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Northwest Atlantic Fisheries Organization

Serial No. N2561 NAFO SCR Doc. 95/50

SCIENTIFIC COUNCIL MEETING - JUNE 1995

Status of the Greenland halibut Fishery in Cumberland Sound, Baffin Island.

by

D. G. Pike and J. A. Mathias

Department of Fisheries and Oceans, Central and Arctic Region
Freshwater Institute Science Laboratory
Winnipeg, Manitoba, Canada. R3T 1N6

Abstract

A winter longline fishery for Greenland halibut was started in Cumberland Sound Baffin Island in 1987 (Pike, 1994). Fishing takes place between mid-January and the end of May. By 1992 the harvest had risen to just under 400 tons , a level which remained stable from 1992-1994. The catch has been monitored each year to the present by means of fishermen's records and a sampling of the catch for length, weight, age and maturity. Catch per unit of fishing effort (CPUE) varied significantly among years, but has not shown any temporal trend during the life of the fishery. Year-to-year variations in CPUE are confounded by changes in fishing location and changes in fishing technology. Ninety-seven percent of Greenland halibut sampled were female, and both males and females were either immature or not in spawning condition. Ripe or spent males or females were not observed. Growth rates of Greenland halibut from Cumberland Sound were similar to those found in Davis Strait. Mean length and weight of fish in the harvest was lower in 1993-1994 than in previous years, but there was no corresponding decrease in age. The dominant age range in the commercial harvest was 9-13 years and did not vary from year-to-year. The major by-catch consisted of Greenland shark and thorny skate. The harvest weight of sharks was often similar to the harvest weight of Greenland halibut, yet no market has been developed for these fish. The main issue for the halibut fishery at the present is whether the population in Cumberland Sound contributes significantly to the recruitment of fish in Davis Strait or whether it is a largely isolated population, similar to the situation in some of the Greenland Fjords. A scientific program is presently trying to resolve this issue through genetic, morphological and meristic comparisons of Cumberland Sound and Davis Strait populations, and through tagging and distribution studies.

Catch History and TAC

Since the mid-1980s, Baffin Island Inuit have sought access to marine commercial fishery opportunities for turbot, shrimp and scallops in the inshore marine areas and adjacent offshore areas of Hudson and Davis Straits. Marine fisheries are an important supplement to the traditional Inuit fisheries for arctic charr and marine mammals. The 1993 Nunavut Land Claims Agreement stipulates that special consideration will be given by government to the principles of adjacency and economic dependence when allocating commercial fishing licences in the adjacent offshore marine areas.

Greenland halibut are caught in Cumberland sound only during the winter, typically from February until the end of May. The fishery generally takes place within about 60 km of the town of Pangnirtung (Fig. 1) and is accessed by snowmobile. Fishermen commonly use longlines with about 100 hooks (range 50-200), attached to the longline at 2 m intervals by snoods approximately 0.5 m in length. The most widely used hook is a 14/0 circle hook, baited with strips of turbot meat with skin attached, usually 2-5 cm wide and 15-20 cm long. The longline is attached to a groundline which consists of at least 2 000 m of 2-4 mm braided polypropylene or nylon cord. Power winches are typically used to retrieve the longlines. Longlines are set using a 'kite' consisting of a weighted, rectangular piece of sheet metal attached to the end of the longline. The kite is oriented in the proper direction in the ice hole, then released and allowed to drag the longline and groundline. The kite provides enough lateral movement to allow the full length of the longline to lie on the bottom. When the kite reaches the bottom, a sliding weight is dropped, travelling down the groundline to the longline. More line is then released until the entire longline lays on the bottom. In the early years of the fishery, most fishermen set a single line by hand-cranked winch for a duration of about 2 hours, but today most fishermen operate with power winches and fish more than one longline simultaneously.

Immediately after capture, fish are gutted and their heads are removed. They are then placed in 0.5 m^{-3} insulated tanks filled with seawater slush. In this condition, they can be held for 2-4 days without freezing. They are transported to the fish plant in Pangnirtung by snowmobile and sled. Most fish are filleted and shipped fresh or frozen to southern markets.

Commercial Catch and Effort

The inshore fishery for Greenland halibut in Cumberland Sound, Baffin Island has developed rapidly since an initial harvesting of 186 fish in 1986 when Greenlandic fishermen visited to demonstrate

marine fishing methods. By 1992 the catch had risen to around 400 tons where it has remained relatively stable for the past 3 years (Fig. 2). Most of the increase in catch can be attributed to an increase in the number of fishermen (Fig. 2), but catches in the past three years are also affected by changes in technology. The Cumberland Sound fishery is now an important part of the local economy, valued at about $750,000 in 1993, and employing about 130 people seasonally as fishermen and fish plant workers.

The 1995 Total Allowable Catch (TAC) of Greenland halibut set by the Northwest Atlantic Fisheries Organization (NAFO) in Subareas 0 and 1 combined, was 11 000 tons. Of this, the Canadian allocation in Subarea 0 was 5 500 tons. From the Canadian allocation 1 000 tons has been sub-allocated to the Baffin inshore, Inuit fishery. Currently, the Cumberland Sound fishery operates within this sub-allocation under an experimental licence.

The catch and effort have been monitored each year of the fishery except 1988 by the fishermen who fill out forms on which they record details of their fishing activity. Each year the Canadian Department of Fisheries and Oceans samples the catch from entire longline sets of individual fishermen to measure the length, weight, sex and maturity of fish. Total catch is monitored at the fish processing plants in Pangnirtung.

Estimation of catch-per-unit-effort (CPUE) in the Greenland halibut fishery of Cumberland Sound is complicated by rapid technical change between 1987 and 1994. The major change has been a shift from hand-operated winches to power winches, an increase in the average number of longlines set daily per fisherman, and an increase in the average duration of longline sets. From 1987 to 1990, most longline sets were fished from 1-3 hours and the average duration was 2.0 hours (Table 1). But from 1991 to 1994, the set duration ranged as high as 20 hours (Fig. 3), and the average set duration increased to 6.9 hours (Table 1). Although there has been little change in the number of hooks fished per set (Table 1), the catch of Greenland halibut per set was significantly correlated with the number of hooks. Therefore the catch rate was adjusted to a standard unit of 100 hooks. When data from all sets and years were combined, there was an observable relationship between the catch per 100 hooks and the duration of sets (Fig. 4). On average, the catch after a set of one hour was about 12 fish/100 hooks, and for each hour after that, the catch increased at a rate of about 0.8 fish/100 hooks until a set duration of 8 hours was reached (Fig. 4). In order to adjust the catch rate for the set duration, catch rate was regressed against set duration within each year (Table 2). This relationship was not statistically significant (probability that $m = 0$ was greater than 0.05, Table 2) in 1987, 1988 and 1989 because set duration had not varied greatly during this time. Therefore in these years the catch per 100 hooks was simply averaged. From 1990 to 1994 however the relationship was statistically significant, and for these years catch per 100 hooks was adjusted by regression to a standard set duration of 2.0 hours. The standard CPUE was then expressed as number of fish caught per 100 hooks per 2.0 hours of set. Although CPUE varied significantly between years, there was no temporal trend (Fig. 5). The CPUE in the last three years of the fishery were not statistically different from that in the first two years. Factors which might cause CPUE to vary among years are the location and depth of fishing. Although fishing locations vary among years because of the location of the ice edge and ice conditions at the completion of freeze-up, the most common locations are generally found within a 25 km radius of each other (Fig. 1). Within this area, water depth can vary between 750 m and 950 m.

The weight of turbot caught per 100 hooks has remained stable from 1987 to 1994 (Fig. 6). This is the result of two opposing factors: since 1993, the mean weight of turbot has decreased (Fig. 6), while the number of turbot caught per 100 hooks has increased. The latter effect has been brought about by a shift to longer longline set duration (see above).

There was no seasonal change in the catch rate within years. When the catch per 100 hooks per hour for each set was plotted against date within each year, showed no consistent seasonal trend was observed.

The most frequently caught by-catch species were the Greenland shark (*Somniosus microcephalus*), and thorny skate, (*Raja radiata*), with catch rates (number of fish per 100 hooks) approximately two orders of magnitude less than that for Greenland halibut. The annual harvest weight of Greenland shark caught however, approximates that of Greenland halibut. The catch of Greenland shark was significantly correlated with set duration ($P<0.05$) but not with the number of hooks set. The catch of thorny skate was significantly correlated with the number of hooks set ($P<0.01$) but not with the duration of the set.

Catch-at-age and Size-at-age

The commercial catch was sampled over a period of several days in each year. The age of fish in the commercial catch ranged from 7-16 years (Table 3). Fish between 9 and 13 years of age dominated 85% of the catch while fish between 10 and 12 years dominated 65% of the catch. The age of fish which dominate the commercial catch did not exhibit a discernable trend between 1987 and 1994 (Table 3) and there was no decrease in the average age of fish in the catch between 1987 and 1994.

There has been a decreasing trend in average length-at-age of Greenland halibut in samples from the commercial catch from 1987 to 1994 (Fig. 7). This trend is most pronounced for larger fish. The sample size on which these analyses are based is shown in Table 3, and the variability (standard error of the means) is shown in Table 4.

