Canadian Technical Report of

Fisheries and Aquatic Sciences 1924

1994

THE FISHERY FOR GREENLAND HALIBUT (*Reinhardtius hippoglossoides*) IN CUMBERLAND SOUND, BAFFIN ISLAND, 1987-1992

by

D.G. Pike[1]

Central and Arctic Region

Department of Fisheries and Oceans

Winnipeg, Manitoba R3T 2N6

This is the 55th Technical Report

from the Central and Arctic Region, Winnipeg

[1] Department of Fisheries and Oceans, Eastern Arctic Office, P.O. Box 358, Iqaluit, NT. X0A 0H0

ERRATA

Pike, D.G. 1993. The fishery for Greenland halibut (*Reinhardtius hippoglossoides*) in Cumberland Sound, Baffin Island, 1987-1992. Can. Tech. Rep. Fish. Aquat. Sci. 1924: iv + 20 p.

Page 9 - Titles of Table 3 should read

Year	Site	N	Mean Length (mm)	Mean Age (Yrs)	Mean Weight (g)	Mean K[a]	Z[b]	Range[c] (yrs)	M12[d] (mm)	Growth Rate Length=m(Age)+b	
										m	b

Page 9 - Table 4 should read

Hook[a]	No. Sets	No. Fish	CHH[b]	Mean Age (yrs)	Mean Fork Length (mm)
S	11	22	.026	10.5	629
M	11	49	.067	10.3	652
L	11	48	.058	10.3	670
COM	476	148	.070	11.0	662

Cat. no. Fs 97-6/1924E ISSN 0706-6457

Correct citation for this publication is:

Pike, D.G. 1994. The fishery for Greenland halibut (*Reinhardtius hippoglossoides*) in Cumberland Sound, Baffin Island, 1987-1992. Can. Tech. Rep. Fish. Aquat. Sci. 1924: iv + 20 p.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Pike, D.G. 1994. The fishery for Greenland halibut (*Reinhardtius hippoglossoides*) in Cumberland Sound, Baffin Island, 1987-1992. Can. Tech. Rep. Fish. Aquat. Sci. 1924: iv + 20 p.

Catch per unit effort (CPUE) and biological data were collected from the fishery for Greenland halibut (*Reinhardtius hippoglossoides*) in Cumberland Sound from 1987-1992. Catch per unit effort showed no consistent diurnal or seasonal trends within years, but did vary between years. Mean CPUE was lower in 1991 and 1992 than in the earlier years of the fishery. Ninety-seven percent of the fish caught were female, and all were either immature or not in spawning condition. The prevalence of females in the catch may have been a result of gear selectivity. Males were smaller, younger and grew more slowly than females. There were no trends in mean length, mean age, total instantaneous mortality or growth rate of female Greenland halibut that were indicative of possible overexploitation. By-catch of Greenland shark (*Somniousus microcephalus*) and thorny skate (*Raja radiata*) was significant but unutilized in the fishery. Management and research recommendations for the Cumberland Sound fishery are outlined.

Key words: Greenland halibut; *Reinhardtius hippoglossoides;* longlining; catch/effort; fisheries; fishery monitoring; fishery management.

RÉSUMÉ

Pike, D.G. 1994. The fishery for Greenland halibut (*Reinhardtius hippoglossoides*) in Cumberland Sound, Baffin Island, 1987-1992. Can. Tech. Rep. Fish. Aquat. Sci. 1924: iv + 20 p.

Des données sur les prises par unité d'effort (PUE) et des données biologiques ont été recueillies pour la pêcherie de flétan du Groenland (*Reinhardtius hippoglossoides*) dans le détroit de Cumberland de 1987 à 1992. Les données sur les prises par unité d'effort n'ont révélé aucune tendance diurne ou saisonnière constante dans une année particulière, mais il y avait une variation d'une année à l'autre. Les PUE moyennes étaient plus faibles en 1991 et 1992 que dans les années antérieures. Quatre-vingt-dix-sept pour cent des poissons capturés étaient des femelles et tous étaient immatures on n'étaient pas en état de frayer. La fréquence élevée des femelles dans les prises pourrait être le résultat de la sélectivité des engins de pêche. Les mâles étaient plus petits, plus jeunes et avaient une croissance plus lente que les femelles. In n'y avait pas de tendance en ce qui a trait à la longueur moyenne, à l'âge moyen, à la mortalité instantanée totale ou au taux de croissance des femelles de flétan du Groenland qui indiquerait une surexploitation possible. La prise accidentelle de laimargue (*Somniosus microcephalus*) et de raie radiée (*Raja radiata*) était élevée, mais ces prises demeurent inutilisées par la pêcherie. Les recommandations pour la gestion et la recherche en ce qui concerne la pêcherie du détroit de Cumberland sont décrites.

Mots clés: flétan du Groenland; *Reinhardtius hippoglossoides*; pêche à la palangre; prises effort; pêcheries; surveillance des pêches; gestion des pêches.

INTRODUCTION

Greenland halibut (*Reinhardtius hippoglossoides*) have been harvested in Davis Strait and in Greenlandic inshore waters since the mid-1800's. In 1986 a group of Greenlandic fishermen were brought to the community of Pangnirtung, NT to teach their methods of marine ice fishing to local fishermen. They were immediately successful, catching 186 Greenland halibut over a period of a few days. The fishery has developed rapidly since that time (Fig. 1), and is now of great economic importance to the community, having replaced to some extent the now moribund commercial seal fishery. Other Baffin and Keewatin communities are also interested in developing inshore Greenland halibut fisheries, and will be mounting exploratory efforts in the near future.

Greenland halibut in the NW Atlantic are presently managed as four separate stocks, as outlined in the 1991 Atlantic Groundfish Management Plan (Anonymous 1992):

1. Baffin Bay and Davis Strait (Subareas 0 and 1 of the North Atlantic Fishery Organization (NAFO));
2. Northern Labrador (NAFO Divisions 2GH);
3. Southern Labrador and Eastern Newfoundland (NAFO Divisions 2J and 3KL), and;
4. Gulf of St. Lawrence (NAFO Divisions 4RST).

However, stock discrimination studies using meristic characters (Misra and Bowering 1984) and protein electrophoresis (Fairbairn 1981; Sevigny et al. 1992) have shown that only the Gulf of St. Lawrence stock is clearly biologically separate from the rest of the NW Atlantic stocks. Quotas for the Cumberland Sound fishery are presently allocated from the NAFO Area 0 Total Allowable Catch (TAC) of 12,500 tonnes, but the stock relationships of the Cumberland Sound Greenland halibut remain unassessed.

Greenland halibut are caught in Cumberland Sound only during the winter. Exploratory fisheries conducted there during the summer have so far been unsuccessful. It is therefore not feasible to assess the stock directly using standard methods. Management must rely on indirect indices of abundance, such as catch per unit effort (CPUE) and population parameters such as age and length distributions and mortality rates to indicate trends in abundance. In this study, I will examine catch records and data obtained from annual sampling of the Cumberland Sound catch to determine if any changes have occurred over the first six years of fishing. In addition I will report results of an experimental fishery carried out to determine if the observed population structure is dependent on gear selectivity.

MATERIALS AND METHODS

FISHING METHODS

Fishermen commonly used longlines with about 100 hooks (range 50-200), attached to the longline at 2 m intervals by gangions approximately 0.5 m in length. The most widely used hook in 1992 was a 14/0 circle, but other sizes and types were also used. Hooks were baited with strips of turbot meat with skin attached, usually 2-5 cm wide and 15-20 cm long. The longline was tied to a groundline which consisted of at least 2000 m of 2-4 mm braided polypropylene or nylon cord. A hand-cranked winch was used to retrieve the longline, although recently some fishermen have started to use power winches.

Longlines were set using a 'kite' consisting of a weighted, rectangular piece of sheet metal attached to the end of the longline. The kite was oriented in the proper direction in the ice hole, then released and allowed to drag the longline and groundline. The kite provided enough lateral movement to allow the full length of the longline to lie on the bottom. When the kite reached the bottom, a sliding weight was dropped, travelling down the groundline to the longline. More line was then released until the entire longline lay on the bottom. Most fishermen left their lines set for about 2 hours (range 0.5-18 hrs). Retrieval took between one half and one hour. The entire process of a longline set typically took between three and four hours.

Immediately after capture, fish were gutted and their heads and tails were removed. They were then placed in insulated tanks filled with seawater slush. In this condition, they could be kept from freezing for 2-4 days. Fish were transported back to the fish plant in Pangnirtung by snowmobile and qamutiq. Most fish were filleted and shipped fresh by air to southern markets.

SAMPLING METHODS

Sampling was carried out at fishing sites on the ice of Cumberland Sound (Fig. 2) in March 1987, 1988, and 1989, February and April 1990, and March 1991 and 1992. Several fishing camps were visited during each sampling period. When a longline was hauled, all fish caught were sampled.

Fish were sampled for fork length (±1 mm), round weight (±50 g), dressed head-off weight and stomach contents. Fish heads were collected in individually labelled bags for later otolith removal. In 1990, 1991 and 1992, sex and maturity were determined by gross examination of the gonads.

Otoliths were removed, cleaned and stored dry until read. The left sacculus otolith was prepared and read according to the methods of Lear and Pitt (1975).

All fishermen were issued bilingual (English and Inuktitut) forms on which to record their catch and effort. Catch per unit effort data were collected in all years but 1988.

EXPERIMENTAL FISHERY

In March 1992 longlines were set in the same area fished by commercial fishermen (Fig. 2). Water depth was measured with a depth sounder, and the site location was determined with a global positioning system. Each set had 100 Mustad Gravitational hooks of three sizes (16, 15 and 13) attached alternately along the line. The hooks were baited with Greenland halibut strips approximately 5, 8 and 12 cm in length. Each set was of 2 hrs duration, and all baits were renewed after each set.

