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An Analysis of Meristic Characters of Greenland Halibut (Reinhardtius hippoglossoides W.) in the Northwest Atlantic

by

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Abstract.

As part of a stock identification study of Greenland halibut meristic characters from six areas in the western North Atlantic were analyzed. No correlation between counts of meristic characters and length of fish was found. No differences in meristic characters between sexes were found. Left and right pectoral fin ray numbers as well as anal and dorsal fin ray numbers were highly correlated but were not correlated with vertebral numbers. No significant differences in numbers of pectoral, anal and dorsal fin rays were found between any of the areas, whereas numbers of vertebrae showed significant heterogeneity. The mean number of vertebrae from the offshore area of NAFO Div. 3K, 1C and ICES Subarea XIVb showed small differences, while those of the inshore areas at West Greenland differed substantially from the offshore areas as well as mutually.

1. INTRODUCTION.

Greenland halibut (Reinhardtius hippoglossoides Walb.) is widely distributed in the Northwest Atlantic. Spawning is supposed to take place in the deeper waters of the Davis Strait south of 67°N (Jensen, 1935 and Smidt, 1969). The larvae are dispersed by the currents both to the west coast of Greenland and to the eastern Canadian coast (Templeman, 1973). While growing up Greenland halibut in West Greenland migrate to the deeper parts of the fjords. When reaching maturity they are assumed to migrate to the spawning area in the Davis Strait (Smidt, 1969).

Similarly, in the East Greenland/Iceland area, spawning seems to occur on the continental slopes west of Iceland. Eggs and larvae are supposed to be carried either north-eastward along the northern Icelandic coast or more possibly first north-west ward later south-westward toward East Greenland by the Irminger Current (Sigurdsson, 1980). Fish growing up in the northern area at Iceland are assumed to migrate to the spawning area when reaching maturity. It therefore seems that Greenland halibut in the western North Atlantic (i.e. including Icelandic waters) forms two spawning stocks, although migrations between the areas have been observed (Riget & Boje 1989).

Several studies on stock identification of Greenland halibut in the Northwest Atlantic have been carried out. Templeman (1970) and Misra & Bowering (1984) analysed meristic characters, Bowering (1988) analysed morphometric characters, Fairbairn (1981) investigated frequencies of electrophoretically detectable protein loci, and Khan et al. (1982) dealt with blood protozoa used as biological tags. All authors suggest that Greenland halibut form a single interbreeding stock throughout the Northwest Atlantic although there is evidence that those in the Gulf of St. Lawrence and Fortune Bay constitute two separate stocks (Bowering, 1982).

Recently, Riget and Boje (1989) summarized present knowledge of the biology of Greenland halibut in West Greenland waters. They hypothesize that the stocks in the southernmost fjords of West Greenland can be recruited from the spawning grounds west of Iceland and further that stocks in the West Greenland fjords may be regarded as mainly stationary. Furthermore they point out that adults from the West Greenland fjords have never been included in the stock identification studies. From these points of view a stock identification study of Greenland halibut in the Northwest Atlantic was initiated in 1987. The study covers samples from the Denmark Strait, the Davis Strait, the inshore areas of West Greenland and the area off Newfoundland north of Grand Bank. The study includes methods analysing meristic characters, biochemical genetics and the natural parasite fauna.

This paper presents the result of analyses of the meristic characters. The results of the biochemical analyses are also presented at this meeting (NAFO SCR Doc. 89/26), while the analyses of the parasite fauna are in progress for later presentation.

2. MATERIALS AND METHODS.

The samples included in this study were collected in six different areas in the Northwest Atlantic (Fig. 1) during 1987-1988 (Table 1). The areas include an offshore area in the Davis Strait (NAFO Div. 1C), an offshore area off Newfoundland Div.3K, an area in the Denmark Strait (ICES Subarea XIVb) and three inshore areas at West Greenland (NAFO Div. 1A, 1D and 1F). The sample from from Div. 3K was collected from the Canadian research vessel "Gadus Atlantica" by staff from Northwest Atlantic Fisheries Centre in St.John's, Newfoundland. The samples from Div. 1C and Subarea XIVb were collected from the Japanese research vessel "Shinkai Maru" and the inshore samples were collected from research vessels of the Greenland Fisheries Research Institute.