There has been a decreasing trend in average weight-at-age of Greenland halibut in samples from the commercial catch from 1987 to 1994 (Fig. 8). This trend is most apparent in larger fish. The sample size on which these analyses are based is shown in Table 3, and the variability (standard error of the means) is shown in Table 5.

It is not clear why there the pronounced decrease in size-at-age was not accompanied by a decrease in the mean age of fish in the sampled commercial catch. There is no reason to assume errors in age reading since the age reader has been constant throughout this study.

Sex, Maturity ,Growth,and Distribution

Sex and maturity of Greenland halibut in the commercial fishery were assessed from 1990 onwards. Ninety-seven percent of Greenland halibut sampled were female, and both males and females were either immature or not in spawning condition. It is perhaps not surprising that males form only a small proportion of the catch since recruitment into the Cumberland Sound longline fishery begins at a length of about 500 mm, and males are much smaller than females (Fig.9). Females also dominate the catch in Greenland longline and gillnet fisheries (Riget and Boje, 1987).

Growth was essentially linear over the observed age range (Fig. 10). Females grew faster than males, and growth rates were similar to those found for Greenland halibut in Davis Strait by Atkinson *et al.* (1982). Length and age distributions for female Greenland halibut caught in Cumberland sound (Fig. 11) covered a much narrower range than those for fish caught in otter trawl fisheries in Davis Strait (Atkinson and Bowering, 1987) or the Gulf of St. Lawrence (Bowering, 1982), but were similar to those for fish caught by otter trawl in Cumberland Sound (see below). The Cumberland Sound length and age distributions were similar to those seen in Newfoundland and Greenland longline fisheries (Lear, 1970; Boje, 1991). It is likely that this is at least partially a function of gear selectivity, since otter trawls are far more effective in catching Greenland halibut <500 mm in length than are longlines (Chumakov *et al.*, 1981). However, experimental use of hook and bait sizes smaller than those used in the commercial fishery did not produce significantly smaller fish in Cumberland Sound. Thus it may be that smaller fish simply do not occupy the deep areas of Cumberland Sound that are fished commercially.

Stratified, Non-random Trawl Survey in Summer, 1994

In the summer of 1994, an exploratory trawl was fished in Cumberland Sound in an area outside of the winter fishing ground (Anon, 1994). A 67 foot, 650 hp, wooden stern dragger trawled to a maximum depth of 960 m using an IC 350 otter trawl with a 38 m headrope and 46 m foot rope. The trawl had a mesh size of 140 mm (5 1/2 in). The cod end had a 38 mm (1 1/2 in) mesh liner inside it. A total of 23 trawls were made along the northeastern shore of Cumberland sound from Pangnirtung to the mouth of the sound, but excluding the winter fishing area where no mobile gear was permitted (Fig. 12). The trawled area was divided into equal zones 30' of latitude and 1 degree of longitude in size. Some trawls were made in each area. The total area was further stratified into 50 m depth strata and fishing effort was distributed equally to these. Within each depth stratum trawl locations were non-random.

The trawlable biomass ranged from 0.0 kg/km2 at <275 m depth, to 2 678 kg/km2 at 900 m depth (Table 6). The length of Greenland halibut ranged from 184-980 mm with a mean of 494 mm (Fig. 13). Of 165 fish sampled, 156 were sexed, and 48.1% were females and 51.9% were males. Seventy-seven percent of fish were immature (Table 7). Ten percent of fish, mostly females, were in maturity stage 2, and 11%, all females, were ripening for the current year. The distribution of maturity stages was confirmed by an additional sample of 53 fish caught by a variety of gears and sent for analysis at the Freshwater Science Laboratory in Winnipeg. In that sample, which ranged in length from 365-728 mm (mean, 497 mm) 69.4% were females and 30.6% were males. Seventy-three percent of the fish were immature, 21.1% were in maturity stage 2 and 5.8% were in maturity stage 3.

During the summer of 1994, longlines and gillnets were fished on the winter fishing ground. Ground-lines consisted of an 11 mm rope, 91 m in length, with 36 cm hook lines attached at 1.8 m intervals. Each hook line had a #12 "Millward" circle hook, that was baited with seal entrails, mackerel or herring until turbot became available. Ground-lines were joined to form a longline fleet with a length of 549 m and 300 hooks. The CPUE of these longlines was fifteen times lower than comparable longlines fished during the winter in the same area. The summer Longline CPUE was similarly low in areas where turbot were caught by summer trawling. Gillnets fished on the bottom during the summer in the same areas also yielded low catches. These nets were monofilament, with a panel size of 91 m long by 3.7 m deep. The nets were joined to make a fleet of 10 or 15 nets.

Issues in the Cumberland Sound Fishery

One of the most important issues regarding the Cumberland Sound Greenland halibut fishery is whether the fish in Cumberland Sound contribute to the Davis Strait stock, either by emigration of juveniles spawned in Cumberland Sound, or by migration of adults into Davis Strait for spawning. Understanding the contribution of Greenland halibut from Cumberland Sound to Davis Strait is critical to the management of the fishery, especially in view of quota allocations between the inshore fishery and the Davis Strait fishery.

The channel connecting Cumberland Sound to Davis Strait is much more shallow (ca. 300 m) than the Sound proper, which extends to over 1 000 m. Also, bottom water temperatures down to a depth of 300 m during the summer are colder than -0.5 degrees celsius, while temperatures near the bottom of the Sound are slightly above 0 degrees (Fig. 14). It may be that colder water at 300 m depth acts as a barrier to adult migration out of the sound. Several attempts to catch Greenland halibut with longlines and gillnets in deep water during the summer have been unsuccessful. This suggests that the turbot might migrate away from the fishing areas in summer, or alternatively, that the fish are less associated with the bottom during the summer. Low longline and gillnet catches in the same areas where fish were caught by trawling during the summer tend to support the latter supposition. Attempts to tag fish during the winter fishery have not been successful, presumably because of low water temperatures in the top 100 m of the water column (Fig. 15). A program to locate concentrations of Greenland halibut for tagging during the summer is scheduled for August, 1995.

The genetic and morphological relationship among stocks of Greenland halibut in Cumberland Sound, Davis Strait, Gulf of St. Lawrence and other locations is being analyzed by the Canada Department of Fisheries and Oceans. Alloenzyme, meristic and morphometric analyses are being carried out through the Freshwater Institute Science Laboratory in Winnipeg, Manitoba, in collaboration with the Northwest Atlantic Fisheries Centre in St. John's, Newfoundland which is carrying out DNA analyses on the same samples of fish.

Very few fish from Cumberland Sound have been observed in spawning or post-spawning condition. This situation is analogous to that in the fiords of western Greenland. Boje and Riget (1987) postulated that temperatures were not warm enough in the Greenland fiords to permit spawning in most years. It is possible that a similar situation exists in Cumberland Sound.

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Table 1. Characteristics of longline sets in the Cumberland Sound Greenland halibut fishery, 1987-94.

YEAR	NO. SETS EXAMINED	MEAN SET DURATION (hrs)	MEAN NO. HOOKS SET	MEAN NO. HOOKS LOST	MEAN NO. HOOKS FISHED
1987	111	1.9	96	19	87
1989	827	2.0	106	5	100
1990	1447	2.0	102	5	98
1991	485	3.0	103	2	101
1992	482	3.4	107	2	105
1993	1127	5.2	105	3	102
1994	699	6.9	104	4	101

Table 2. Linear regressions between Greenland halibut catch per 100 hooks and set duration, Cumberland Sound commercial fishery, 1987-1994. Regression equation is: CPU = a + m(D), where CPU = catch per 100 hooks and D = set duration.

YEAR	N	a	P[a]	m	P[b]
1987	110	10.053	0.116	3.520	0.295
1989	808	15.853	0.000	0.127	0.401
1990	1395	13.121	0.000	0.273	0.241
1991	474	11.843	0.000	0.243	0.032
1992	476	14.086	0.000	1.598	0.000
1993	477	15.706	0.000	0.868	0.000
1994	690	17.293	0.000	0.670	0.000

[a] probability that a = 0.
[b] probability that m = 0

Table 3. Greenland halibut in the Cumberland Sound commercial fishery. Distribution of catch-at-age by year between 1987 and 1994.

AGE	1987	1988	1989	1990	1991	1992	1993	1994	TOTAL
7	4	0	1	3	0	0	0	0	8
8	16	4	1	1	1	3	4	0	30
9	65	3	13	7	2	20	16	9	135
10	65	30	20	15	5	29	35	16	215
11	62	47	50	41	6	37	45	38	326
12	29	39	35	25	13	27	27	40	235
13	9	26	4	9	16	16	11	32	123
14	3	1	3	3	3	7	3	12	35
15	1	0	0	1	1	0	0	5	8
16	1	0	0	0	1	0	1	1	4

Table 4. Greenland halibut in the Cumberland Sound commercial fishery. Length-at-age for each year. Mean fork length (mm) and C.V. are shown.