Data analysis and graphics preparation was carried out using SYSTAT PC software (Wilkinson 1990).

RESULTS

FISHING METHODS

Fishermen changed their fishing patterns between 1987 and 1992. The number of hooks used increased slightly in later years, while the mean number of hooks lost in a set decreased (Table 1). Mean set duration was significantly higher in 1991 and 1992 than in earlier years (ANOVA, $p<.001$). This was due to an increase both in the modal set duration and the proportion of longer sets in 1991 and 1992 (Fig. 3).

CATCH COMPOSITION

Other species caught in the fishery included the Greenland shark (*Somniosus microcephalus*), thorny skate (*Raja radiata*), grenadier (*Coryphaenoides* sp.) and wolffish (*Anarchichas* sp.). The most frequently caught by-catch species were the Greenland shark and thorny skate, with catch rates approximately two orders of magnitude less than that of Greenland halibut. Grenadier and wolffish were not caught frequently enough to warrant analysis of catch data.

CATCH AND EFFORT

Catch of Greenland halibut had a significant overall positive correlation with both number of hooks set and set duration ($p<.001$). However the correlation between catch and set duration was very weak and variable between years. Nevertheless, catch per hook per hour (CHH) was chosen as the descriptor of catch per unit effort to facilitate comparisons between years.

CHH showed seasonal trends in some years, but these trends were not consistent from year to year (Fig. 4). In 1987 and 1990, CHH showed a slight increasing trend between late January and late March. In 1989, CHH showed a decreasing trend between early March and early May. No trends were apparent in 1991 or 1992.

To determine if there were diurnal patterns in CHH, sets were classified as having occurred in darkness if more than one half their duration occurred between one hour after sunset and one hour before sunrise. CHH was significantly higher (ANOVA, $p<.05$) for sets carried out in darkness than for those carried out during daylight in 1992, but there was no significant difference in 1989, 1990 or 1991. Set time was not recorded in 1987, so the comparison could not be carried out for that year.

CHH varied between fishing locations in some years, but not in others. In 1989, CHH was significantly higher at site C than at sites A or B (ANOVA, $p<.05$, see Fig. 2), but this difference was not apparent in 1990. In 1991 and 1992, fishing was concentrated at sites C and E respectively, and there were too few sets carried out at other locations to warrant analysis.

CHH varied significantly between years (ANOVA, $p<.001$, Fig. 5). CHH was highest at the beginning of the fishery in 1987, and remained high through 1989. CHH declined from 1989 to reach a low point in 1991, then recovered to 1990 levels in 1992.

SEX AND MATURITY

Sex and maturity 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. No ripe or spent males or females were observed. A total of only 30 male Greenland halibut were sampled, precluding between-year comparisons of biological parameters in males.

LENGTH AND AGE

Both mean length and mean age were greater in females than in males (ANOVA, $p<.001$, Fig. 6, Table 2). Males reached a maximum age of 14 yrs, while females survived to an age of 16 yrs. Mean length and age of female Greenland halibut varied significantly from year to year (ANOVA, $p<.001$, Fig. 7, Table 3). Mean length was significantly lower in 1987 and 1992 than in any other year. Mean age was lower in 1987 and higher in 1991 than in any other year. The dominant commercial age range, defined as that part of the age range where more than 80% of the commercial catch occurs (Bowering and Brodie 1991), did not change greatly from year to year (Table 3). In February 1990, there were significant differences in length and age of females between sites A and B (ANOVA, $p<.001$, Fig. 2 and Fig. 7). Length and age were greater at site B than at site A.

GROWTH AND CONDITION

Length at age was essentially linear over the observed age range (Fig. 9). Therefore linear regression was chosen as an appropriate model for comparing growth. Both slope and intercept varied between males and females (ANCOVA, $p<.001$, Table 2) and from year to year in females (ANCOVA, $p<.001$, Table 3). Males grew more slowly than females between ages 7-12. There was no temporal trend in growth rate in females. Mean length at age 12 (the most common modal age) was lower in 1992 than in any other year. Condition factor (K) was significantly higher in females in 1987 than in any other year (ANOVA, $p<.001$, Table 3). There was no difference in K between male and female Greenland halibut (Table 2).

MORTALITY

Instantaneous total mortality (Z) in female Greenland halibut was calculated for all years for ages ≥12 years. There were no significant differences between years (ANCOVA, $p>.05$, Table 3).

FEEDING

Stomach contents were examined from 1990 on. Most fish (81%) had empty stomachs. Food items found most frequently in Greenland halibut stomachs were fish remains (10%), shrimp (4%), squid (3%) and amphipods (1%).

EXPERIMENTAL FISHERY

Hook and bait size had no significant effect on the mean length or age of Greenland halibut caught in the 1992 experimental fishery (ANOVA, $p>.05$, Table 4). However hook and bait size did influence catch per unit effort. CHH was lower for the smallest size of hook than for both of the larger sizes used in the experimental fishery, and for the 1992 commercial fishery (ANOVA, $p<.05$).

BY-CATCH

Catch of Greenland shark was significantly correlated with set duration ($p<.05$) but not with number of hooks set. Nevertheless CHH was used as a measure of catch per unit effort to facilitate comparison with other species.

Greenland shark CHH was significantly higher for sets carried out in darkness than for those carried out during daylight in 1990 (ANOVA, $p<.05$), but not in any other year. Shark CHH did not vary with fishing location in any year. Shark CHH varied significantly between years (ANOVA, $p<.001$). CHH was lower in 1990, 1991 and 1992 than in the early years of the fishery (Fig. 9).

Catch of thorny skate was correlated with the number of hooks set ($p<.01$), but not with set duration; however CHH was again used as a measure of catch per unit effort for this species.

Thorny skate CHH was higher in daytime sets than nightime sets in 1990 ($p<.05$), but not in any other year. Skate CHH varied with fishing location in some years, but not in others. In 1989, skate CHH was higher at site B than at site C (ANOVA, $p<.01$), while in 1990, CHH was higher at site A than at sites B or C (ANOVA, $p<.001$). Skate CHH varied significantly between years (ANOVA, $p<.001$, Fig. 10). Skate CHH increased steadily until 1990, dropped drastically in 1991, then recovered to 1990 levels in 1992.

DISCUSSION AND CONCLUSIONS

DISTRIBUTION

The life history and distribution of Greenland halibut in North Atlantic waters was recently reviewed by Crawford (1992). Spawning occurs in early winter in the deep (650-1000 m) waters of Davis Strait. The pelagic larvae drift with the West Greenland current north along the west coast of Greenland into Davis Strait and Baffin Bay. The young eventually settle onto the shelf waters of Greenland, Baffin Island and Labrador at depths of 50-200 m. As they grow, they gradually migrate into deeper waters, and upon maturation, return to the Davis Strait spawning grounds.

The seasonal distribution and migratory patterns of Cumberland Sound Greenland halibut are not well known. In this analysis, CHH did not vary consistently between January and May, suggesting that no significant migrations into or out of the Sound occur during that period. Experimental summer fisheries have been attempted in the same areas that are fished in the winter fishery, but very few Greenland halibut have been caught, indicating that they are less available in the summer than in the winter. They may move out of Cumberland Sound during the summer, or at least change their distributional pattern such that they no longer occupy the areas fished during the winter. Bowering (1982) observed seasonal changes in the distribution of Greenland halibut in the Gulf of St. Lawrence. They were concentrated in the deeper, warmer waters of the Gulf during the winter, but distributed more widely into shallower areas during the summer. A similar pattern may be followed by Cumberland Sound Greenland halibut. More extensive summer exploratory fishing is required to test this hypothesis.

Greenland halibut are a highly mobile species, and unlike most flatfish, may make extensive excursions into the pelagic zone. Bowering and Parsons (1986) found that bottom trawl catches off the coast of Labrador were higher during the day, while the mean size of the fish was lower, suggesting that smaller Greenland halibut may migrate into the water column at night. Lear and Pitt (1971) reported that small Greenland halibut were sometimes caught in herring nets set in shallow water. It was therefore expected that longline catches in Cumberland Sound might be higher during the day, when smaller, more migratory fish would be accessable to longlines set on the bottom. However, this was not the case; in fact CHH was higher at night than during the day in 1992. The fishery takes place in water depths of 600-1000 m, where there may be few small, migratory fish.

The abundance (as indicated by CHH) and size/age distribution of female Greenland halibut showed locational variations within Cumberland Sound. In some years, CHH varied significantly among fishing areas. In 1990, larger, older Greenland halibut were caught at site B than at site A (Fig. 2 and 8). Two major factors which affect the distribution of Greenland halibut are water depth and temperature (Crawford 1992; Atkinson and Bowering 1987; Atkinson et al. 1982; Bowering 1982). The abundance of larger, older fish increases with water depth, and Greenland halibut may occupy deeper waters during the winter to take advantage of the warmer temperatures found there. Neither depth nor temperature was measured in this study, and hydrographic charts available for Cumberland Sound are generally not of sufficient detail to estimate depth at most locations. Nevertheless, it is highly probable that depth and temperature do influence the distribution of Greenland halibut in Cumberland Sound, and they should be measured in any future studies.