Greenland halibut in the lenght range 50-70 cm were selected for sampling. Separate tissue samples from each fish were taken immediately after capture. Sex of all specimens was determined. Length was measured as total length to the centimeter below. Otoliths were taken for age determination. The vertebral column, dorsal fin, anal fin and pectoral fins were sampled and stored in frozen condition for later analysis. Furthermore samples for the parasitic and electrophoretical studies were taken from the same fish.

In the laboratory only all intact vertebrae were counted with the urostylar half vertebrae counting as one vertebra. Some vertebral columns were prepared for counting by cooking to remove the flesh. Fin ray counts were made without any special treatment.

Counts on a discontinous variable such as a meristic character are distributed over a finite range of integral values and are not normally distributed. Therefore counts have been analysed with nonparametric statistical tests.

3. RESULTS.

3.1 Variation with length.

Greenland halibut in the length range 50-70 cm can be expected to cover several age groups. To evaluate possible bias in averages of counts of meristic characters resulting from differences in the length compositions of the samples, Spearman Correlation Coefficients relating meristic value to total length were calculated and the nill hypothesis that there is no correlation between the two variables was tested (Table 2). Except for the right pectoral fin rays both positive and negative correlations were obtained for each meristic character. The Spearman Correlation Coefficients differed significantly from zero in only three instances, of which two are for the right pectoral fin rays, and one for number of vertebrae. It was felt that this significance is partially a reflection of sample size, and hence that no significant bias in meristic averages due to differences in length compositions occurs.

3.2 Variation between sexes.

Differences in sex composition within samples could also cause bias in meristic averages. Therefore difference of the meristic characters between sexes was tested by Wilcoxon 2-sample test (SAS anon., 1985) (Table 3). Only at the left pectoral fin rays in the sample from Newfoundland, Div. 3K was found a significant difference at the 5% level between males and females. It is evident from this that differences in meristic characters between sexes is negligible. Males and females were therefore combined for subsequent comparisons.

3.3 Variation between areas.

3.3.1 Fin ray number.

Table 4 gives means of numbers of rays in left and right pectoral fin rays, anal fin and dorsal fin for the different areas. The left and right pectoral fin ray numbers range from 11 to 16. The greatest difference in mean left pectoral fin ray numbers was found between the sample from Denmark Strait and Newfoundland and for the right pectoral fin between West Greenland fjords and Newfoundland. However, a Kruskal-Wallis test for difference between areas gave no significant difference at the 5% level (left pectoral fin: p= 0.478, right pectoral fin p= 0.057).

Mean anal fin ray numbers ranged from 64 to 87 with the greatest difference between the sample from Denmark Strait, and that from

Davis Strait. The Kruskal-Wallis test gave no significant difference at the 5% level between areas (p= 0.171).

Mean dorsal fin ray numbers ranged from 85 to 109 with greatest difference found between Denmark Strait and Davis Strait. A Kruskal-Wallis test gave no significant difference at the 5% level between areas (p= 0.281).

However, although no significant difference in mean number of fin rays between the areas is found, there is an overall tendency for Denmark Strait to have the lowest mean values among the samples as shown in the text table below:

Text table. Samples ordered in range of highest mean value to lowest mean value for fin rays.

	highest mean value					lowest mean value
Pectoral fin rays, left	3K	1C	1F	1A	1D	XIVb
Pectoral fin rays, right	3K	1A	1F	1C	XIVb	1D
Anal fin rays	1C	3K	1D	1A	1F	XIVb
Dorsal fin rays	1C	1A	1D	3K	1F	XIVb

3.3.2 Number of vertebrae.

Numbers of vertebrae range from 57 to 64 and means for areas range from 60.126 for West Greenland fjords, Div.1D to 61.693 for West Greenland fjords, Div.1F (Table 5). A Kruskal-Wallis test showed high significance ($p<0.0001$) for heterogenity between areas. A pairwise test (Wilcoxon 2-sample test) showed that the three samples from offshore areas (Newfoundland, 3K, Davis Strait, 1C and Denmark Strait, XIVb) do not differ significantly from each other (5% level) while samples from West Greenland fjords are significantly different from the other samples (5% level) see text table.