AGE	1987	1988	1989	1990	1991	1992	1993	1994
7	493	-	572	533	-	-	-	-
	0.02	-	-	0.06	-	-	-	-
8	528	523	-	595	580	583	563	-
	0.04	0.05	-	-	-	0.05	0.06	-
9	607	593	607	620	600	602	569	549
	0.05	0.09	0.13	0.08	0.01	0.10	0.10	0.04
10	671	642	685	668	626	646	607	559
	0.04	0.06	0.09	0.06	0.15	0.10	0.08	0.06
11	723	704	725	716	701	632	653	594
	0.03	0.05	0.05	0.06	0.18	0.12	0.09	0.07
12	781	760	767	773	754	688	718	656
	0.03	0.03	0.10	0.03	0.12	0.12	0.06	0.07
13	849	813	809	823	798	749	784	700
	0.05	0.04	0.01	0.06	0.09	0.15	0.10	0.09
14	823	880	853	859	891	779	868	790
	0.07	-	0.07	0.07	0.06	0.12	0.04	0.11
15	870	-	-	945	790	-	-	829
	-	-	-	-	-	-	-	0.09
16	1050	-	-	-	1010	-	935	905
	-	-	-	-	-	-	-	-
	-							

Table 5. Greenland halibut in the Cumberland Sound commercial fishery. Annual weight-at-age for the most frequently caught ages. Mean weight (kg) and C.V. are shown.

AGE	1987	1988	1989	1990	1991	1992	1993	1994
7	1.330	-	2.650	1.583	-	-	-	-
	0.09	-	-	0.25	-	-	-	-
8	1.623	1.425	-	2.10	1.95	1.90	1.763	-
	0.14	0.08	-	-	-	0.16	0.20	-
9	2.436	2.317	2.327	2.436	1.950	2.192	1.822	1.639
	0.16	0.37	0.37	0.22	-	0.44	0.35	0.17
10	3.336	2.895	3.475	3.063	2.540	2.846	2.360	1.753
	0.16	0.20	0.31	0.23	0.52	0.34	0.33	0.20
11	4.140	3.737	4.044	3.887	4.075	2.647	2.917	2.158
	0.16	0.17	0.16	0.19	0.65	0.46	0.31	0.23
12	5.476	4.713	5.134	5.066	5.304	3.628	3.922	2.943
	0.12	0.11	0.24	0.14	0.43	0.40	0.22	0.22
13	7.469	5.979	5.625	6.572	5.959	5.009	5.236	3.770
	0.19	0.12	0.13	0.24	0.31	-	0.32	0.30
14	6.433	7.150	6.650	7.567	8.500	5.521	7.067	5.867
	0.22	-	0.30	0.27	0.22	0.45	0.27	0.37
15	7.800	-	-	8.500	6.400	-	-	6.370
	-	-	-	-	-	-	-	0.30
16	13.60	-	-	-	13.05	-	10.05	8.500
	-	-	-	-	-	-	-	-

Table 6. Summary of trawlable biomass of Greenland halibut by depth strata, in Cumberland Sound, Baffin Island. Area and Total Trawlable Biomass refer to strata within the survey area only.

DEPTH STRATUM (m)	NUMBER OF TOWS	TRAWLABLE BIOMASS (kg/m^2)	AREA (km^2)	TOTAL TRAWLABLE BIOMASS (kg)
91-183	1	0	6,277	0
184-274	5	0	6,625	0
275-366	7	10.99	3,961	43,531
367-457	1	9.71	1,477	14,342
458-640	2	523.98	1,105	578,998
641-732	1	18.94	997	18,883
732-823	2	2,171.29	885	1,921,592
824-914	2	2,677.80	859	2,369,853
915-1006	2	605.46	496	300,308
	TOTAL		22,684	5,247,507

Table 7. Percent of Greenland halibut caught by otter trawl in August, 1994 in Cumberland Sound at different maturity stage, by sex. N = 156.

	SEX		
MATURITY STAGE[a]	FEMALE	MALE	COMBINED
1	26.3	50.6	76.9
2	10.3	0.6	10.9
3	11.5	0.0	11.5
4	0.0	0.0	0.0
5	0.0	0.6	0.6

[a] Stage 1 = immature, Stage 2 = resting, first time mature, or ripening for next year, Stage 3 = maturing or ripening for the present year, Stage 4 = running or recently spent, Stage 5 = spent and recovering.

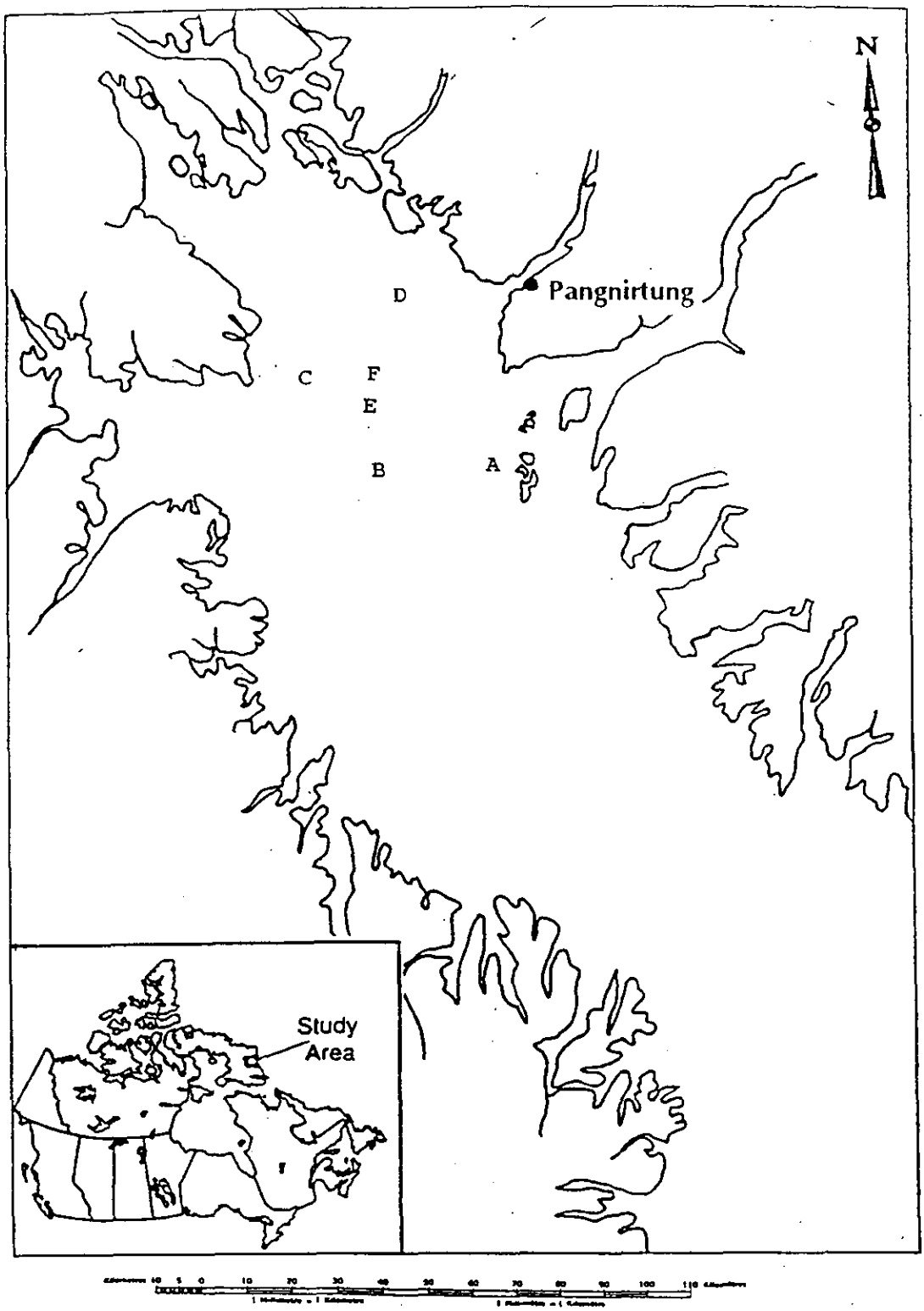

Fig. 1. Areas fished commercially and experimentally in Cumberland Sound, 1987-1992. A - Fished 1989, 1990; B - Fished 1989, 1990; C - Fished 1989, 1990, 1991; D - Fished 1992; E - Fished 1991, 1992; F - Experimental fishery, 1992.