The observed locational changes in CHH also complicate the interpretation of the annual variations in CHH, since the same areas were not fished every year (Fig. 2 and 7). Also, changes in fishing techniques may have resulted in spurious CHH variation. Catch of Greenland halibut was only weakly and inconsistently related to set duration, and mean set duration increased in 1991 and 1992 over previous years (Table 1, Fig. 3). Thus increasing set durations might have had the effect of lowering CHH, without reflecting any real change in Greenland halibut catch per unit effort. Figure 5b shows the annual changes in mean CHH, using sets with durations of three hours or less only. The same pattern of decline in 1990-1991, followed by a recovery in 1992, is observed, but the changes, while significant (ANOVA, $p<.05$), are of lesser magnitude than those produced with the unrestricted data. This indicates that while the observed annual changes in CHH may be due partially to changes in fishing patterns, they do reflect real changes in catch per unit effort. It is also possible that CHH may not be the most appropriate indicator of catch per unit effort for this fishery.

SIZE, AGE AND GROWTH

Length and age distributions for Greenland halibut caught in Cumberland Sound (Fig. 6 and 7) covered a much narrower range than and did not include the smaller, younger fish that were caught in otter trawl fisheries in Davis Strait (Atkinson and Bowering 1987) or the Gulf of St. Lawrence (Bowering 1982). 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, use of hook and bait sizes smaller than those used in the commercial fishery did not produce significantly smaller fish (Table 4). Thus it may be that smaller fish simply do not occupy the deep areas of Cumberland Sound that are fished commercially. Trial fisheries using alternate gear types set at various depths would be useful in determining the distribution of size/age classes within Cumberland Sound.

Male Greenland halibut comprise only about 3% of the commercial catch in Cumberland Sound. Male Greenland halibut mature earlier at a smaller size than do females (Atkinson et al. 1982). Growth up to age 9 is similar for males and females, after which males direct more energy towards reproduction and grow more slowly than females. In Cumberland Sound, females exceeded males in mean and maximum size and age, and growth rate (Fig. 6 and 9, Table 2). Similarly, in Davis Strait, males rarely exceed 600 mm in length and 10 years of age, while females up to 1000 mm and 16 years are not uncommon (Atkinson et al. 1982). Recruitment into the Cumberland Sound longline fishery begins at a length of about 500 mm, so it is not surprising that males form only a small proportion of the catch. Females also dominate the catch in Greenland longline and gillnet fisheries (Riget and Boje 1987).

Mean fork length and age of female Greenland halibut fluctuated from year to year, but did not show any consistent temporal trends (Fig. 7). The collapse of the Greenland halibut fishery in northeastern Newfoundland was preceded by a decline in both mean length and age (Lear 1970); there is no indication that this has happened in Cumberland Sound. Bowering and Brodie (1991) related decreases in the abundance of various flatfish species to reductions in the commercially dominant age ranges, and increases in growth rate as indicated by increases in mean fork length at age 12. No trends in these parameters which might be attributable to overexploitation were observed in Cumberland Sound (Table 3).

Size at age of male and female Greenland halibut for Cumberland Sound was indistinguishable from that for fish caught in Davis Strait (Fig. 9). Atkinson et al. (1982) noted a north to south gradient in size at age, with fish from southern waters growing more slowly than those from northern waters.

STOCK DELINEATION

Crawford (1992) postulated that Cumberland Sound Greenland halibut are a component of the Davis Strait stock complex, spawning either within Cumberland Sound, or migrating into Davis Strait to spawn. The deep (>300 m) channel connecting Cumberland Sound to Davis Strait should allow Greenland halibut to pass freely between the two areas. An analogous situation exists in the deep fiords of western Greenland. There, tagging experiments have provided no evidence of migration outside of the fiords (Riget and Boje 1987), and very few fish in spawning or post--spawning condition have been observed (Boje and Riget 1988). Boje and Riget (1988) postulated that temperatures were not warm enough in the fiords to permit spawning in most years: the fiords would be a "dead end" for fish migrating from the major spawning grounds of Davis Strait. It is possible that a similar situation exists at Cumberland Sound, where no fish in spawning or post-spawning condition have been observed. Alternatively, Greenland halibut may leave Cumberland Sound to spawn, or go to areas of the sound not fished commercially.

There is little direct evidence on the stock identity of the Greenland halibut of Cumberland Sound. Arthur and Albert (1993) found that Cumberland Sound fish could not be discriminated from Hawke Channel (Labrador) fish on the basis of their parasite fauna, and concluded that this could reflect either similar ecological conditions or actual stock mixing. Sevigny et al. (1992) found a relatively low level of genetic diversity and high gene flow among north Atlantic Greenland halibut. However Cumberland Sound fish had a significantly different allozymatic makeup from those from other northwest Atlantic sites, indicating some degree of genetic differentiation of Cumberland Sound fish. Unfortunately, neither Arthur and Albert (1993) nor Sevigny et al. (1992) included fish from Davis Strait or Greenlandic waters in their studies. The stock relationships of Cumberland Sound Greenland halibut thus remain undefined.

BY-CATCH

The low diversity of fish species caught in the Cumberland Sound commercial fishery is not surprising. Species richness is relatively low in Arctic waters, and fish faunas tend to be dominated by pelagic Arctic cod (*Boreogadus saida*) and small benthic species (Hudon 1990), which would not be vulnerable to commercial longline gear.

Greenland shark catch was a major source of annoyance and gear loss for fishermen. When caught, the sharks tended to entangle themselves in the gear, and their rough skin would often rasp through the longline, causing it to break. They were also very difficult to bring to the surface and get out of the ice hole. Shark CHH has decreased dramatically in recent years (Fig. 10). Fishermen have indicated that the adoption of circle hooks in the fishery was effective in reducing shark catch. These hooks seem less prone to entangling the sharks. This is probably the main factor responsible for the reduction in CHH, rather than any real decline in abundance. The high correlation between shark catch and set duration suggests that minimizing set duration should also be effective in reducing shark catch.

Thorny skate CHH varied by location fished and year. The extremely low CHH observed in 1991 (Fig. 11) may be the result of locational rather than temporal variation in skate abundance. In 1991, most set data came from site C (Fig. 2), an area which had significantly lower skate catch rates in other years. The factors which affect skate abundance in Cumberland Sound are not known.

By-catch is not utilized in the Cumberland Sound fishery. Thorny skates have little commercial value (Leim and Scott 1966), but Greenland sharks have been fished commercially in the past. Jensen (1914) estimated that the Greenland catch amounted to

32,000 sharks in the early 1900's. The major product was liver oil, although shark skins were sometimes utilized. The meat was said to be toxic when fresh, but edible when dried or boiled (Jensen 1925; Jensen 1914). Anthoni et al. (1992) found that the flesh of Greenland sharks contained high concentrations of trimethylamine oxide, and identified this substance as the probable toxic agent. This toxicity has not been noted in sharks caught in Cumberland Sound, which have been consumed to a small extent locally (pers. obs.). Shark catch is quite significant by weight. Assuming an estimated average weight of 200 kg, and using the ratio of shark:Greenland halibut CHH to estimate catch, shark catch was about 455 tonnes in 1992, greater than the catch of Greenland halibut. It would be very beneficial to the fishery if a market could be found for this by-catch.

FISHERY PROGNOSIS

The decline in catch per unit effort in the Cumberland Sound Greenland halibut fishery is coincident with increases in total harvest and fishing effort, and thus may be evidence of overexploitation. However, there are no trends in biological parameters such as mean length and age, commercially dominant age range, growth rate and mortality to support this evidence. It is possible that the decline in CHH is due to natural variation. The apparent recovery of CHH in 1992 to 1990 levels, despite a large increase in catch and effort, suggests that the fluctuations may indeed be natural. I conclude that there is not sufficient evidence to indicate that there has been a stock decline. Nevertheless, continued monitoring of catch per unit effort and biological parameters is necessary to assess the levels of natural variation in stock abundance indicators.

MANAGEMENT RECOMMENDATIONS

1. There is not sufficient evidence to accept or reject Crawford's (1992) hypothesis that Cumberland Sound Greenland halibut are part of the Davis Strait stock complex. Therefore the most conservative management approach is to treat the Cumberland Sound population as a separate stock of unknown size.
2. Lacking any stock assessment for Cumberland Sound, quotas should be increased slowly in a stepwise fashion. Quota increments should be considered at 2-3 year intervals, only after monitoring data indicates no evidence of stock decline.
3. The quota should be maintained at the 1992 level of 500 tonnes until at least 1994.

RESEARCH RECOMMENDATIONS

The following research objectives are most important for the management of the Cumberland Sound Greenland halibut management stock.

1. Determine the stock relationships of the Cumberland Sound management stock.
2. Determine the population size of the Cumberland Sound management stock.
3. Determine the migration patterns and seasonal distribution of the Cumberland Sound management stock.

The research recommendations of Crawford (1992) are supported, but the following projects should be considered of highest priority.

1. Annual monitoring of the fishery should be continued and enhanced to include locational, water depth and temperature information, and a more detailed collection of maturity data.
2. Determine stock relationships using biochemical genetic (Fairbairn 1981; Sevigny et al. 1992), parasite marker (Khan et al. 1982; Arthur and Albert 1993) or meristic (Misra and Bowering 1984) methods.
3. Conduct tagging studies to confirm stock relationships and assess population size, exploitation rates and migration patterns.

ACKNOWLEDGMENTS

I thank Seeglook Akeeagok, Doug Chiperzak, Larry Dow, Norman Komoartok and Kim Seto for their assistance in fieldwork. Margaret Keast and Daniel Watson assisted in fieldwork, laboratory analyses and data entry. Thanks to Ross Tallman and W.R. Bowering for providing constructive criticisms in their reviews of the manuscript. Finally, I thank the fishermen of Pangnirtung for their patience in providing catch-effort data and allowing me to sample their catch.

REFERENCES

Anonymous. 1992. Atlantic groundfish management plan. Canada Department of Fisheries and Oceans. Ottawa, ON.

