.884006	4	4.7210	8.97**
Port and Year-class	33.186044	8	4.1483	7.89**
Error	794.913289	1511	0.5261	
Total	858.30599	1525		

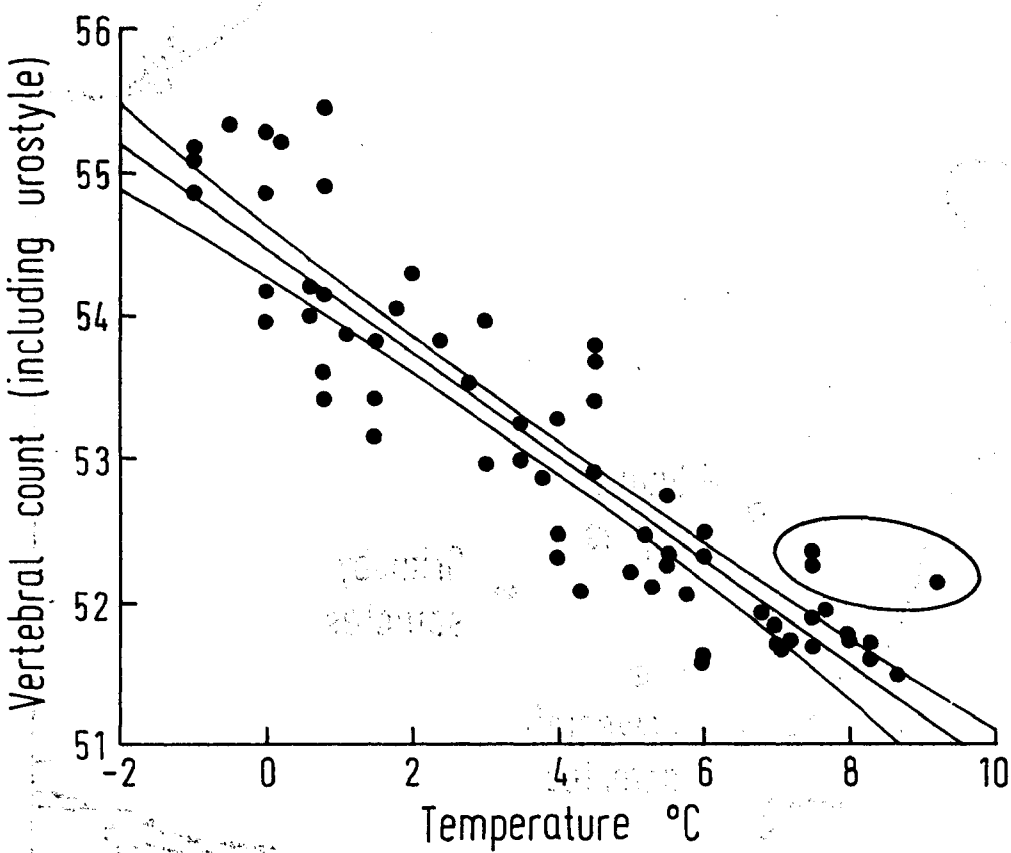

Fig.1. Relationship between temperature in the month of spawning and vertebral count for cod in all parts of the North Atlantic.

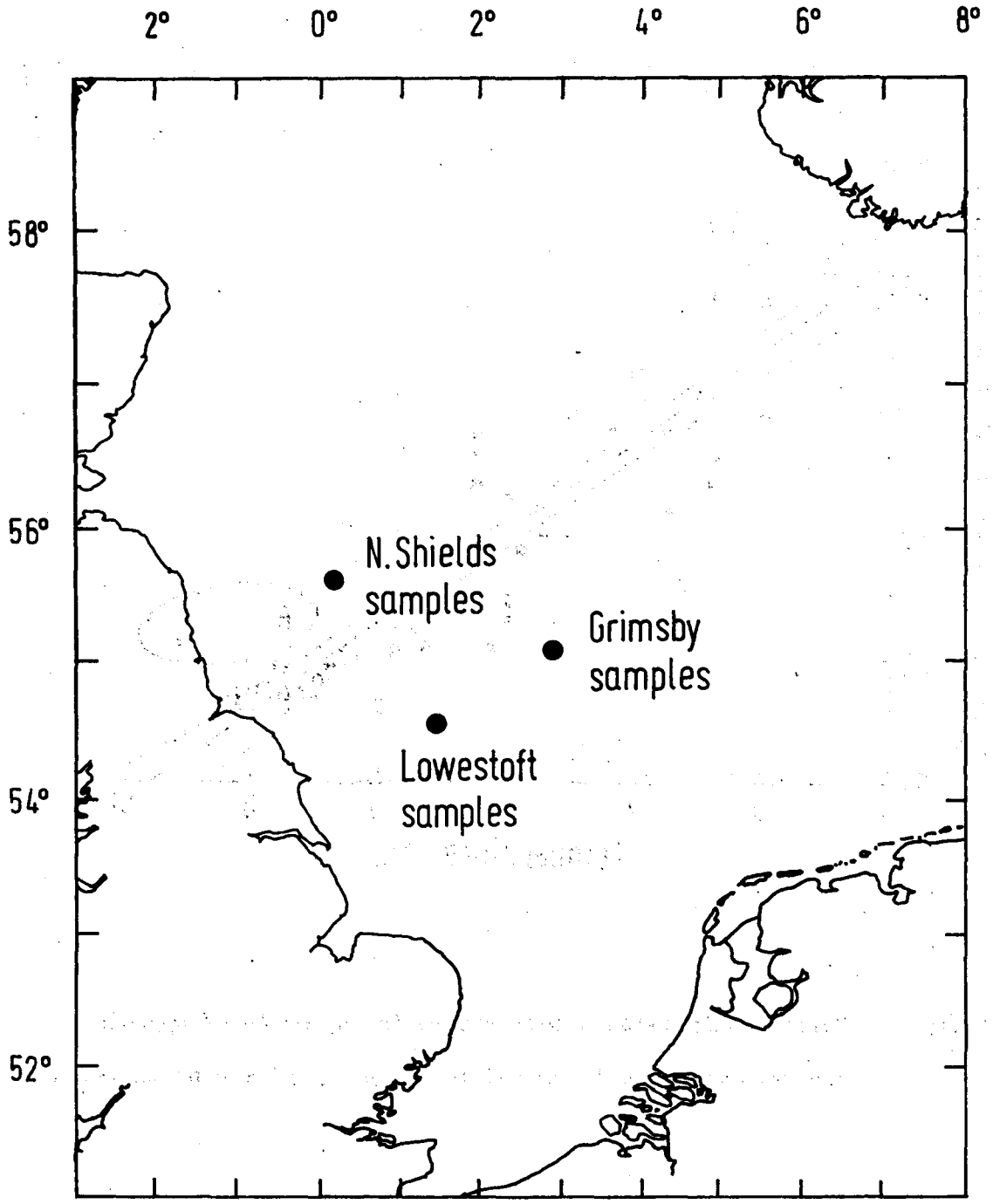

Fig. 2. "Centres of gravity" of the distribution of vertebral count samples at Lowestoft, Grimsby and N. Shields.