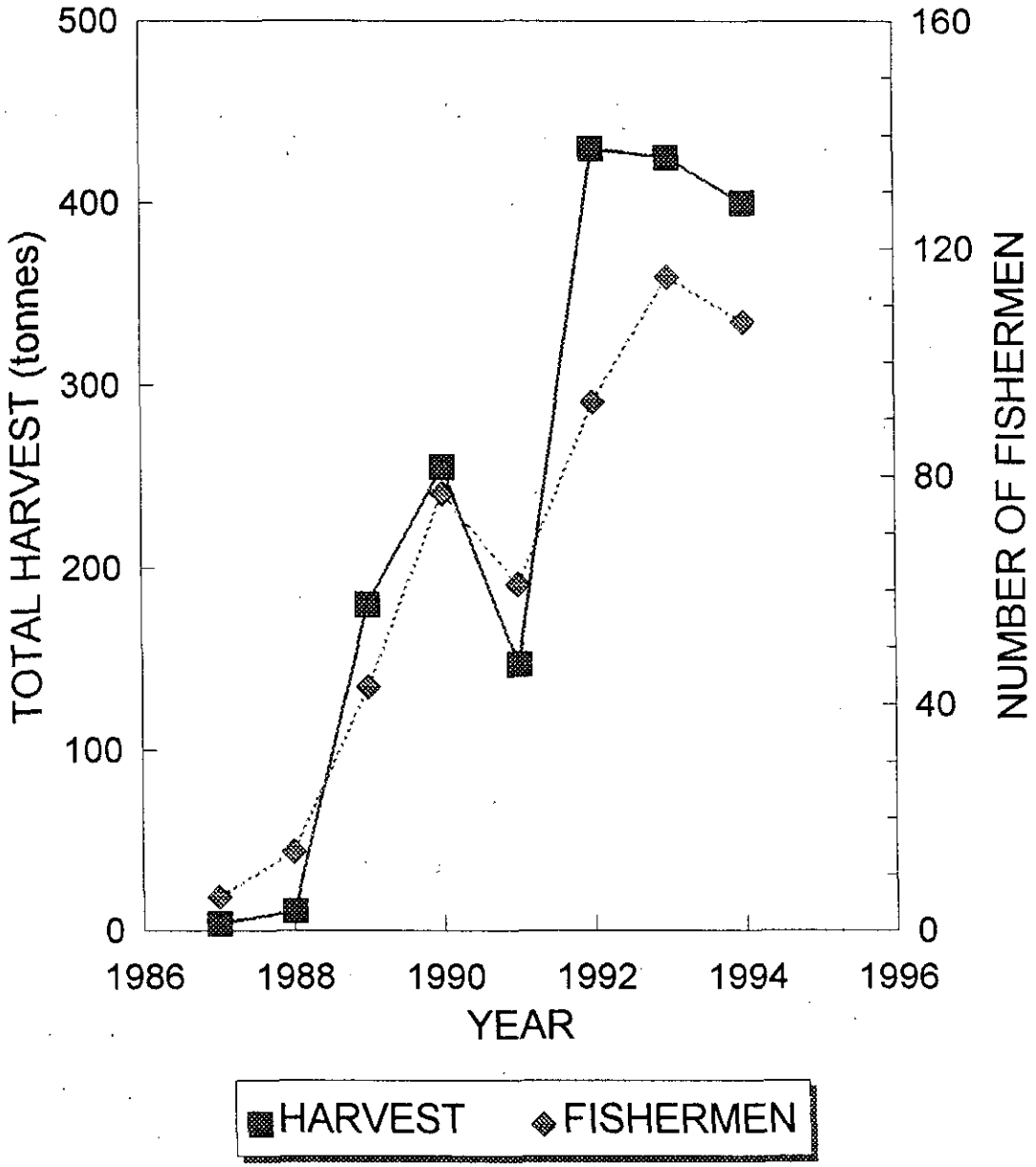

Fig. 2. Commercial harvest of Greenland halibut in Cumberland Sound from 1987 to 1994, (left axis), and number of licenced fishermen plus assistants (right axis), from 1987-1993. Number of licenced fishermen not including asisstants is shown for 1994.

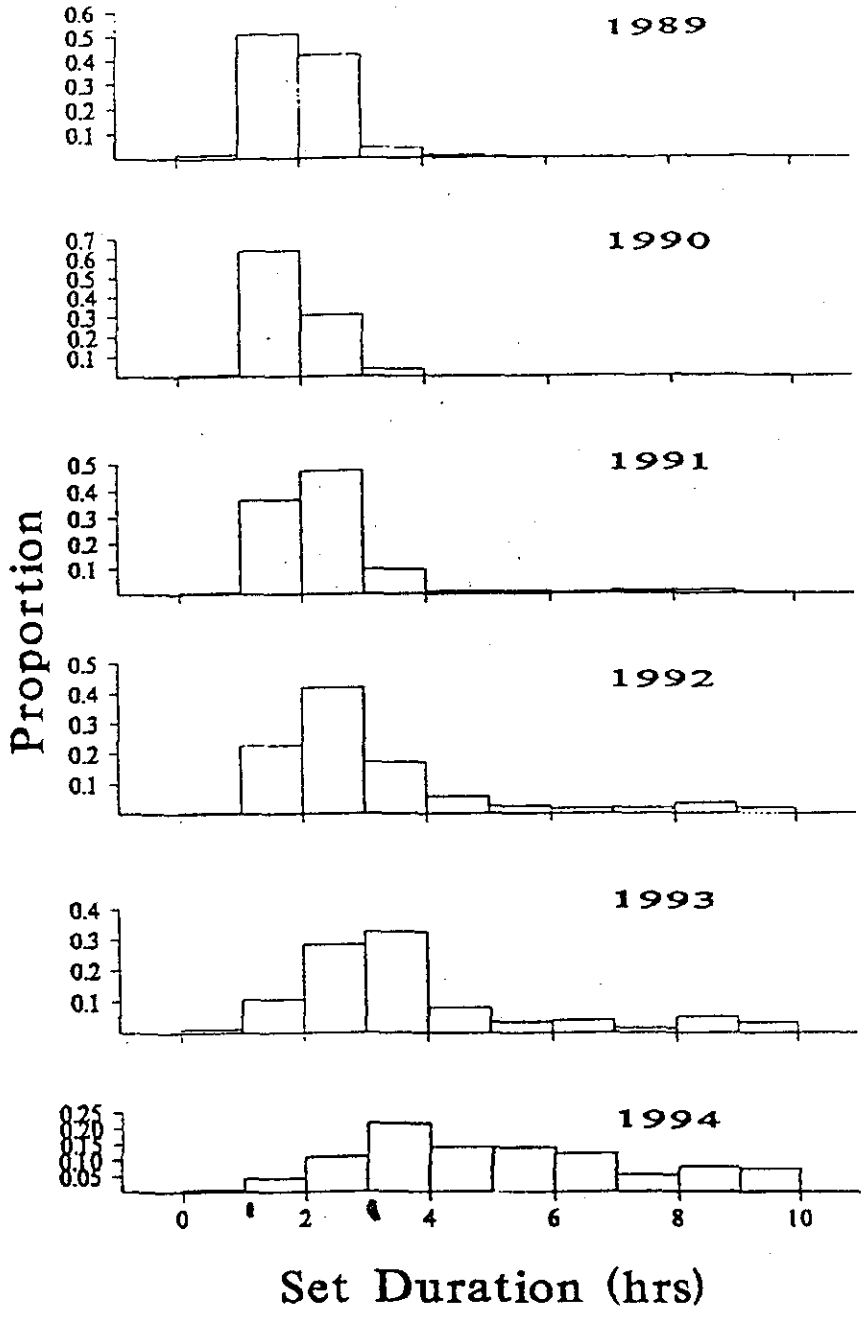

Fig. 3. Frequency distributions of longline set durations in Greenland halibut fishery, Cumberland Sound, 1987-1994. A few set durations ranged as high as 20 hours (not shown).

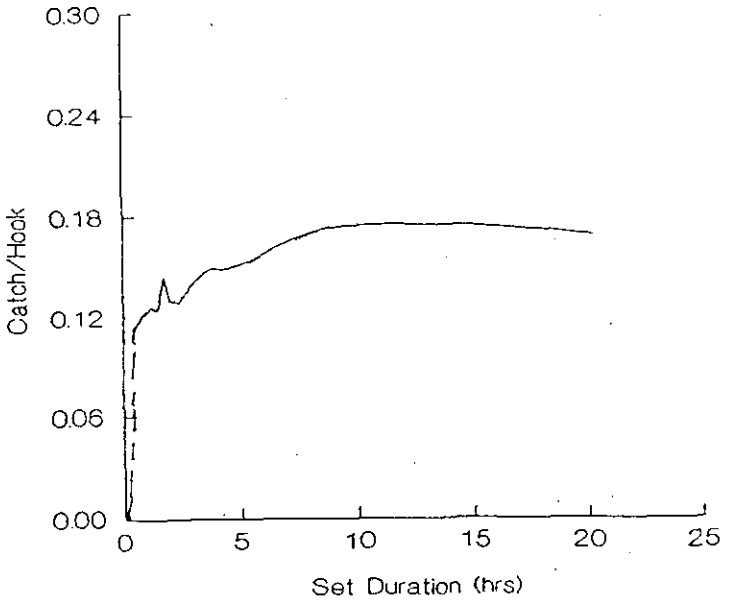

Fig. 4. Relationship between Catch/hook and set duration of longline sets in Cumberland Sound, 1987-1994. Solid line is mean trend line using non-parametric LOWESS smoothing (Wilkinson 1990).