Anthoni, U., C. Christophersen, L. Gram, N.H. Nielsen, and P. Nielsen. 1992. Poisonings from the flesh of Greenland shark *Somniosus microcephalus* may be due to trimethylamine. Toxicon 29: 1205-1212.

Arthur, J.R., and E. Albert. 1993. Use of parasites for separating stocks of Greenland halibut (*Reinhardtius hippoglossoides*) in the Canadian Northwest. Can. J. Fish. Aquat. Sci. 50(10): 2175-2181.

Atkinson, D.B., and W.R. Bowering. 1987. The distribution and abundance of Greenland halibut, deepwater redfish, golden redfish, roundnose grenadier and roughhead grenadier in Davis Strait. Can. Tech. Rep. Fish. Aquat. Sci. 1578: v+29 p.

Atkinson, D.B., W.R. Bowering, D.G. Parsons, Sv.Aa. Horsted, and J.P. Minet. 1982. A review of the biology and fisheries for roundnose grenadier, Greenland halibut and northern shrimp in Davis Strait. Northwest Atl. Fish. Organ. Sci. Counc. Stud. 3: 7-27.

Boje, J. 1991. A comparison of selectivity in longlines and gillnets in the fishery for Greenland halibut in West Greenland. Northwest Atl. Fish. Organ. SCR Doc. 91/39: 7 p.

Boje, J., and F. Riget. 1987. Catch and size distribution of Greenland halibut (*Reinhardtius hippoglossoides*) at Jakobshavn, West Greenland. Northwest Atl. Fish. Organ. SCR Doc. 87/33: 11 p.

Bowering, W.R. 1982. Population dynamics of Greenland halibut in the Gulf of St. Lawrence. J. Northwest Atl. Fish. Sci. 3: 141-147.

Bowering, W.R., and W.B. Brodie. 1991. Distribution of commercial flatfishes in the Newfoundland-Labrador region of the Canadian Northwest Atlantic and changes in certain biological parameters since exploitation. Neth. J. Sea Res. 27: 407-422.

Bowering, W.R., and D.G. Parsons. 1986. Diel variability in trawl catches of Greenland halibut from the channels off coastal Labrador and implications for resource management. N. Am. J. Fish. Manage. 6: 149-155.

Chumakov, A.K., K.N. Nikeshin, and A.S. Gorshkova. 1981. Bottom trawl codend selectivity for Greenland halibut in NAFO Subarea 0 and Div. 2H, 2J and 3K. Northwest Atl. Fish. Organ. SCR Doc. 81/IX/89.

Crawford, R.E. 1992. Life history of the Davis Strait Greenland halibut, with reference to the Cumberland Sound fishery. Can. Manuscr. Rep. Fish. Aquat. Sci. 2130: iv + 19 p.

Fairbairn, D.J. 1981. Biochemical genetic analysis of population differentiation in Greenland halibut (*Reinhardtius hippoglossoides*) from the Northwest Atlantic, Gulf of St. Lawrence, and Bering Sea. Can. J. Fish. Aquat. Sci. 38: 669-677.

Hudon, C. 1990. Distribution of shrimp and fish by-catch assemblages in the Canadian eastern Arctic in relation to water circulation. Can. J. Fish. Aquat. Sci. 47: 1710-1723.

Jensen, Ad. S. 1914. The selachians of Greenland. Mindeskrift For Japetus Steenstrup XXX, Kobenhavn, Bianco Lunos Bogtrykkeri, 1914.

Jensen, Ad. S. 1925. On the fishery of the Greenlanders. Meddelelser fra Kommissionen for Havudersogelser. Serie: Fiskeri, Bind VII, Nr. 7.

Khan, R.A., M. Dawe, R. Bowering, and R.K. Misra. 1982. Blood protozoa as an aid for separating stocks of Greenland halibut, (*Reinhardtius hippoglossoides*), in the northwestern Atlantic. Can. J. Fish. Aquat. Sci. 39: 1317-1322.

Lear, W.H. 1970. Catch statistics, length and age composition of Greenland halibut in the Newfoundland area. Fish. Res. Board Can. Tech. Rep. 179: 27 p.

Lear, W.H., and T.K. Pitt. 1971. Distribution of Greenland halibut in the Newfoundland-Labrador area in relation to depth and temperature. Fish. Res. Board Can. Tech. Rep. 274: 34 p.

Lear, W.H., and T.K. Pitt. 1975. Otolith age validation of Greenland halibut (*Reinhardtius hippoglossoides*). J. Fish. Res. Board Can. 32: 289-292.

Leim, A.H., and W.B. Scott. 1966. Fishes of the Atlantic Coast of Canada. Fish. Res. Board Can. Bull. 155: 485 p.

Misra, R.K., and W.R. Bowering. 1984. Stock delineation of Greenland halibut in the northwest Atlantic using a recently developed, multivariate statistical analysis based on meristic characters. N. Am. J. Fish. Manage. 4: 390-398.

Riget, F., and J. Boje. 1987. Biology and fishery for Greenland halibut at West Greenland. Northwest Atl. Fish. Organ. SCR Doc. 87/81: 29 p.

Sevigny, J.M., G. Ross, D. Archambault, and E. Parent. 1992. Genetic variation in Greenland halibut, *Reinhardtius hippoglossoides*, from the St. Lawrence system and the Northwest Atlantic. Can. Atl. Fish. Sci. Advis. Com. Res. Doc. 92/99:/21 p.

Wilkinson, L. 1990. Systat: The System for statistics. Systat, Inc. Evanston, IL.

Table 1. Characteristics of longline sets in the Cumberland Sound Greenland halibut fishery, 1987-1992.

Year	No. Sets	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	3.4	107	2	105
1992	482	3.4	107	2	105

Table 2. Summary of age, fork length, condition factor and growth rate of male and female Greenland halibut caught in Cumberland Sound, 1987-1992.

Sex	N	Age (yrs)			Length (mm)			K[a]	Growth Rate length=m(Age)+b	
		Min	Max	Mean	Min	Max	Mean		m	b
M	30	7	14	9.4	481	853	568	0.974	268	32
F	820	7	16	10.9	354	1050	701	1.092	169	49

[a] K = Condition Factor = (Weight x 10^5)/Length^3

Table 3. Biological characteristics of female Greenland halibut sampled in Cumberland Sound, 1987-1992.

Year	Site	N	Mean Length (mm)	Mean Age (Yrs)	Mean Weight (g)	Mean K[a]	Z[b]	Range[c] (yrs)	M12[d] (mm)	Growth Rate Length=m(Age)+b	
1987		245	682	10.3	3665	1.104	1.026	7-11	781	58	89
1988	C	154	719	11.2	4140	1.076	NS	8-12	760	57	79
1989	C	114	724	11.0	4148	1.088	NS	7-12	767	44	239
1990[e]	A	95	694	10.7	3648	1.023	NS	7-12	769	59	56
1990[e]	B	61	781	12.3	5384	1.075	0.387	10-14	766	57	81
1990[f]	C	148	716	11.2	4062	1.048	0.887	7-12	773	44	259
1991	E	52	752	12.1	5190	1.108	NS	8-13	754	52	125
1992	F	144	665	11.0	3348	1.128	0.540	8-12	691	32	307
Total		882	702	10.9	3921	1.091	1.213	7-12	755	49	169

[a] K = Condition Factor=(Weight x 10^5)/$Length^3$.
[b] Total Instantaneous Mortality calculated for ages ≥12, NS=regression not significant.
[c] Dominant commercial age range (Bowering and Brodie 1991).
[d] M12 = Mean fork length at age 12.
[e] February 1990.
[f] April 1990.

Table 4. Characteristics of longline sets and Greenland halibut caught in experimental and commercial fisheries in Cumberland Sound, 1992.

Hook[a]	No. Sets	No. Fish	CHH[b]	Mean Age (yrs)	Mean Fork Length (mm)
S	11	22	.026	10.5	629
M	11	49	.067	10.3	652
L	476	148	.070	11.0	662

[a] Hook size, Mustad Gravitational Hooks, S=#16, M=#15, L=#13, COM=commercial fishery.
[b] CHH = Catch/Hook/Hr.

