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Distribution, Abundance and Migration of Atlantic Wolffish (*Anarhichas lupus*) and Spotted Wolffish (*Anarhichas minor*) in West Greenland Waters

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Abstract

Results from stratified-random bottom-trawl surveys off West Greenland during the autumns of 1982–86 indicated substantial decline in biomass and abundance of both Atlantic wolffish and spotted wolffish. Atlantic wolffish were the more abundant of the two species, with the catch rate generally decreasing from north to south, and occurred mainly in the 0–200 and 200–400 m depth ranges. Spotted wolffish, on the other hand, were rather uniformly distributed over the three depth ranges (to 600 m) and also over the north-south strata. Mean lengths of both species tended to increase from north to south.

Reported recaptures from the taggings, during 1955–64, of 174 Atlantic wolffish and 746 spotted wolffish were 2 and 53 respectively. The two Atlantic wolffish were taken in the vicinity of the tagging site about 2 years after they were tagged. Spotted wolffish exhibited rather stationary behavior, with most recaptures generally within 20 nautical miles (nm) of the tagging sites up to 10 years after they were tagged. Only three spotted wolffish were found more than 100 nm from the tagging sites, two southward and one northward. Analysis of longline catches of spotted wolffish in the Nuuk area indicated local seasonal movements.

Introduction

Three species of wolffish are found in Greenland waters: Atlantic wolffish (*Anarhichas lupus* L.), spotted wolffish (*A. minor* Olafsen), and northern wolffish (*A. denticulatus* Krøyer). Only Atlantic wolffish and spotted wolffish are of commercial interest, but little is known about their general distribution and abundance in the West Greenland area, although some information on the commercial fishery was reported by Smidt (1981) and on the effects of depth and temperature on distribution by Beese and Kändler (1969). Fishery statistics are not available for the two species separately, but the nominal catches of both species in NAFO Subarea 1 have declined from an average of about 6,000 (metric) tons annually in the 1970's to about 3,000 tons in 1980–85.

More data on Atlantic wolffish and spotted wolffish are available from other parts of the North Atlantic. For the Newfoundland area, the distribution and abundance for both species were studied by Albikovskaya (1982) and migrations from tagging by Templeman (1984). Furthermore, Templeman (1986a, 1986b) described the biology of the two species in the Northwest Atlantic. In Iceland waters, Jónsson (1982) studied the biology of Atlantic wolffish, partly based upon tagging experiments. Barsukov (1959) described the biology of both species in the Barents Sea, and Østvedt (1963) dealt with spotted wolffish in the northern Norwegian and Barents Sea areas.

In this paper, the distribution, abundance and migration of Atlantic wolffish and spotted wolffish in West Greenland waters (NAFO Subarea 1) are described from data collected during bottom-trawl surveys, experimental longlining, and tagging studies.

Materials and Methods

Stratified-random bottom-trawl surveys were carried out in late autumn from mid-October to mid-December (1982–86) by research vessels from the Federal Republic of Germany. The surveys were especially designed to cover the distribution of cod off West Greenland, comprising the offshore areas of Subarea 1 south of 67° N outside territorial waters, more than 12 nm from the coast, to a depth of 600 m (Fig. 1). However, wolffish are known to be distributed considerably further north than the northern border of the survey area and also within territorial waters (Smidt, 1981). Consequently, the survey results deal only with parts of the stocks. The survey area (in Div. 1B to 1F) was