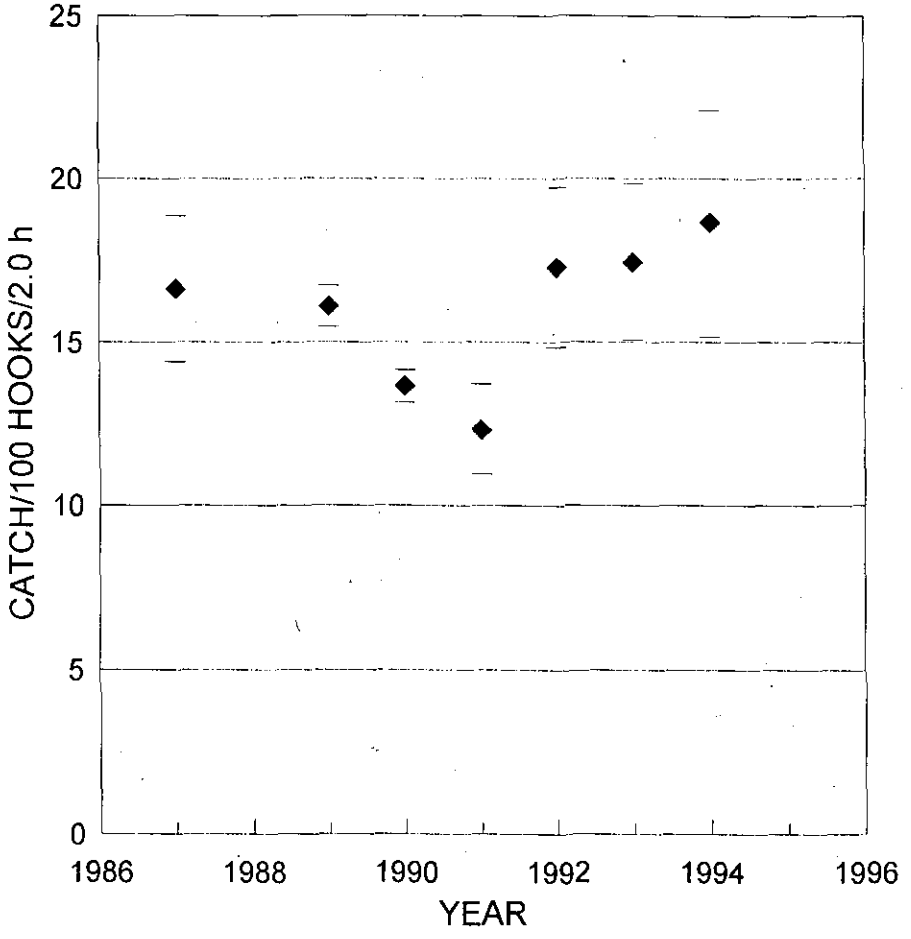

Fig. 5. Average catch per unit effort (CPUE) of longline sets for Greenland halibut in Cumberland Sound, and 95% confidence limits. See text for method of calcuclation.

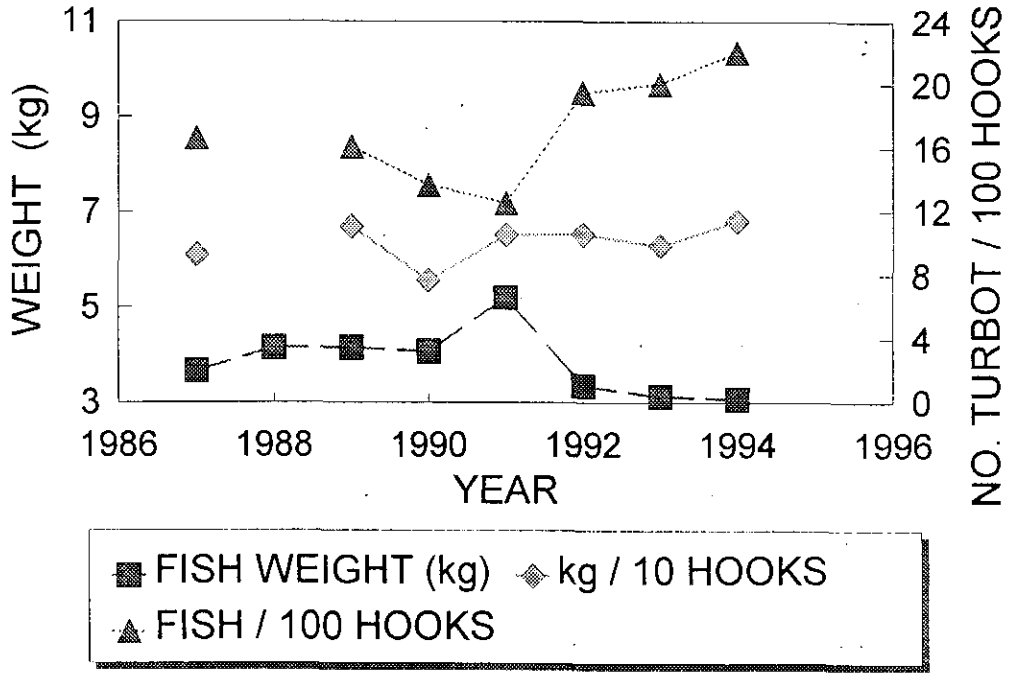

Fig. 6. Average fish weight in samples of the commercial catch (left axis). Average total weight of fish caught per 10 hooks of longline set (left axis). Average number of fish caught per 100 hooks of longline set (right axis). Greenland halibut fishery in Cumberland Sound, Baffin Island.

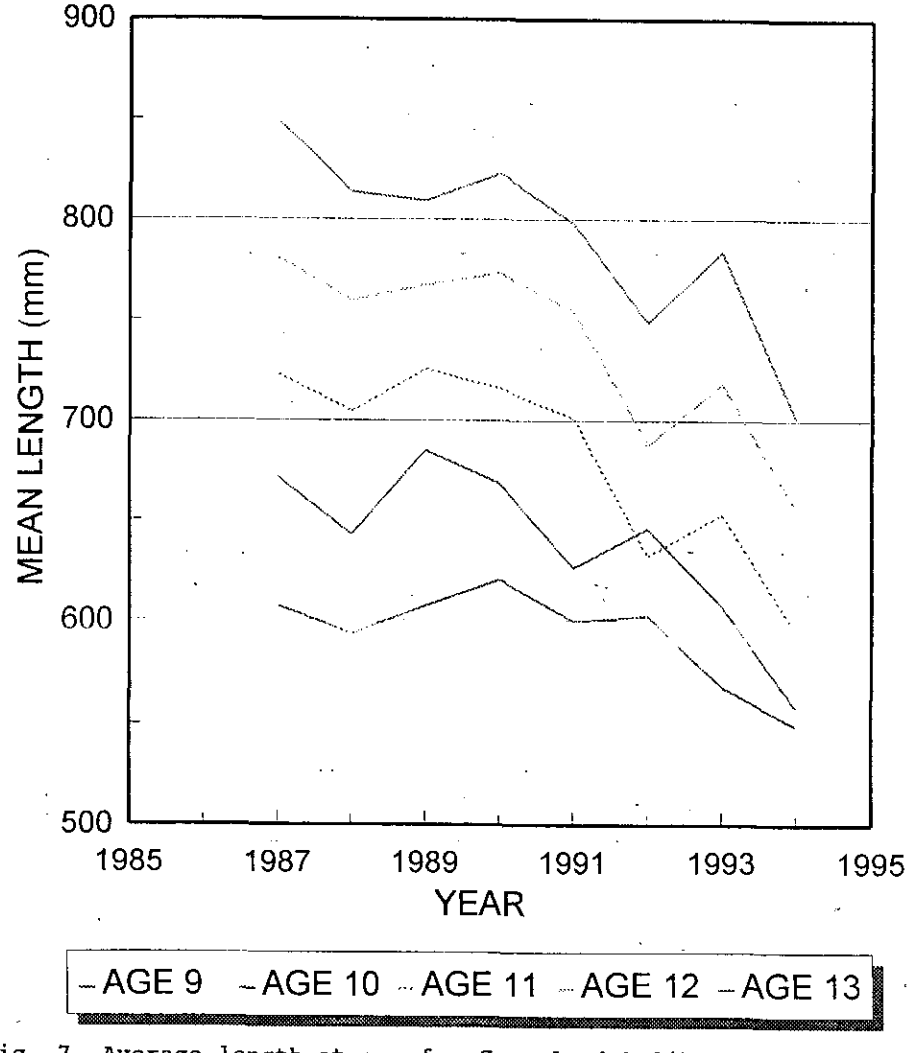

Fig. 7. Average length-at-age for Greenland halibut sampled from the commercial longline fishery in Cumberland Sound, Baffin Island, 1987-1994.