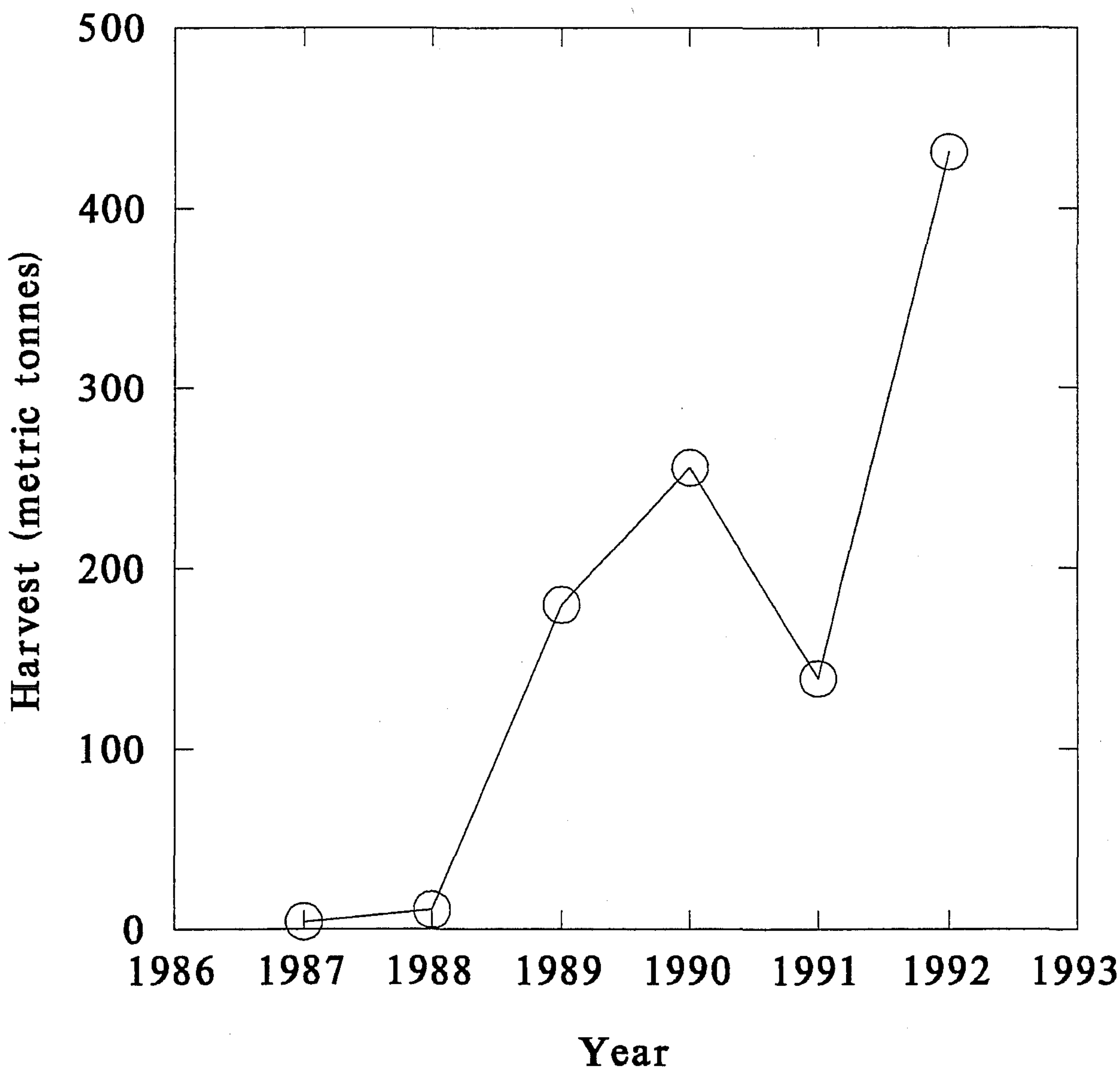

Fig. 1. Commercial harvest of Greenland halibut in Cumberland Sound, 1987-1992. The commercial quota was 500 metric tonnes in 1992.

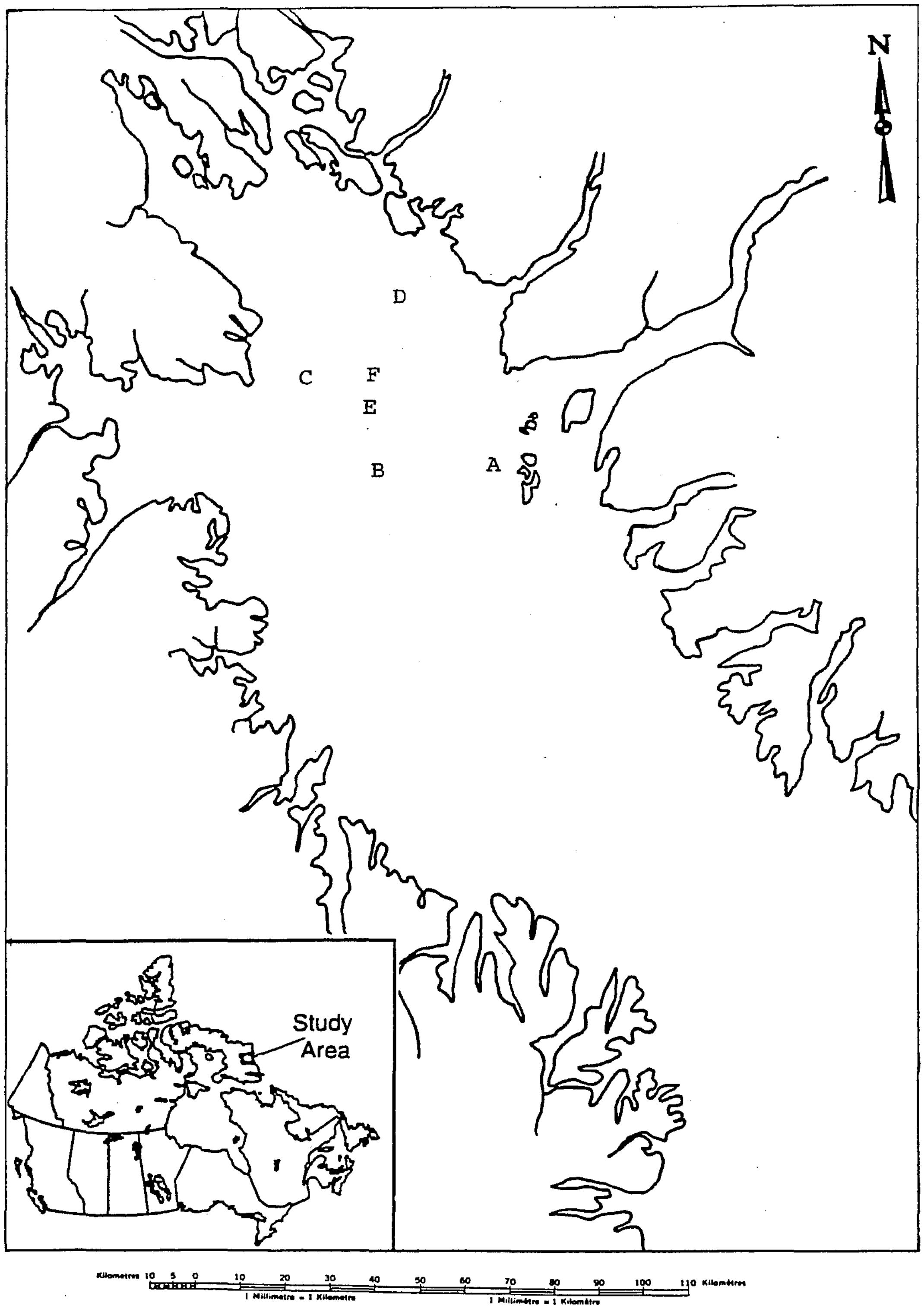

Fig. 2. Areas fished commercially and experimentally in Cumberland Sound, 1987-1992. A - Fished 1989, 1990; B - Fished 1989, 1990; C - Fished 1989, 1990, 1991; D - Fished 1992; E - Fished 1991, 1992; F - Experimental fishery, 1992.

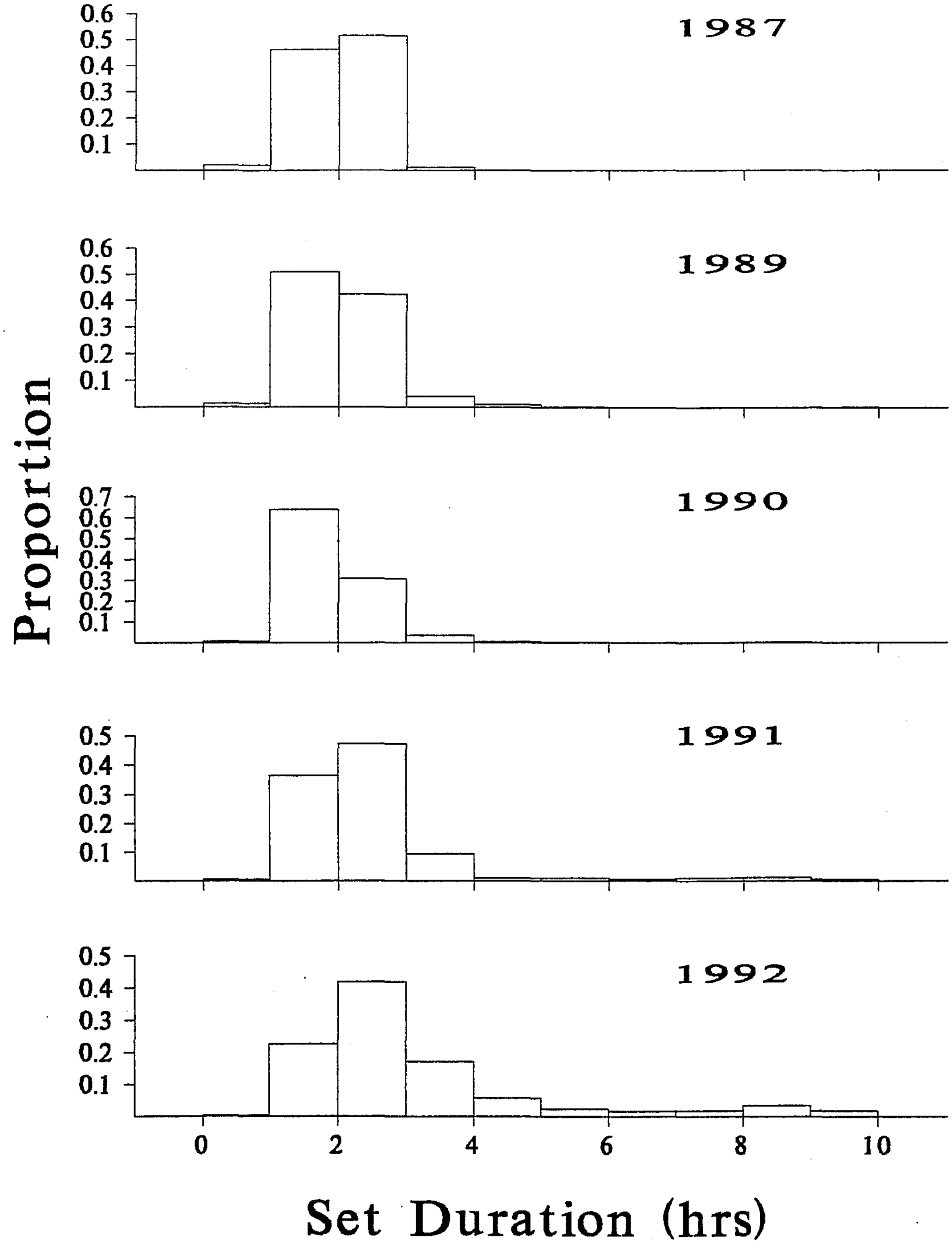

Fig. 3. Frequency distributions of longline set durations in the Cumberland Sound Greenland halibut fishery, 1987-1992.