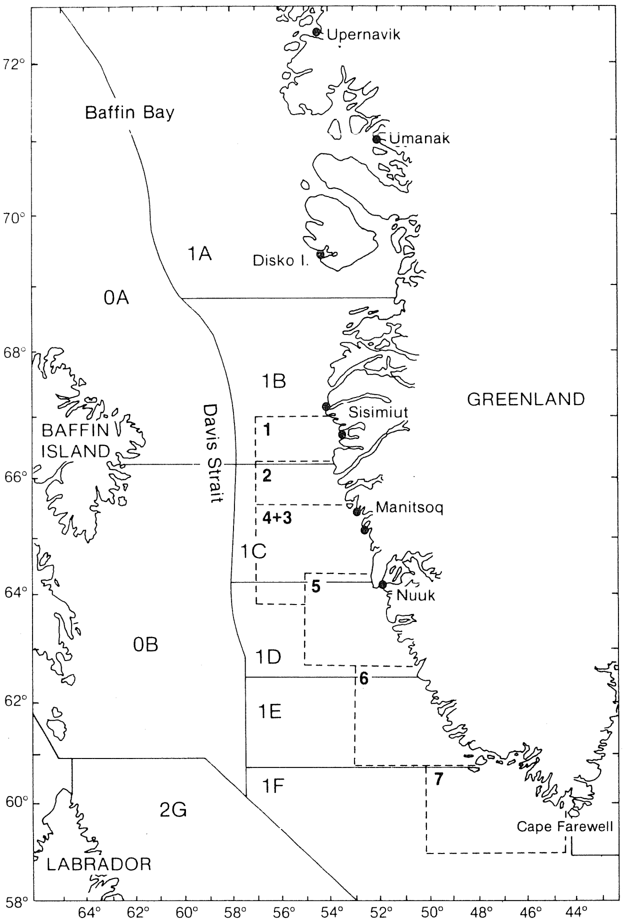

Fig. 1. West Greenland region, showing NAFO divisions, trawl-survey strata 1-7, and general tagging locations (dots).

divided into seven main strata, each of which was subdivided into three substrata by 200 m isobaths. Strata areas in nautical square miles and coverage by number of sets in 1982-86 are given in Table 1. Duration of each tow was 30 min and towing speed was 4.5 km/hr. Information on trawl parameters was reported by Horsted (MS 1986), who also described the methods by which abundance and biomass of wolffish were estimated. All length measurements were recorded as total length to the cm below (i.e. 60 cm = 60.0-60.9 cm).

Catch data from the surveys were analysed further after logarithmic (base e) transformation with a three-way analysis of variance. All effects (year, strata and depth) were regarded as deterministic in the model

$$Y_{ijkl} = \overline{Y} + A_i + B_j + C_k + E_{l(ijk)}$$

where Y_{ijkl} = *ln* (number-per-hour trawling + 1), $\overline{Y}$ = overall logarithmic mean, A_i = year i effect, B_j = strata j effect, C_k = depth k effect, and $E_{l(ijk)}$ = error.

During 1955-64, 174 Atlantic wolffish and 746 spotted wolffish were tagged at several localities along the West Greenland coast between 61°N and 72°N. Atlantic wolffish was tagged in the Nuuk, Manitsoq and Sisimiut districts, and spotted wolffish were tagged mainly in the Nuuk, Manitsoq, Sisimiut, Disko Island and Upernavik-Umanak areas. The fish were captured with longlines and tagged with Petersen discs.

TABLE 1. Number of trawl hauls by stratum and depth interval during research surveys off West Greenland, 1982-86.

Stratum	Depth (m)	Area (nm^2)	Number of trawl hauls 1982	1983	1984	1985	1986
1	0-200	2,121	8	6	5	4	8
	200-400	506	4	1	2	2	5
	400-600	364	1	0	2	0	3
2	0-200	2,167	5	7	9	0	10
	200-400	313	3	2	2	0	1
	400-600	415	1	1	2	0	3
3+4	0-200	2,517	12	21	13	7	12
	200-400	1,062	6	10	9	6	4
	400-600	412	3	3	10	3	2
5	0-200	2,350	17	25	26	27	26
	200-400	1,018	7	13	10	11	11
	400-600	259	2	0	2	2	3
6	0-200	1,938	10	19	19	19	18
	200-400	742	6	7	7	9	7
	400-600	57	0	0	1	0	1
7	0-200	2,568	16	19	23	23	19
	200-400	971	4	10	8	9	8
	400-600	353	0	0	2	1	1
	Total	20,133	105	144	152	123	142

Catches of spotted wolffish from 268 longline sets (approximately 350,000 hooks) by Greenland Fisheries Investigation research vessels in the Nuuk area during 1955-79 were examined for seasonal trends. The fishing operations were grouped according to the location: offshore, inshore and fjords. The depth range of fishing was 60-360 m.

Results

Distribution from trawl surveys

Both species of wolffish were found in all strata during the 1982-86 trawl surveys, but Atlantic wolffish were much more abundant than spotted wolffish (Table 2).