Text table. Samples ordered in range of highest mean value to lowest mean value of vertebral numbers. Values underscored by the same line are not significantly different from each other ($p<0.005$).

highest mean value					lowest mean value
1F	1C	XIV b	3K	1A	1D
61.7	61.5	61.3	61.1	60.8	60.1

3.4 Relation between numbers of left and right pectoral fin rays, and between numbers of anal and dorsal fin rays and vertebrae.

Spearman Correlation Coefficients relating numbers of left to right pectoral fin rays, anal fin rays to dorsal fin rays, anal fin rays to vertebrae and dorsal fin rays to vertebrae were calculated for each sample. A high correlation ($p<0.0001$) was found in each case (Table 6). In only one sample, West Greenland fjords, Div.1A, significant correlation ($p<0.005$) between numbers of anal fin rays and vertebrae was found. A significant correlation was found between numbers of dorsal fin rays and vertebrae in the sample from West Greenland fjords, Div.1A ($p<0.01$) and in the sample from Newfoundland, Div. 3K ($p<0.005$).

4. DISCUSSION.

The number of fin rays and vertebrae are assumed to be determined during egg stages and the early larval development, influenced by environmental conditions, especially the temperature (Tåning 1952). It has been shown that lower temperatures in the early life stages increase the number of vertebrae (Templeman and Pitt, 1961). The number of anal and dorsal fin rays and vertebrae in present study are not closely related, which is in accordance with the findings of Templeman (1970). Number of vertebrae may be determined earlier in life development than number of dorsal and anal fin rays (Tåning, 1952) and the figures for these characters are therefore not necessarily correlated.

4.1 Fin rays.

No significant differences in number of pectoral, anal and dorsal fin rays are found between any of the samples taken. However, there was a tendency for number of fin rays to be lowest in the Newfoundland sample. The means were not significantly different from values by Templemann (1970) for samples in areas comparable to the present studies' sampling sites. He also found no significant differences between fin rays from Newfoundland samples and from the offshore West Greenland area. Schmidt (1904) gave means for 20 specimens caught east of Iceland, these generally being higher than for present samples from Subarea XIVb. The fin ray numbers from present study were highly correlated betweem fins and in summary these characters do not seem to be useful in stock separation studies of Greenland halibut.

4.2 Vertebrae.

The main results of this study is that the mean number of vertebrae showed significant heterogeneity between some of the areas. The sample from Denmark Strait was not significantly different from the Newfoundland and the Davis Strait sample, but showed difference from West Greenland fjord samples.

Templeman (1970) and Misra & Bowering (1984) found no difference in mean number of vertebrae between samples over the area from Baffin Bay to the southern Grand Bank, apart from Gulf of St. Lawrence. With respect to Greenland samples their study included only the offshore areas of West Greenland. The mean number of vertebrae from the present samples from Davis Strait and Newfoundland, which are supposed to represent a single interbreeding stock, are significantly different at the 5% level. Compared to the values given by Templeman (1970), the mean from the Davis Strait is very alike, while that of Newfoundland is slightly below Templeman's values. Anyhow, taking the small difference into account it is difficult to interpret these results as being different from Templeman's studies as well as those of Misra and Bowering (1984).

The sample from Denmark Strait is supposed to derive from the stock spawning at the continental slope off the west coast of Iceland (Sigurdsson, 1979). The present analysis shows that this stock can not be seperated from the stock in the Davis Strait by number of vertebrae.