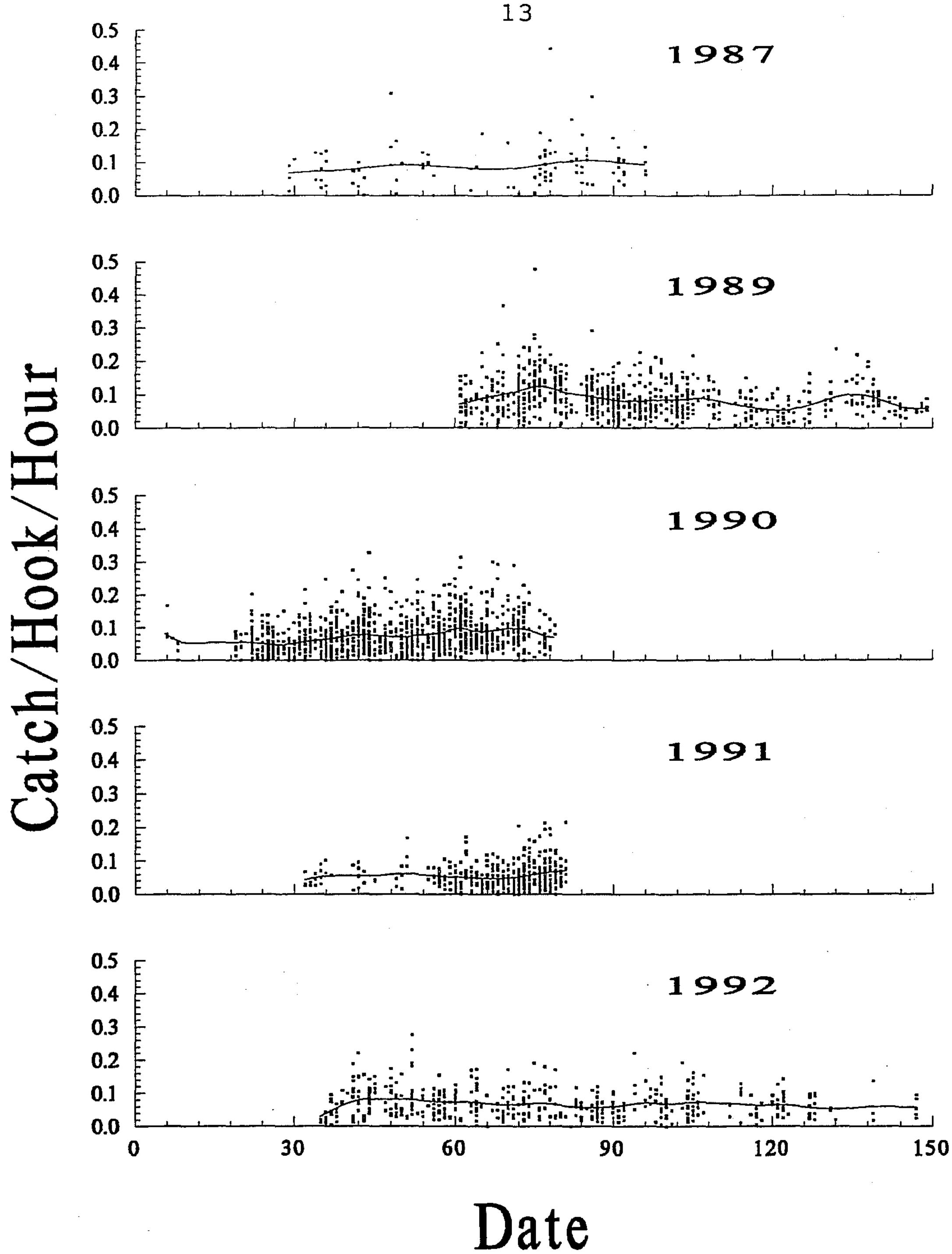

Fig. 4. Catch per unit effort in the Greenland halibut fishery in Cumberland Sound, 1987-1992. Date is number of days after January 1. Solid lines are mean trend lines using distance weighted least squares regression (Wilkinson 1990).

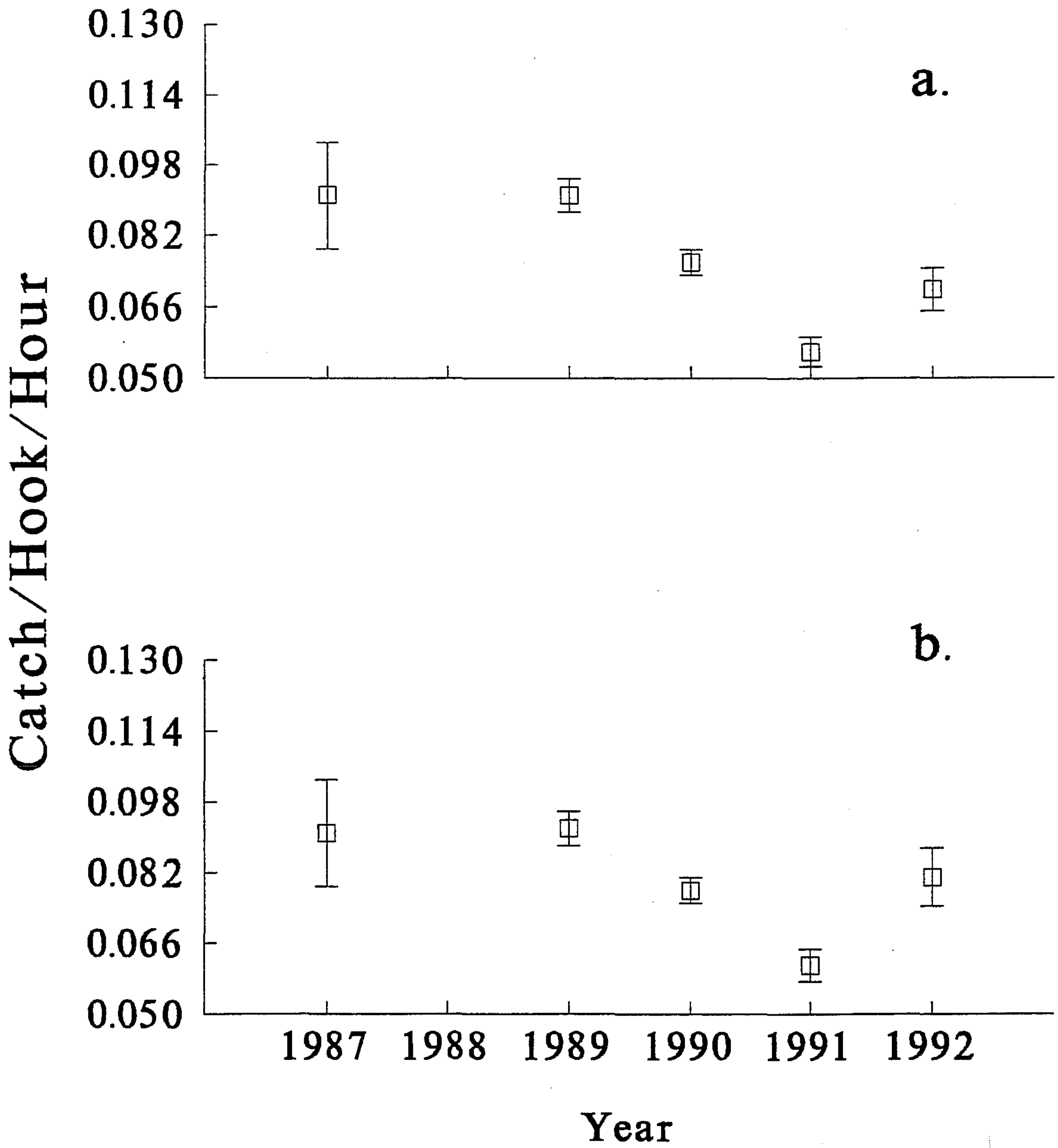

Fig. 5. Annual mean catch per unit effort in the Greenland halibut fishery in Cumberland Sound, 1987-1992. Error bars are 95% confidence intervals. a. Using all data; b. Using sets having a duration of 3 hours or less only.