Atlantic wolffish. Application of Analysis of Variance to the trawl-survey catches in numbers (after transformation to logarithms) showed significant ($P<0.01$) effects of year, strata and depth, and the model explained 24% of the total variation (Table 3). A Newman-Keuls range test (Hicks, 1982) on mean ln (CPUE+1) gave a significantly higher value for 1982 ($P<0.05$) than for the following years, but no significant difference in the abundance index was evident among the remaining years (1983, 1984, 1985 and 1986). There

TABLE 2. Mean number of Atlantic wolffish and spotted wolffish per hour trawling during research surveys off West Greenland, 1982-86. (+ indicates that quantity less than 0.5.)

Stratum	Depth (m)	Atlantic wolffish 1982	1983	1984	1985	1986	Spotted wolffish 1982	1983	1984	1985	1986
1	0-200	92	98	75	9	27	6	3	2	3	7
	200-400	87	4	7	68	50	7	+	3	11	12
	400-600	6	—	+	—	+	2	—	+	—	+
2	0-200	72	46	43	—	39	1	3	3	—	4
	200-400	117	131	129	—	158	6	2	3	—	+
	400-600	—	+	5	—	1	—	+	1	—	1
3+4	0-200	79	39	30	78	52	1	+	+	1	1
	200-400	69	81	22	79	44	2	1	1	1	3
	400-600	8	2	1	1	3	3	3	1	1	1
5	0-200	74	39	29	32	50	8	3	4	2	2
	200-400	122	28	13	23	28	8	+	1	+	2
	400-600	22	—	4	+	+	9	—	2	+	1
6	0-200	48	39	36	27	38	3	2	2	1	2
	200-400	33	11	7	54	37	1	2	1	2	1
	400-600	—	—	+	—	+	—	—	2	—	2
7	0-200	18	16	16	18	16	6	8	4	2	3
	200-400	39	15	20	37	22	12	3	2	2	2
	400-600	—	—	+	+	+	—	—	+	+	4

TABLE 3. Analysis of Variance results for log-transformed catches of Atlantic wolffish in research surveys off West Greenland, 1982-86. (** indicates significance at P = 0.01.)

Effect	Sum of squares	Degrees of freedom	Mean square	F	r^2
Model	381.3	11	34.7	19.0	0.24
Year	61.5	4	15.4	8.4**	
Stratum	38.5	5	7.7	4.2**	
Depth	281.3	2	140.7	77.1**	
Error	1,185.4	650	1.8		

was a general decrease in catch from north to south (Table 2), but the range test showed only stratum 7 (the southernmost area considered) to have a significantly lower value ($P<0.05$). With regard to depth, there was no difference in abundance index between the 0–200 m and the 200–400 m depth ranges, but the range test showed a significantly lower value ($P<0.05$) for the 400–600 m depth range.

Length distributions of Atlantic wolffish during the trawl surveys in the different strata are shown in Fig. 2. The number of fish measured was approximately the same in each year and contributed equally to the strata length distributions. The length distributions in the northern area (strata 1 and 2) were almost alike and were dominated by 20–40 cm fish. Southward, the proportion of larger fish increased, with 40–55 cm fish being the dominant size-groups in stratum 7. Examination of the length distributions by depth interval (not illustrated) indicated little difference apart from a slight tendency toward larger fish in the 400–600 m interval.

Spotted wolffish. Catches were generally too small for Analysis of Variance to be practical. However, some general trends in distribuiton were evident (Table 2). The mean Catch Per Unit Effort (CPUE) values were generally higher in 1982 than in the following years. There was no obvious trend in CPUE from north to south, and the catches were distributed more uniformly over the three depth intervals than for Atlantic wolffish.

The length distributions by stratum, based on combination of data over depths and years, indicate an increase in the proportion of larger fish from north to south (Fig. 3). Although nearly all length groups were represented in each stratum, 10–60 cm fish were dominant in the northern areas (strata 1–4), 50–85 cm fish in strata 5 and 6, and 65–100 cm fish in strata 7.

Biomass and abundance in 1982-86

The survey results for Atlantic wolffish show that the biomass declined greatly from 28,000 tons in 1982 to only 7,000 tons in 1984 and has remained at this low level since then (Table 4). Abundance also declined during the same period but to a lesser extent, coincident with a decline in average weight of fish. The yearly length distributions (Fig. 4) show a transition in the dominant length groups from 50–60 cm in 1982 to 20–40 cm in 1984, with an increase to 30–45 cm in 1986.