The mean number of vertebrae in samples from West Greenland fjords differ between divisions, with the highest value in Div. 1F (Table 5: 61.693) and the lowest in Div. 1D (Table 5: 60.126). It is noteworthy that the difference between the mean value for fjords in Div. 1D (Table 5: 60.126) and that for the Davis Strait, Div. 1C (Table 5: 61.460) is considerable in spite of the small distance between sampling sites (Fig. 1). This might indicate a high isolation of the West Greenland fjord stocks.

Previous studies of the fjord populations including tagging experiments (Riget and Boje, 1989) and investigations on maturity (Boje and Riget, 1988) generally support the theory that populations in the West Greenland fjords are separated from the Davis Strait stock complex. The present study shows great differences in mean number of vertebrae between the samples, especially between the West Greenland fjords, indicating that eggs and larvae from these places must have been under different environmental condition. Information on temperatures in the West Greenland fjords is scarce, which makes it hard to judge whether the mean number of vertebrae observed are correlated with temperature conditions.

Results from other studies in this investigation such as biochemical analysis and analyses of parasite fauna should be included in order to elucidate the relationship between the populations in the Northwest Atlantic.

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Table 1. Periods of sampling and depth interval of sampling sites.

Location	NAFO Division/ ICES Subarea	Date	Depth interval
Newfoundland	3K	Nov.-Dec. 1987	220-835 m
Denmark Strait	XIVb	Oct. 1987	180-930 m
Davis Strait	1C	Sept. 1988	603-869 m
West Greenland fjords	1A	Aug. 1987	210-1080 m
West Greenland fjords	1D	Jan. 1987	140-600 m
West Greenland fjords	1F	Jan. 1988	330-430 m

Table 2. Spearman Correlation Coefficients of each meristic character with length. Number of fish are in parentheses. (^{x} indicate significance at the 5 % level and ^{xx} at 1 % level).

Areas	Pectoral fin rays left	Pectoral fin rays right	Anal fin rays	Dorsal fin rays	Vertebrae
Newfoundland, Div. 3K	0.201(91)	0.162(87)	0.06(99)	0.035(99)	0.046(94)
Denmark Strait, XIVb	0.157(89)	0.207(94)^{x}	-0.141(93)	-0.027(91)	-0.037(97)
Davis Strait, Div. 1C	0.088(98)	0.069(100)	0.178(98)	0.160(98)	-0.023(100)
West Greenland fjords, Div. 1A	0.063(85)	0.033(89)	0.046(87)	0.181(86)	0.308(92)^{xx}
West Greenland fjords, Div. 1D	0.156(93)	0.219(93)^{x}	0.088()4)	0.138(92)	0.170(100)
West Greenland fjords, Div. 1F	-0.084(101)	0.002(99)	-0.028(101)	-0.097(100)	0.163(103)

Table 3. Wilcoxon 2- sample test for differences in meristic characters by sex. (^{x} indicates significance at the 5% level and ^{xx} at the 1 % level). f: female, m: male.

	Newfoundland		Denmark Strait		Davis Strait		West Greenland fjords					
	Div. 3K		Subarea XIVb		Div. 1C		Div. 1A		Div. 1D		Div. 1F	
	P	No	P	No	P	No	P	No	P	No	P	No
Pectoral fin rays, left	0.031^{x}	m 33 f 56	0.156	m 42 f 47	0.540	m 67 f 31	0.761	m 40 f 45	0.302	m 28 f 65	0.078	m 24 f 77
Pectoral fin rays, right	0.938	m 28 f 56	0.286	m 43 f 51	0.633	m 69 f 31	0.265	m 41 f 48	0.854	m 27 f 66	0.066	m 24 f 75
Anal fin rays	0.628	m 36 f 60	0.669	m 43 f 50	0.938	m 68 f 30	0.456	m 41 f 46	0.493	m 29 f 65	0.188	m 24 f 77
Dorsal fin rays	0.665	m 36 f 60	0.723	m 44 f 47	0.856	m 68 f 30	0.824	m 39 f 47	0.908	m 28 f 64	0.295	m 24 f 76
Vertebrae	0.455	m 34 f 58	0.387	m 44 f 52	0.771	m 69 f 31	0.404	m 40 f 48	0.980	m 29 f 66	0.160	m 24 f 77

Table 4. Means of fin ray numbers from different areas (No= number of specimens, X= mean number, r= range S.D.= standard deviation).