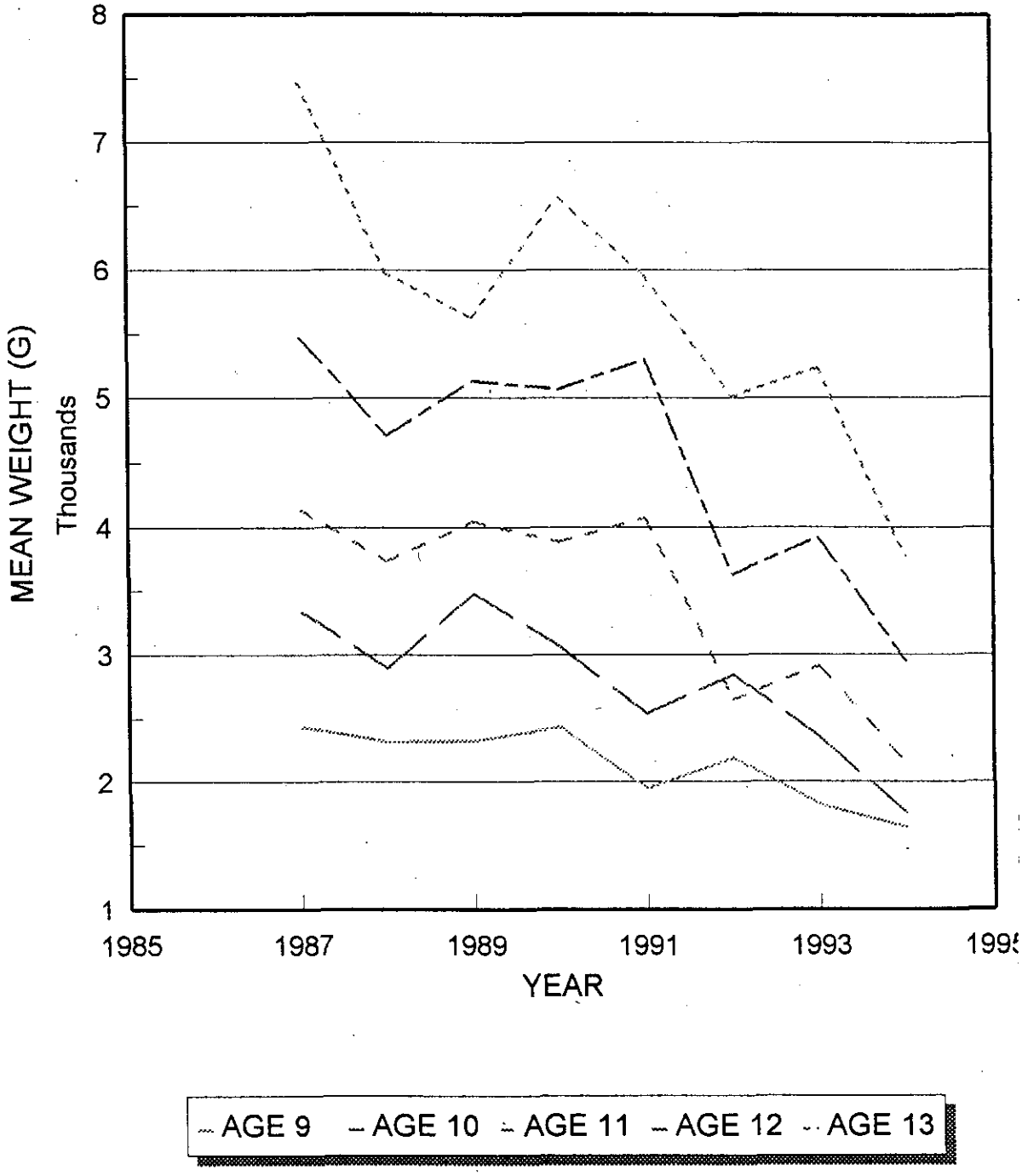

Fig. 8. Average weight-at-age for Greenland halibut sampled from the commercial longline fishery in Cumberland Sound, Baffin Island, 1987-1994.

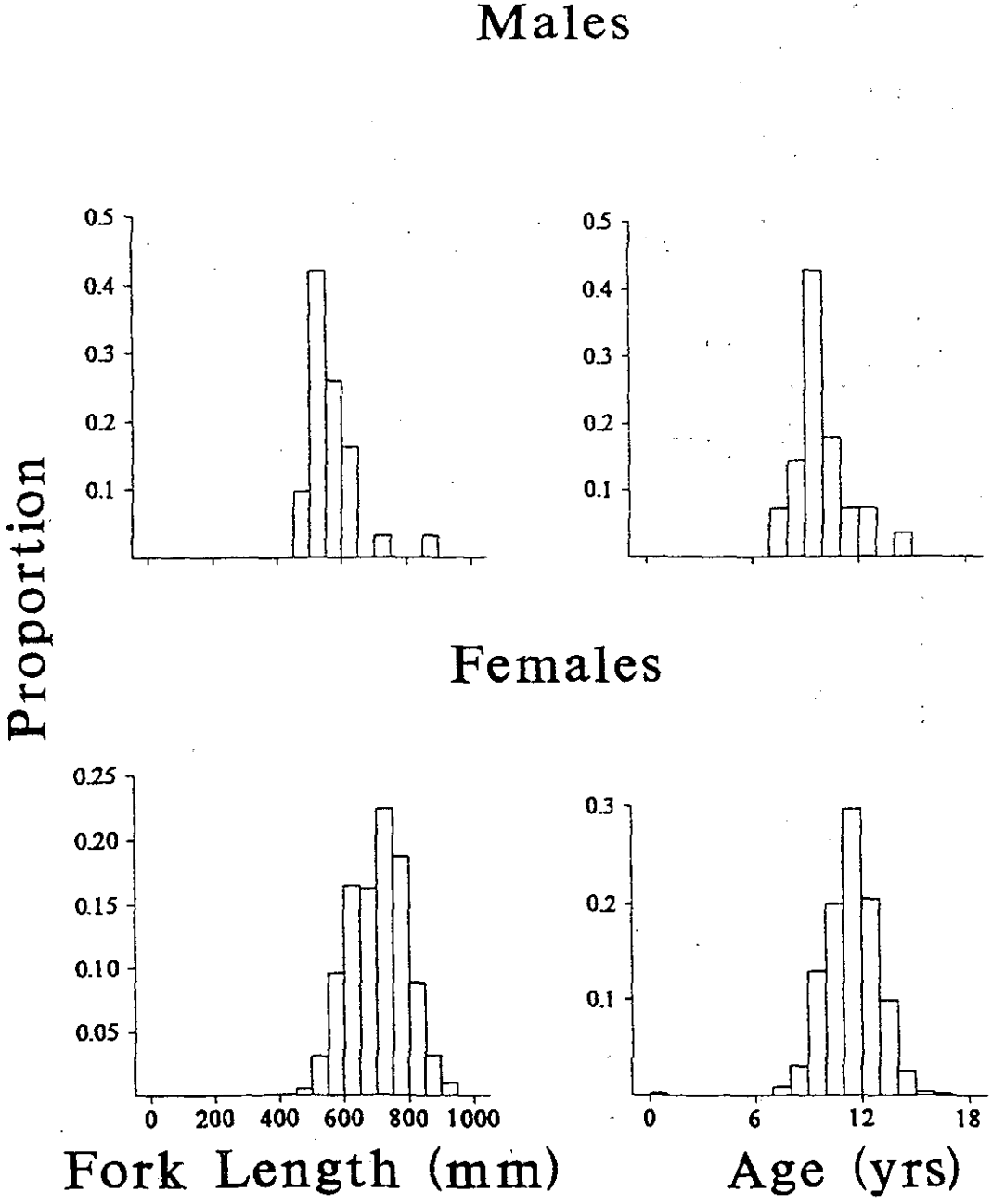

Fig. 9. Length and age frequencies of male and female Greenland halibut sampled from the Cumberland Sound winter longline fishery, 1987-1992.

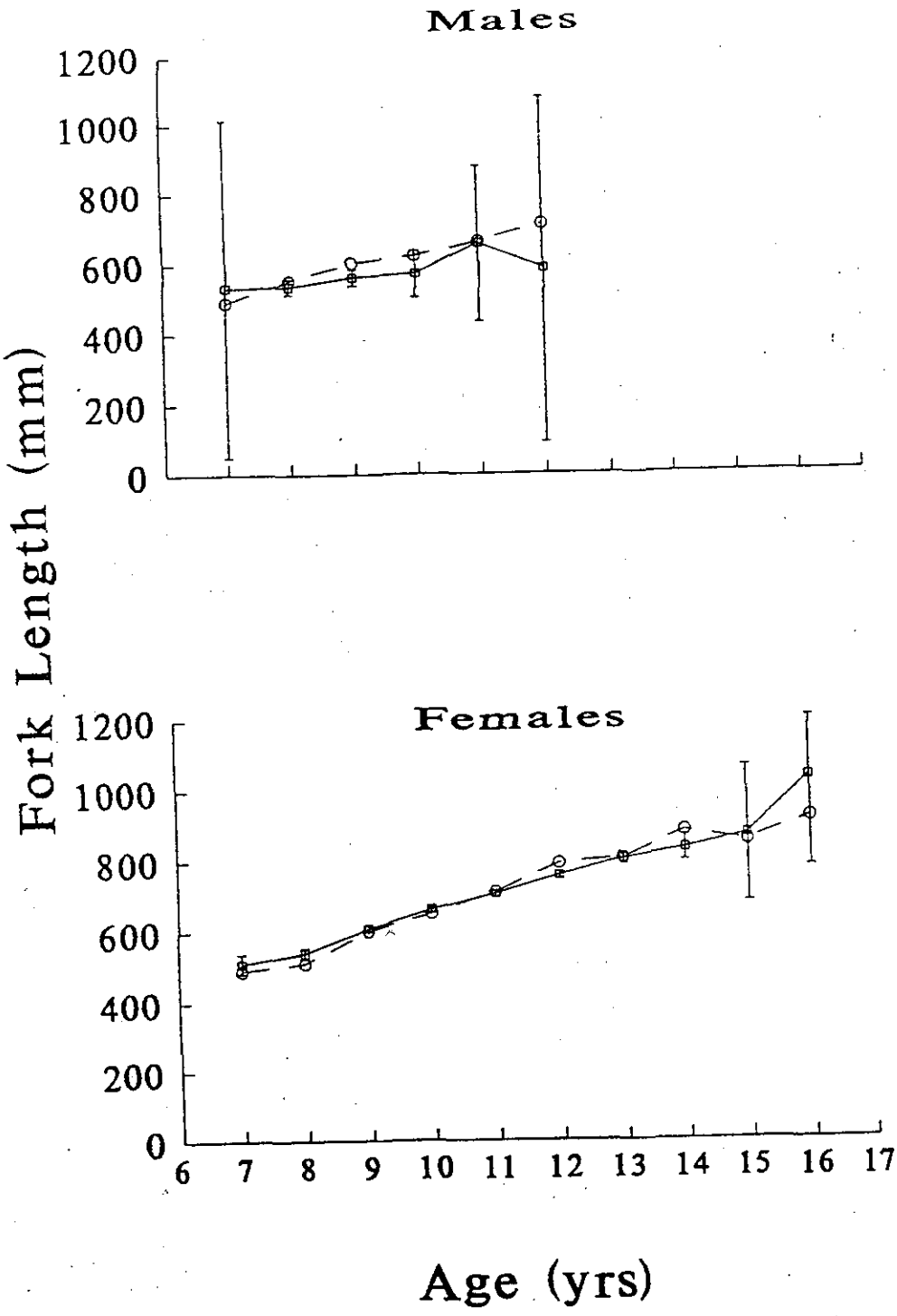

Fig. 10. Average length at average age of male and female Greenland Halibut caught in the Cumberland Sound winter longline fishery (solid line with 95% confidence limits), and from Davis Strait (dashed line, from Atkinson et al. 1982).