The estimated biomass of spotted wolffish declined from about 9,000 tons in 1982 to an average of about 3,000 tons in 1985–86 (Table 4). However, apart from the decline in abundance between 1982 and 1983, there was little variation during 1983–86.

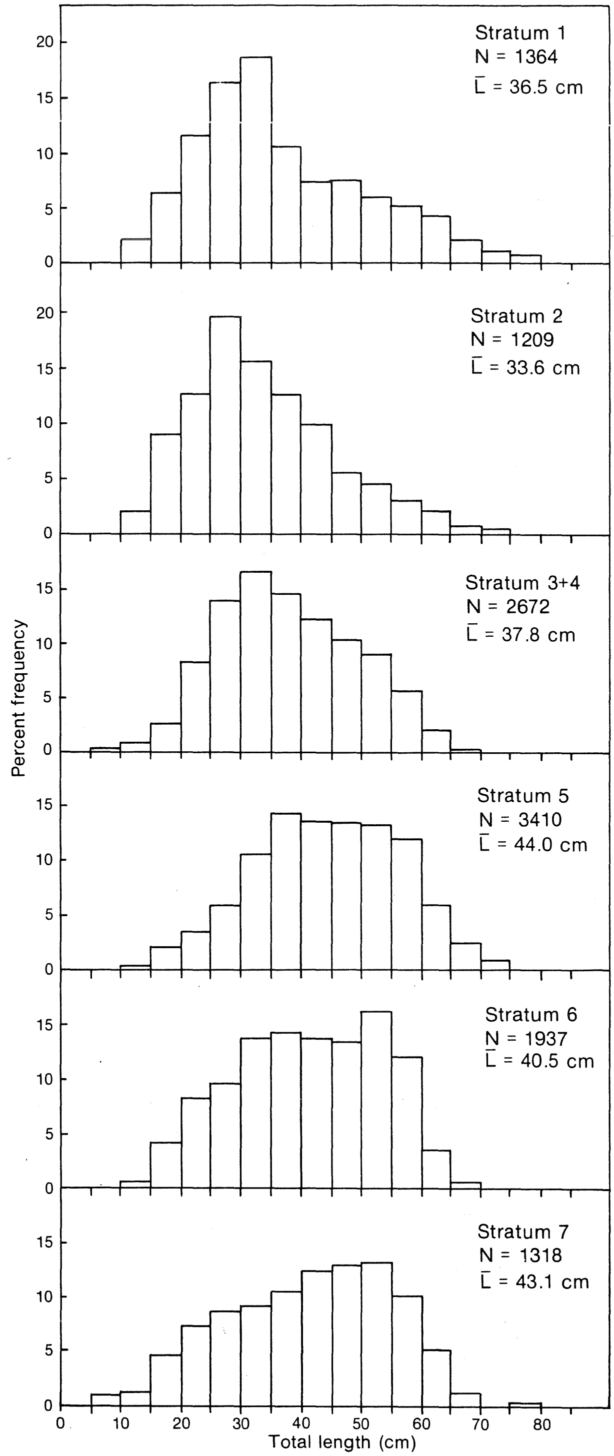

Fig. 2. Length distributions of Atlantic wolffish by strata, from bottom-trawl surveys off West Greenland in 1982-86. (N = number of fish measured; L̄ = mean length.)

The survey results indicate that, while the biomass estimates for Atlantic wolffish were generally about twice as large as those for spotted wolffish, the abundance estimates for the former species were approximately 15 times higher than the estimates for the latter (Table 4), due to the much smaller average sizes of Atlantic wolffish.