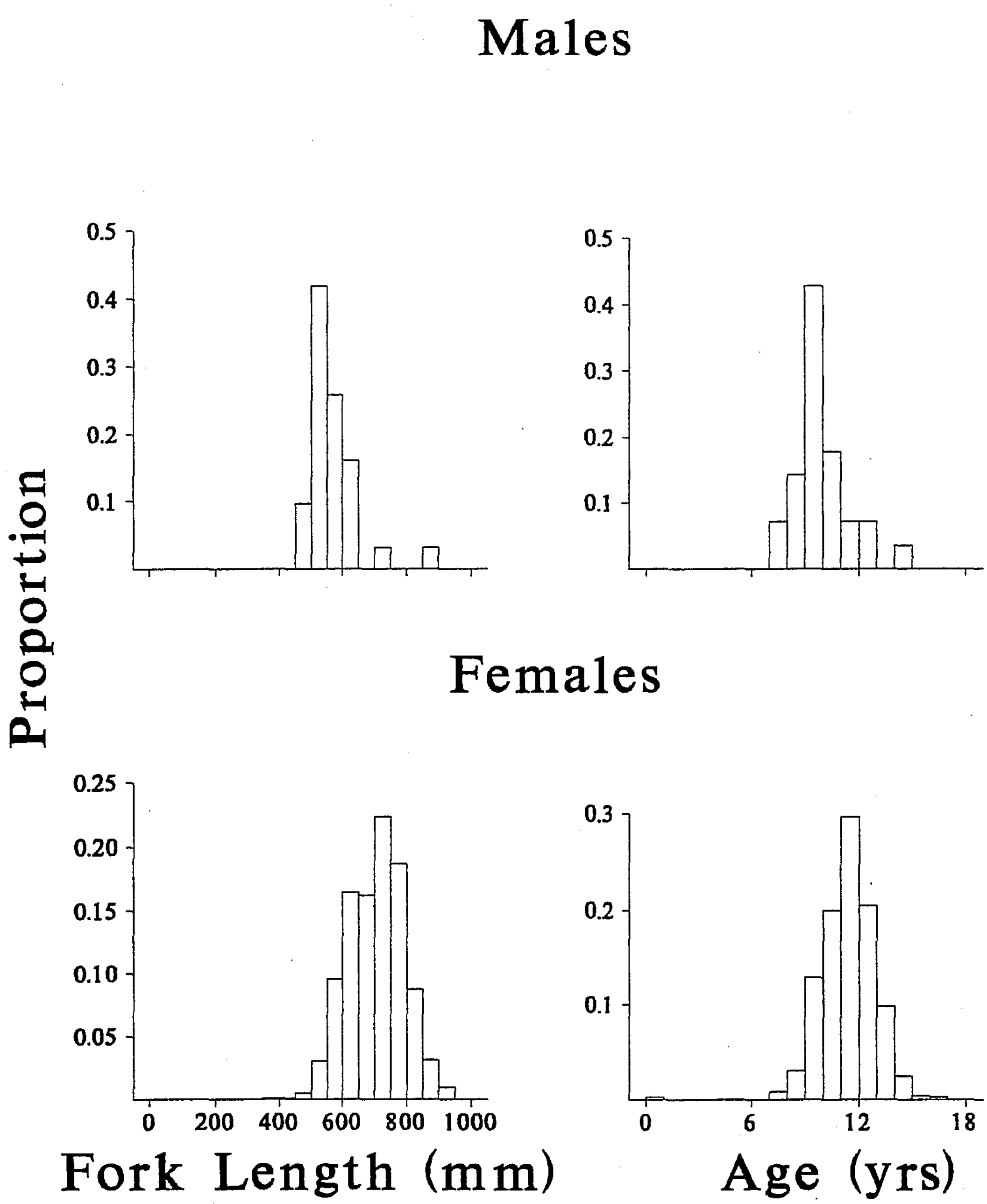

Fig. 6. Length and age frequencies of male and female Greenland halibut captured in Cumberland Sound, 1987-1992.

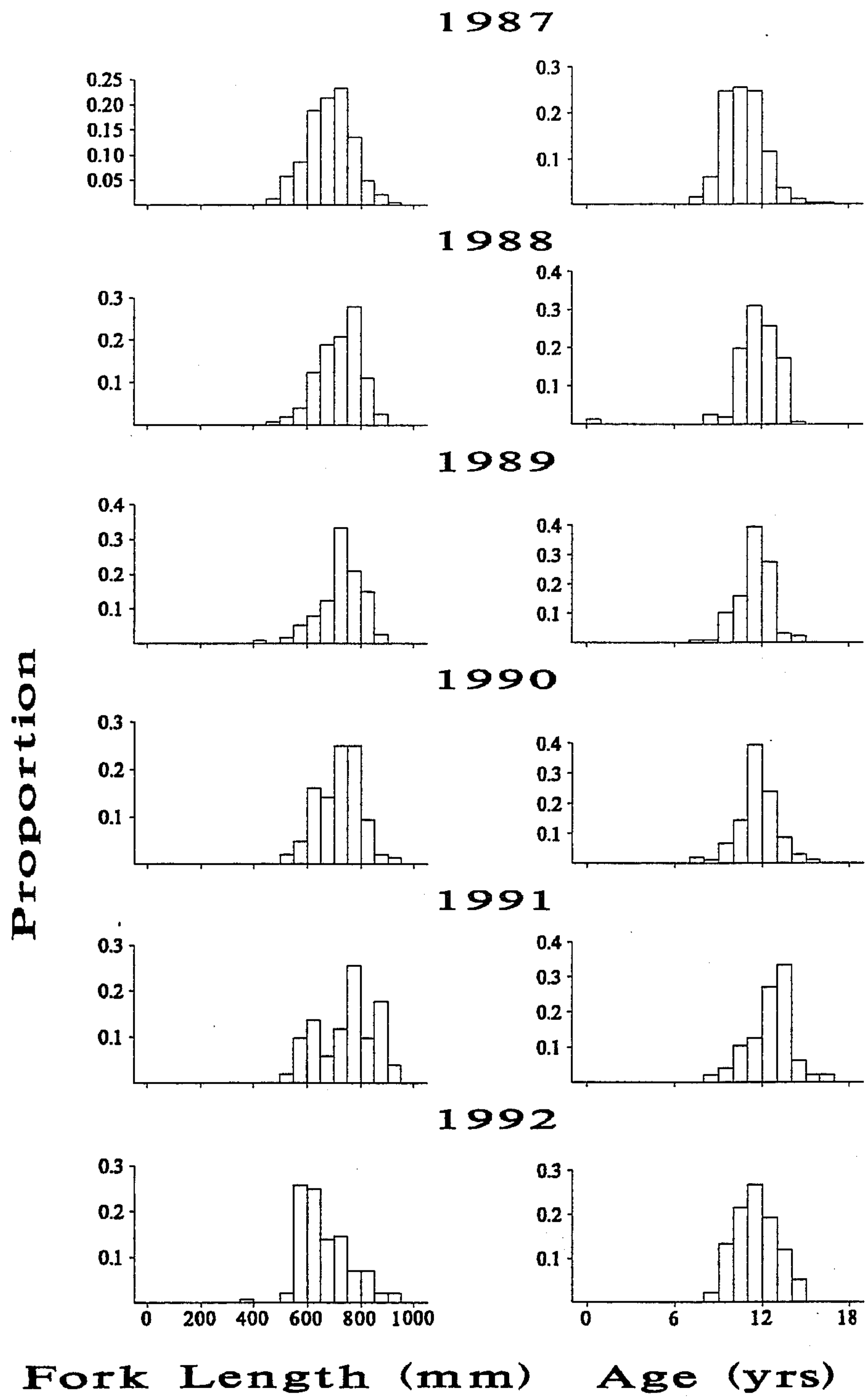

Fig. 7. Length and age distributions of female Greenland halibut caught in Cumberland Sound, 1987-1992.