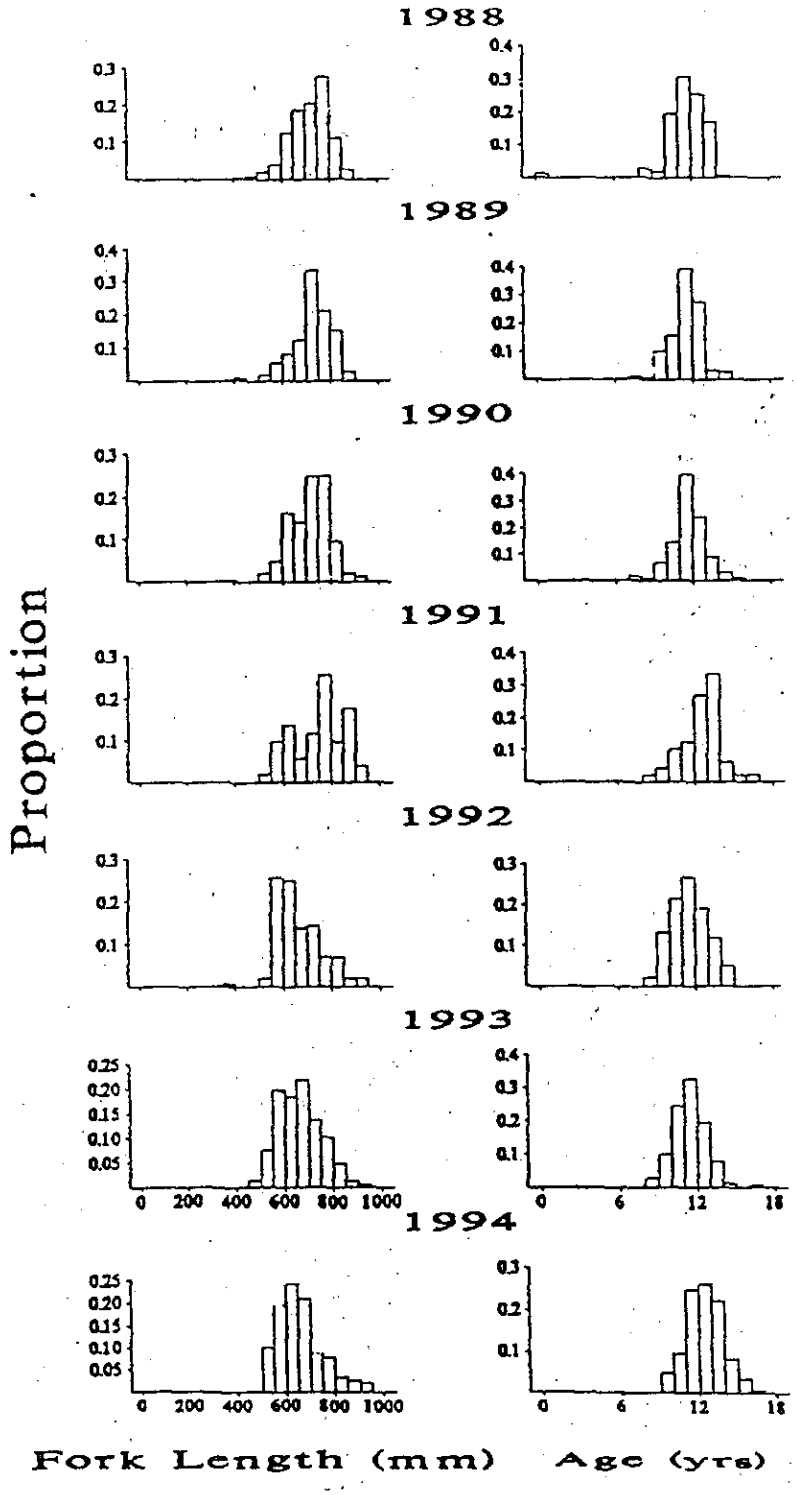

Fig. 11. Length and age distributions of female Greenland halibut caught in the winter longline fishery of Cumberland Sound, 1988-1992.

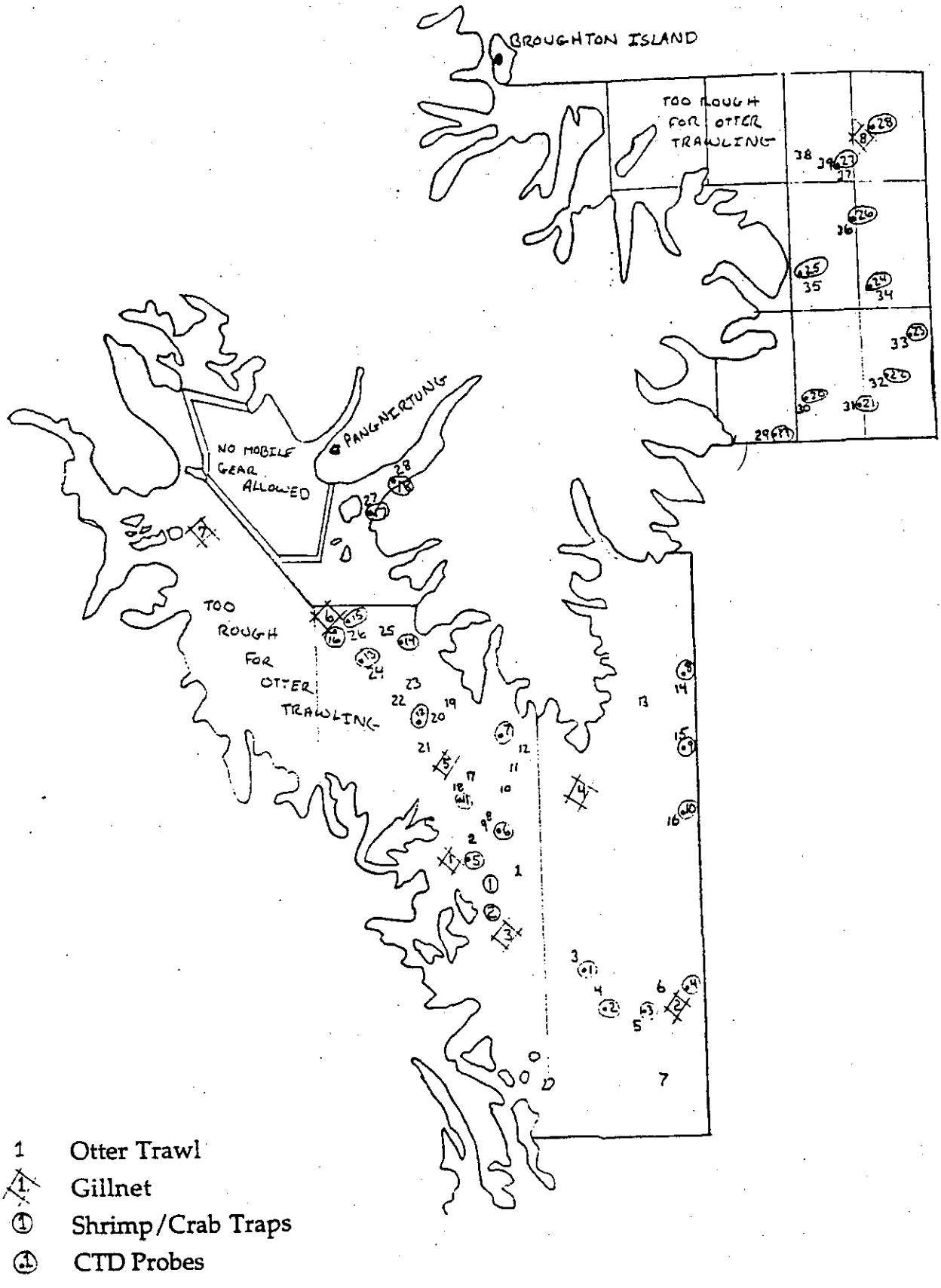

Fig. 12. Map of sampling sites for the Cumberland Sound otter trawl and gillnet survey, August, 1994.