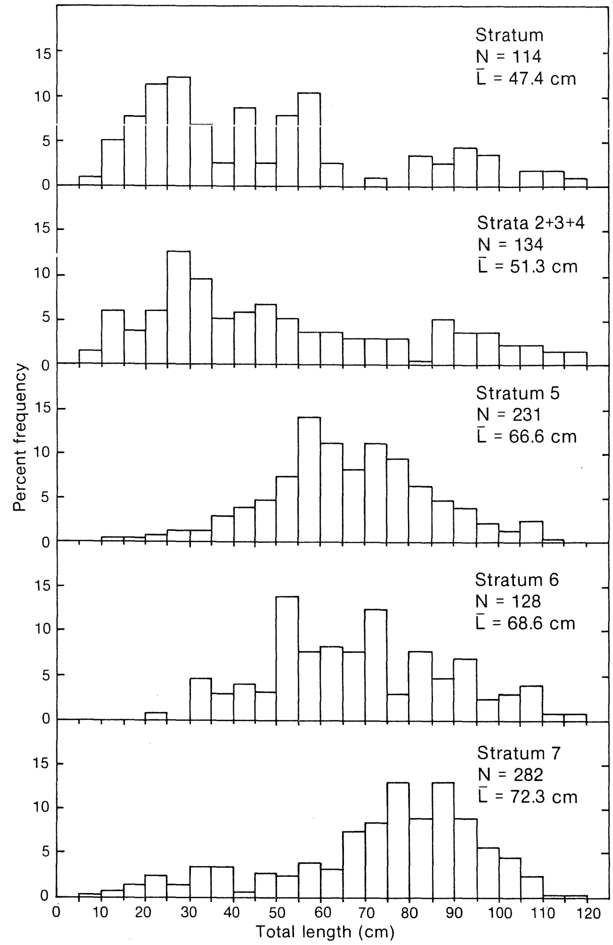

Fig. 3. Length distributions of spotted wolffish by strata, from bottom-trawl surveys off West Greenland in 1982-86. (N = number of fish measured; L̄ = mean length.)

Migration

Only two recaptures from 174 tagged Atlantic wolffish have been reported. Both fish were tagged in the inshore area at Nuuk, and they were recaptured about 2 years later near the tagging area. The two fish measured 72 and 74 cm at the time of tagging.

A total of 53 recaptures (7.1%) have been reported from the tagging of 746 spotted wolffish at various locations along West Greenland during 1955-64 (Fig. 5, Table 5). The periods of freedom varied from 1 day to 13 years, but 87% of the recaptures occurred more than 6 months after tagging. Distance of recaptures from the tagging sites could not be estimated in 12 cases (7, 4 and 1 from Nuuk, Sisimiut and Disko Island taggings respectively) because the places of recapture were unknown or uncertain. About two-thirds of the remain-

TABLE 4. Estimated biomass and abundance (with 95% confidence intervals) of Atlantic wolffish and spotted wolffish, from bottom-trawl surveys off West Greenland, 1982-86.

	Biomass				Abundance				Average
Year	Weighted catch per tow (kg)	Biomass estimate (tons)	Mean density (tons/nm²)	Confidence interval (±%)	Weighted catch per tow (N)	Abundance estimate (N×10⁻³)	Mean density (N/nm²)	Confidence interval (±%)	weight of fish (kg)
				Atlantic wolffish					
1982	38.0	28,257	1.423	32.0	32.8	24,365	1,227	22.9	1.160
1983	17.9	13,336	0.671	32.3	21.9	16,274	819	31.0	0.819
1984	9.4	7,066	0.351	25.7	14.6	11,013	547	29.5	0.642
1985	10.1	7,578	0.376	27.3	20.9	15,769	783	31.2	0.481
1986	9.7	7,337	0.364	21.9	16.9	12,730	632	27.0	0.576
				Spotted wolffish					
1982	12.4	9,235	0.465	40.5	2.4	1,794	90	27.4	5.148
1983	8.4	6,235	0.314	41.6	1.4	1,010	51	35.0	6.173
1984	5.4	4,048	0.201	31.3	1.9	823	41	25.2	4.919
1985	2.8	2,072	0.103	37.8	1.0	717	36	47.8	2.890
1986	5.2	3,914	0.194	32.4	1.4	1,074	53	24.4	3.644

ing 41 recaptures occurred within 10 nm of the tagging areas up to 6.8 years after tagging. Only five fish were found more than 50 nm from the tagging sites: three southward, one eastward into the fjord and one northward (Table 5). There was no evident relationship between distance from tagging site and period of liberation.

In the northern areas (Upernavik to Disko Island), where 9.7% of the tags were returned, all recaptures occurred within 15 nm of the tagging areas except for one fish which was captured about 120 nm southward after 13 years of freedom. In the Sisimiut area, the number of tag returns was very low (2.6%), and recapture locations were known for only two fish, both of which were found south of the tagging area (70 and 420 nm).