	Newfound land Div. 3K	Denmark Strait Subarea XIVb	Davis Strait Div. 1C	West Greenland fjords Div. 1A	Div. 1D	Div. 1F
Pectoral, left						
No	91	89	98	85	93	101
X	13.549	13.326	13.418	13.388	13.366	13.406
S.D.	0.703	0.823	0.625	0.788	0.818	0.710
r	12-15	11-15	12-15	12-15	11-16	12-15
Pectoral, right						
No	87	94	100	89	93	99
X	13.713	13.447	13.480	13.607	13.376	13.556
S.D.	0.746	0.838	0.731	0.763	0.706	0.772
r	12-16	12-15	12-15	12-15	11-15	11-15
Anal						
No	99	93	98	87	94	101
X	72.778	72.021	73.010	72.747	72.766	72.436
S.D.	2.509	2.938	3.141	2.866	2.588	2.547
r	66-81	66-80	65-81	64-80	66-80	67-79
Dorsal						
No	99	91	98	86	92	100
X	99.263	96.429	97.959	97.453	97.271	92.250
S.D.	3.427	3.801	3.799	3.577	3.332	3.325
r	85-104	89-108	90-109	90-105	89-104	90-106

Table 5. Number of vertebrae from different areas (No= number of specimens, X= mean number, S.D.= standard deviation).

	57	58	59	60	61	62	63	64	No	X	S.D.
Newfoundland, Div. 3K		1	1	16	49	20	7		94	61.138	0.899
Denmark Strait, Subarea XIVb			6	16	25	40	9		96	61.313	1.059
Davis Strait, Div. 1C				6	48	40	6		100	61.460	0.702
West Greenland fjords, Div. 1A		1	3	28	36	18	2		88	60.830	0.913
West Greenland fjords, Div. 1D	3	5	14	38	26	8	1		95	60.126	1.160
West Greenland fjords, Div. 1F			1	11	26	44	18	1	101	61.693	0.956

Table 6. Spearman Correlation Coefficients of numbers of left and right dorsal fin rays, and of numbers of dorsal fin rays and vertebrae. (^{x} indicates significance at the 5% level and ^{xx} indicates significance at the 1% level).

	left pect. fin rays / right pect. fin rays	anal fin rays / dorsal fin rays	anal fin rays / vertebrae	dorsal fin rays / vertebrae
Newfoundland, Div. 3K	0.522^{xx}	0.481^{xx}	0.111	0.222^{x}
Denmark Strait, XIVb	0.527^{xx}	0.487^{xx}	-0.036	0.017
Davis Strait, Div. 1C	0.610^{xx}	0.711^{xx}	0.141	0.110
West Greenland fjords, Div. 1A	0.570^{xx}	0.617^{xx}	0.221^{x}	0.288^{xx}
West Greenland fjords, Div. 1D	0.657^{xx}	0.529^{xx}	0.013	-0.005
West Greenland fjords, Div. 1F	0.666^{xx}	0.444^{xx}	0.180	0.102