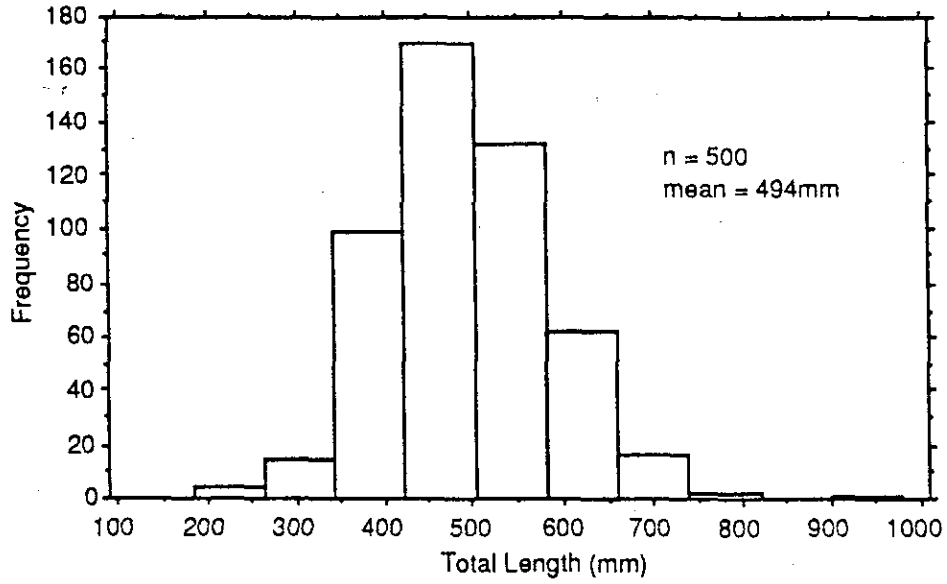

Fig. 13. Length distribution of Greenland halibut sampled by otter trawl in Cumberland Sound, August, 1994.

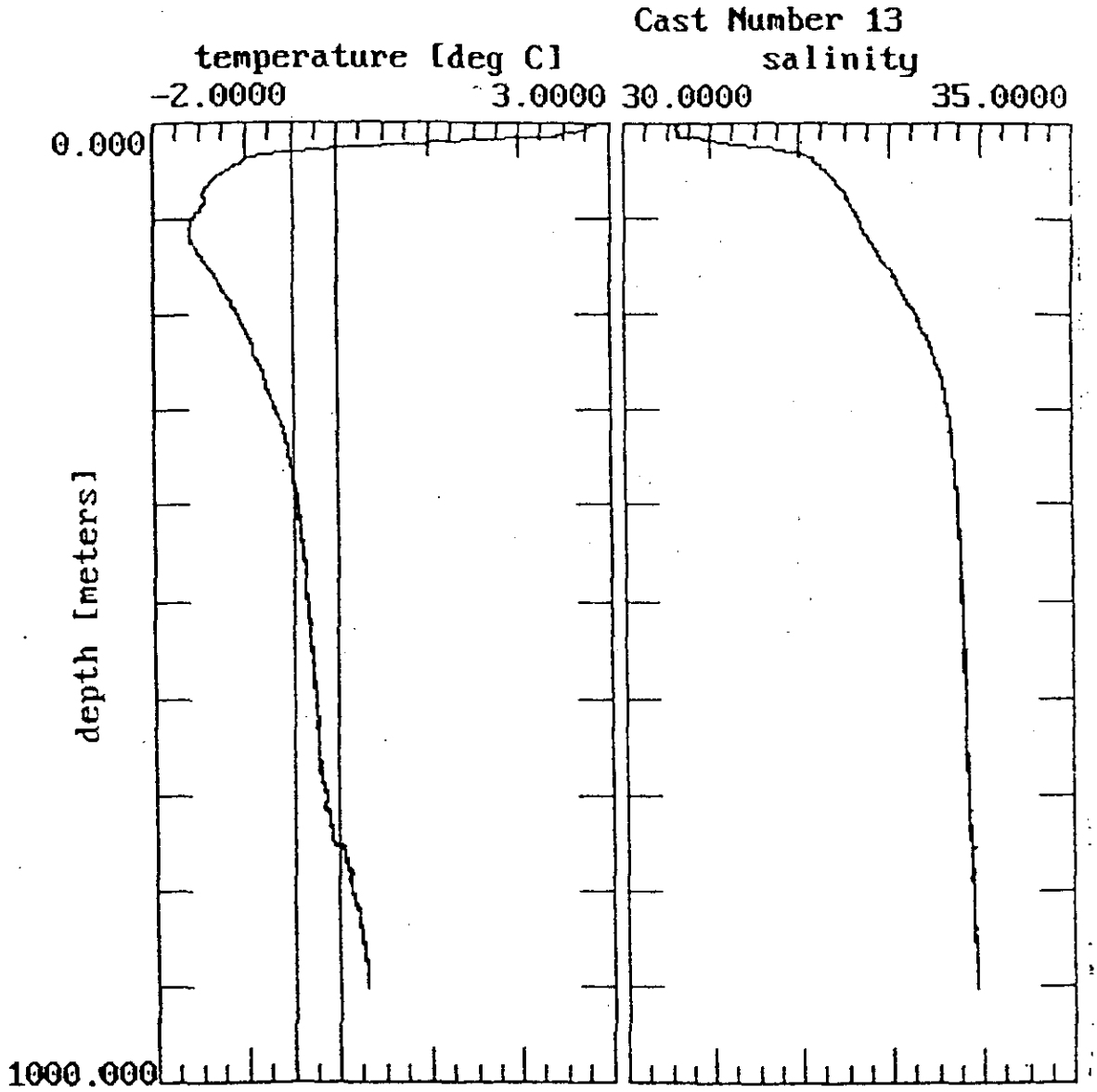

Fig. 14. A typical profile of temperature and salinity in the water column of Cumberland Sound, July, 1994.

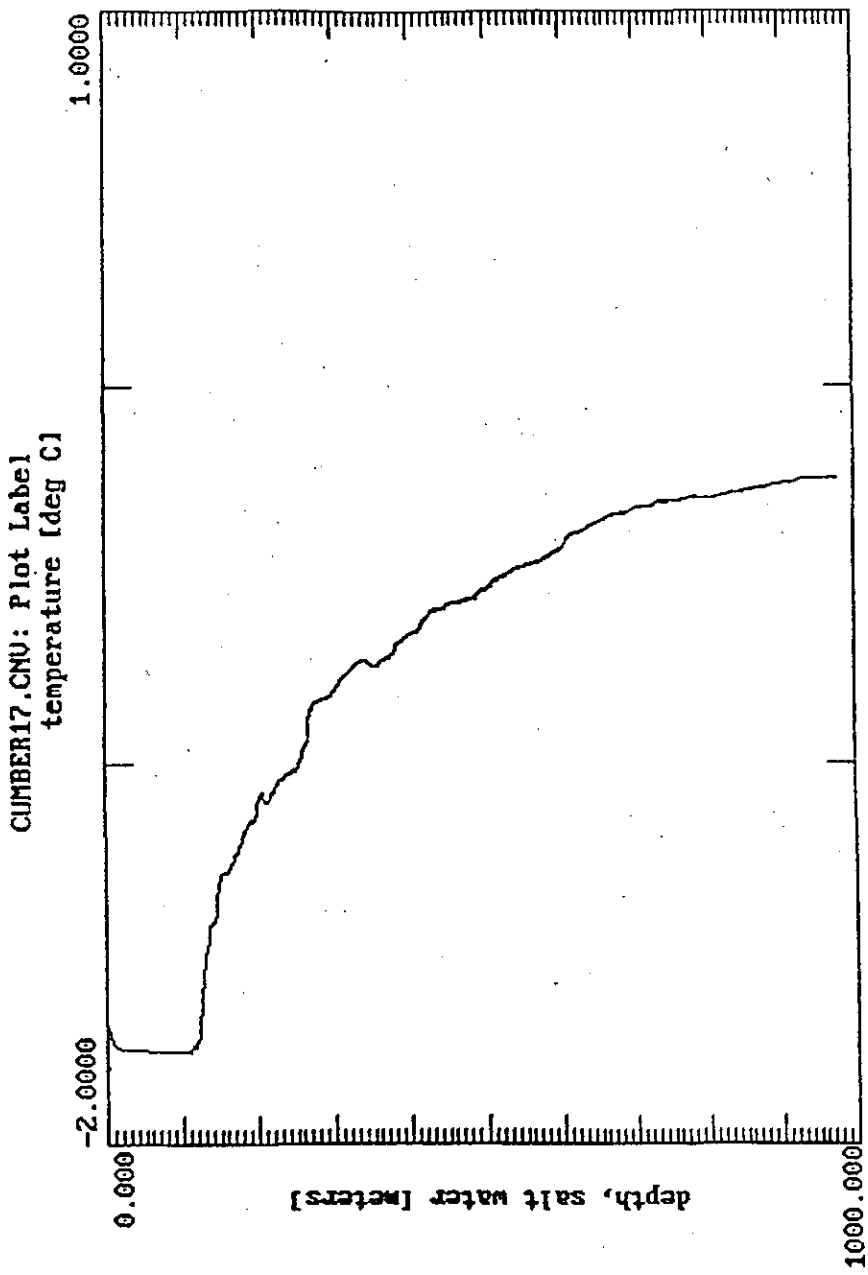

Fig. 15. Temperature profle of Cumberland Sound, March, 1994.