In the Nuuk area, spotted wolffish were tagged mainly in the outer Godthaab Fjord, and 9.2% of the tags were subsequently returned. Of the 19 recaptures for which distances from the tagging area could be estimated (Table 5), nine were taken less than 10 nm from the tagging site over a period of nearly 7 years after the fish were tagged. There were eight recaptures about 15-20 nm from the tagging location: three south of Nuuk and five eastward within Godthaab Fjord. One of these fjord recaptures occurred about 10 years after tagging. Only two fish from the Nuuk tagging were found more than 50 nm from the tagging area, one about 60 nm eastward within Godthaab Fjord and the other about 110 nm northward along the coast. The greater number of recaptures within the Fjord may be interpreted as a local migration pattern.

Because most of the recaptures occurred in the general vicinity of the tagging locations, it was not possible to detect a seasonal movement of fish from the tagging data. However, the analysis of catch and effort data from research longlining in the Nuuk area on a monthly basis indicated a marked peak in mean catch per 100 hooks in June for the coastal area and in July for the fjords (Fig. 6). This implies a migration into the fjords from coastal areas in summer. Catch rates in the offshore area were low with no obvious trend.

Discussion

The research vessel surveys covered only a part of the area of distribution of the two wolffish species. Atlantic wolffish were found to be more abundant within the survey area than spotted wolffish and their abundance increased from south to north. In general, Atlantic wolffish were equally prominent in the 0-200 and 200-400 depth intervals, with a significant reduction in catch rate at depths greater than 400 m. It is known that Atlantic wolffish are even more abundant north of the survey area, especially in Disko Bay (Smidt, 1981). Spotted wolffish, on the other hand, exhibited no clear variation in abundance by stratum and deep within the survey area. Unlike the offshore trawl-survey results, spotted wolffish is the dominant species in inshore waters along West Greenland to about 70° N (Smidt, 1981). The observed vertical distribution of each species from the trawl surveys agrees with earlier observations by Beese and Kändler (1969).

Biomass and abundance of both wolffish species declined during the period of study (1982-86). For Atlantic wolffish, the decline in biomass occurred especially during 1982-84, coincident with a change in length distribution from the rather large fish which dominated in 1982 to considerably smaller fish in 1985 and 1986. Reasons for the changes in biomass and length distribution are unknown. It seems unlikely that the offshore trawl fishery, which exerted a rather low and even decreasing level of fishing effort during the