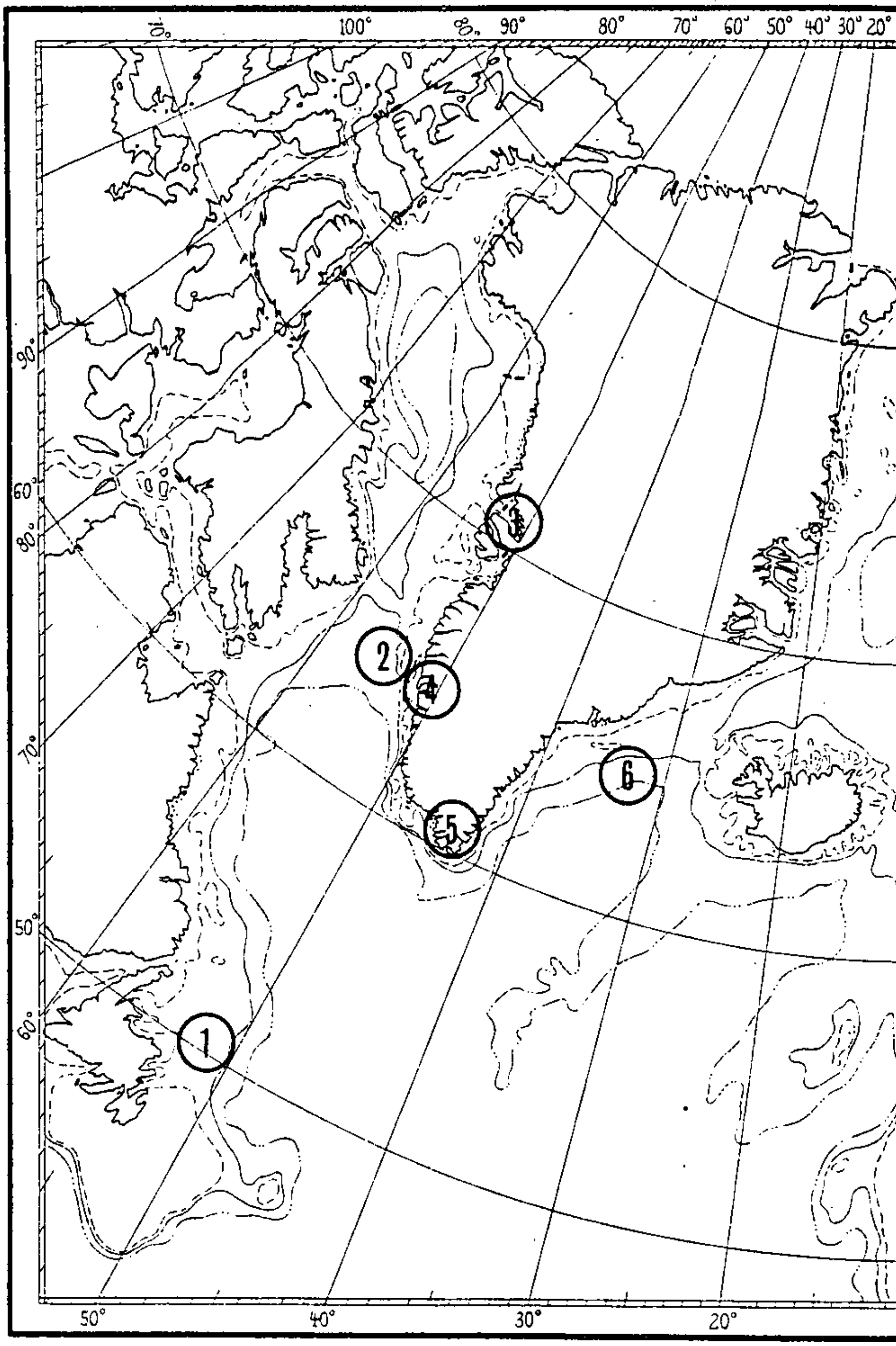

Fig.1. Distribution of Greenland halibut samples in the western North Atlantic. 1: Newfoundland (Div.3K), 2: Davis Strait (Div.1C), 3: Umanak (Div.1A), 4: Godthaab (Div.1D), 5: Julianehaab (Div.1F), 6: Denmark Strait (ICES Subarea XIVb),.