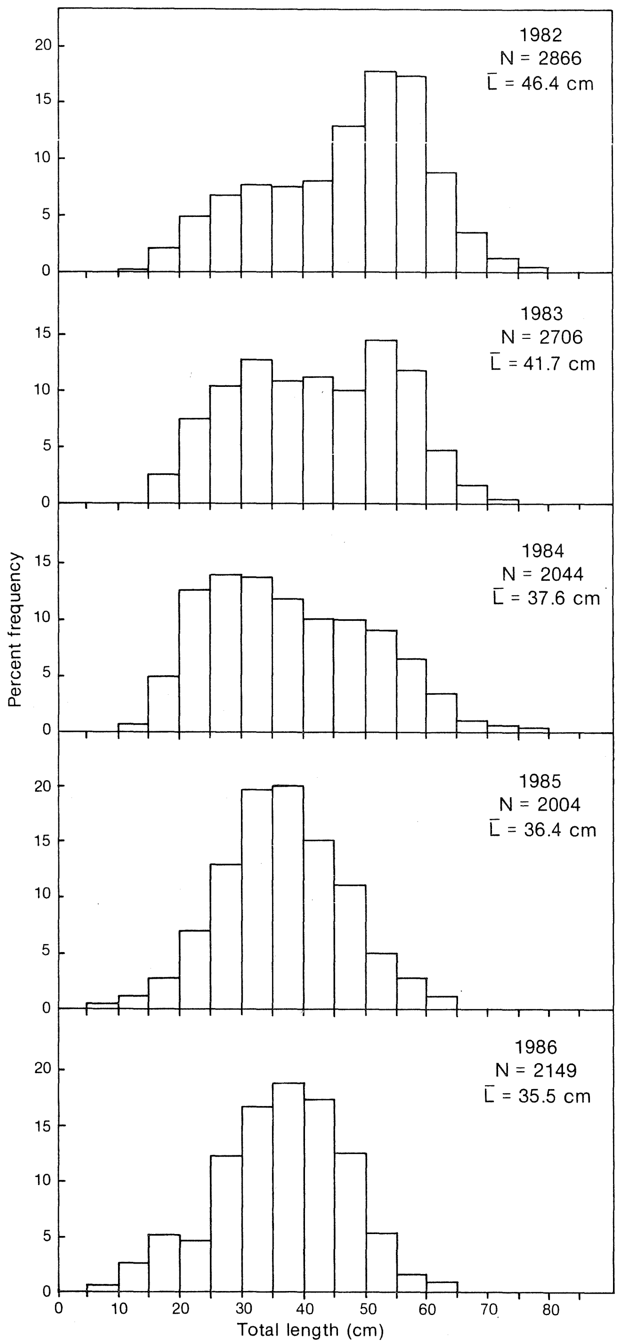

Fig. 4. Length distributions of Atlantic wolffish by year, from bottom-trawl surveys off West Greenland in 1982-86. (N = number of fish measured; $\bar{L}$ = mean length.)

same period, could have contributed significantly to the observed changes. Although the biomass of Atlantic wolffish did not change from 1984 to 1986, there was an increase in abundance after 1984 due to increased recruitment of young fish (see Fig. 4).

The mean lengths of both species in the trawl-survey catches increased from north to south in accord with the trends in modes of the length distributions. The same pattern was reported by Hansen (1957) for spotted wolffish in inshore waters.

TABLE 5. Recaptures of 53 spotted wolffish at West Greenland from tagging at various locations (see Fig. 5) during 1955-64.

Tagging area (Number tagged) (% recaptures)	Distance from tagging area (nm)	Time free (yr)	Direction from tagging area	Length when tagged (cm)
Upernavik and Umanak areas (129) (7.8%)	<10	(1 day)		76
		(<9 days)		71
		0.5		64
		0.7		79
		1.6		53
		1.7		62
		1.7		68
		2.0		67
		2.6		52
	120	13.0	South	66
Disko Island (56) (14.3%)	<10	(17 days)		76
		(23 days)		73
		1.0		67
		1.1		95
		2.0?		70
		3.9		78
	15	2.1	South	84
	?	6.0		107
Sisimiut area (229) (2.6%)	70	1.3	South	94
	420	6.2	South	68
	?	3.0		85
		3.7		86
		4.0		81
		4.0		83
Manitsoq area (44) (4.5%)	<10	1.4		71
		1.5		93
Nuuk area (284) (9.2%)	<10	0.3		91
		0.8		93
		0.8		111
		1.1		127
		1.4		103
		4.8		93
		5.7		97
		6.5		74
		6.8		101
	15	0.8	Fjord	97
		0.8	Fjord	99
		1.8	South	109
	20	0.8	South	108
		1.8	South	93
		1.9	Fjord	86
		1.9	Fjord	92
		10.1	Fjord	105
	60	1.3	Fjord	104
	110	2.9	North	110
	?	0.8		70
		1.3		82
		1.9		76
		2.2		101
		2.9		97
		5.9		74
		6.4		102
Other areas (4)	<10	(28 days)		113

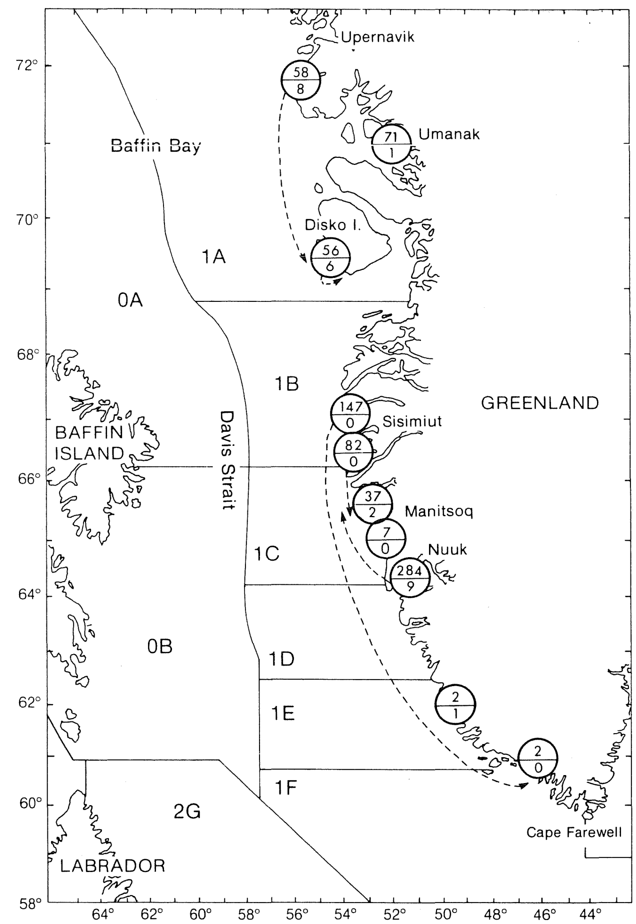

Fig. 5. Tagging locations of spotted wolffish along West Greenland are indicated by circles containing numbers of fish tagged (upper) and numbers of recaptures within 10 nm of tagging sites (lower). Arrow indicates direction and distance of most distant recapture from each tagging.

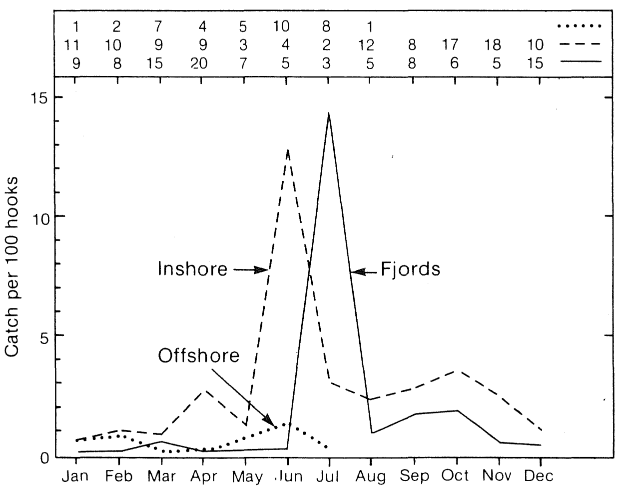

Fig. 6. Monthly distribution of mean catch per 100 hooks of spotted wolffish in the Nuuk area, with numbers of longline sets in the upper panel. (Offshore is more than 12 nm from coast, inshore is coastal area including outer parts of fjords, and fjords represent the inner parts of fjords.)

There were only two recaptures from 174 tagged Atlantic wolffish, and these were taken near the tagging area after about 2 years at large. Their sizes at the time of tagging (>70 cm) imply that they were probably mature. The recaptures of spotted wolffish from tagging in West Greenland inshore waters indicated that this species may be mainly stationary, although there were a few long-distance migrations. Similar conclusions from the tagging of spotted wolffish in the Barents Sea were reported by Østvedt (1963) and in the Newfoundland area by Templeman (1984).

From the tagging of spotted wolffish near Nuuk, six of 19 recaptures occurred east of the tagging area within Godthaab Fjord between 0.7 and 10 years after tagging. These results imply a movement into the fjords. Catch rates of spotted wolffish from extensive longline fishing in coastal waters near Godthaab Fjord and within the Fjord peaked in June and July respectively, implying a seasonal movement to the inner fjord area in summer.

Hansen (1968) hypothesized that adult spotted wolffish live chiefly in the southern waters of West Greenland where they propagate, and that the larvae are carried in surface currents to northern waters where they settle to the bottom. Upon reaching maturity, they migrate to the southern spawning grounds. This hypothesis was based partly on the occurrence of wolffish larvae in plankton samples and partly on trends in length composition of catches along West Greenland. While Hansen's (1968) hypothesis is supported in the present study by the north-to-south increase in size of spotted wolffish (similarly for Atlantic wolffish), it is not supported by the tagging results. Spotted wolffish appear to be rather stationary with little evidence of long-distance migration, although minor seasonal and local movements occur. It is necessary, therefore, to look for other explanations of the observed trends in length distribution. The most important fishery for wolffish occurs in the northern part of the survey area (Div. 1B and 1C), and harvesting of mainly large fish there may affect the length distribution of the population. There may also be a difference in growth of each species along West Greenland. Templeman (1986b) reported that the maximum length of Atlantic wolffish increases from north to south in the Northwest Atlantic, due to the onset of sexual maturity at considerably smaller sizes in the northern than in the southern parts of the region. This observation could be valid for wolffish in Greenland waters, but no data on sexual maturity are available.

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