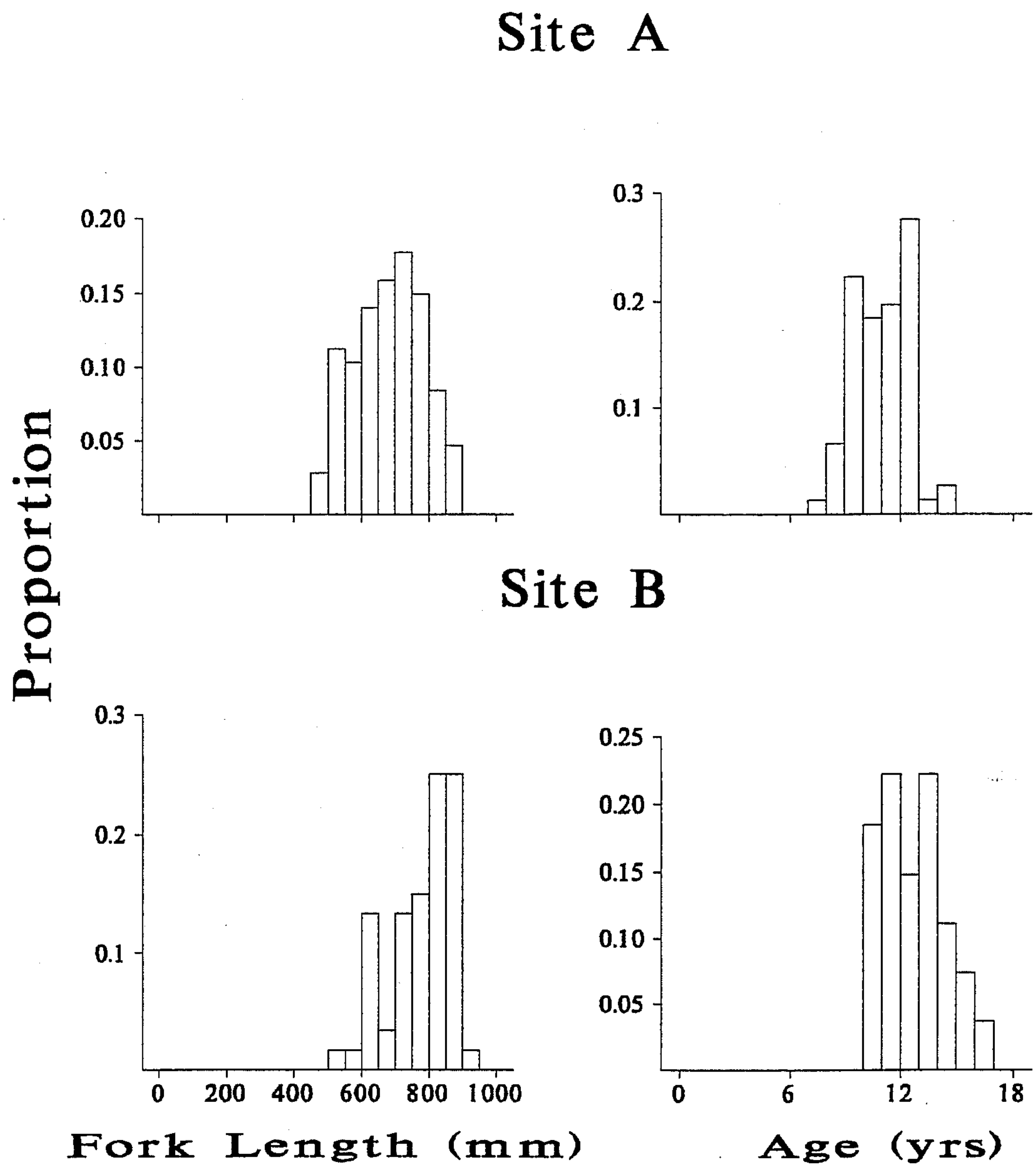

Fig. 8. Age and length distributions of female Greenland halibut caught in different locations (see Fig. 2) in Cumberland Sound in February 1990.

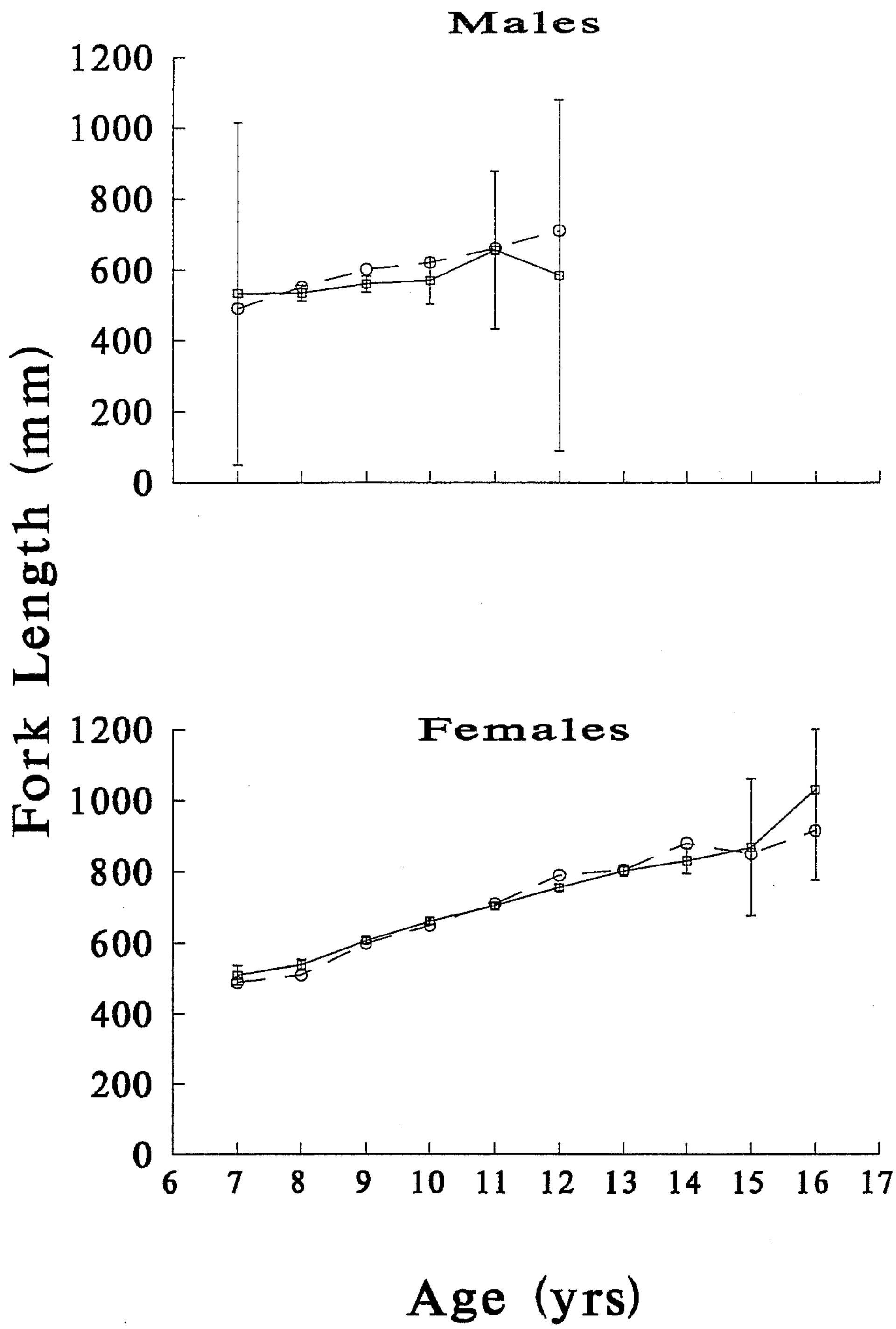

Fig. 9. Length at age of male and female Greenland halibut caught in Cumberland Sound (solid line with 95% confidence intervals) and Davis Strait (dashed line, from Atkinson et al. 1982).

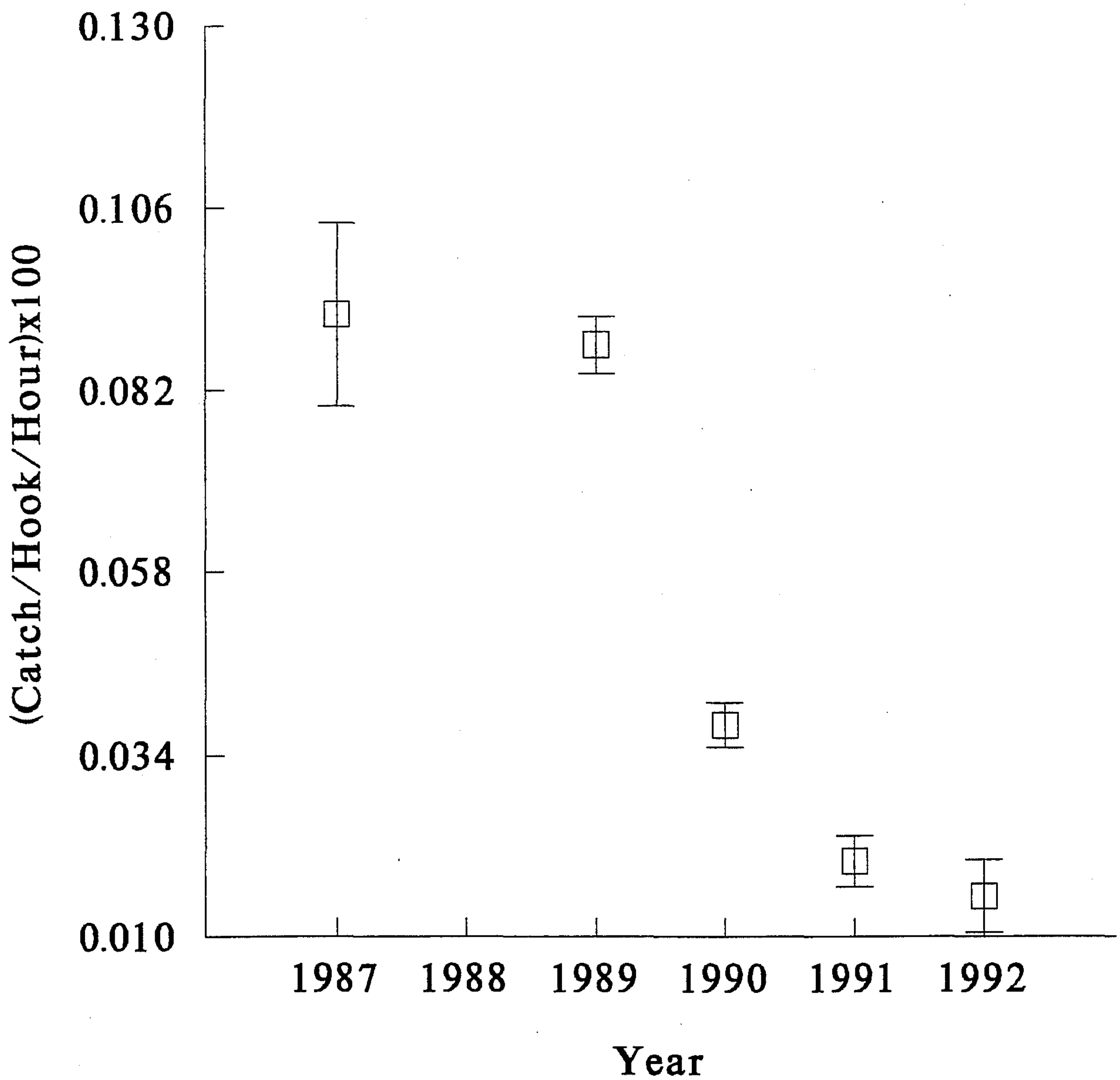

Fig. 10. Mean annual catch per unit effort of Greenland shark in Cumberland Sound, 1987-1992. Error bars are 95% confidence intervals.

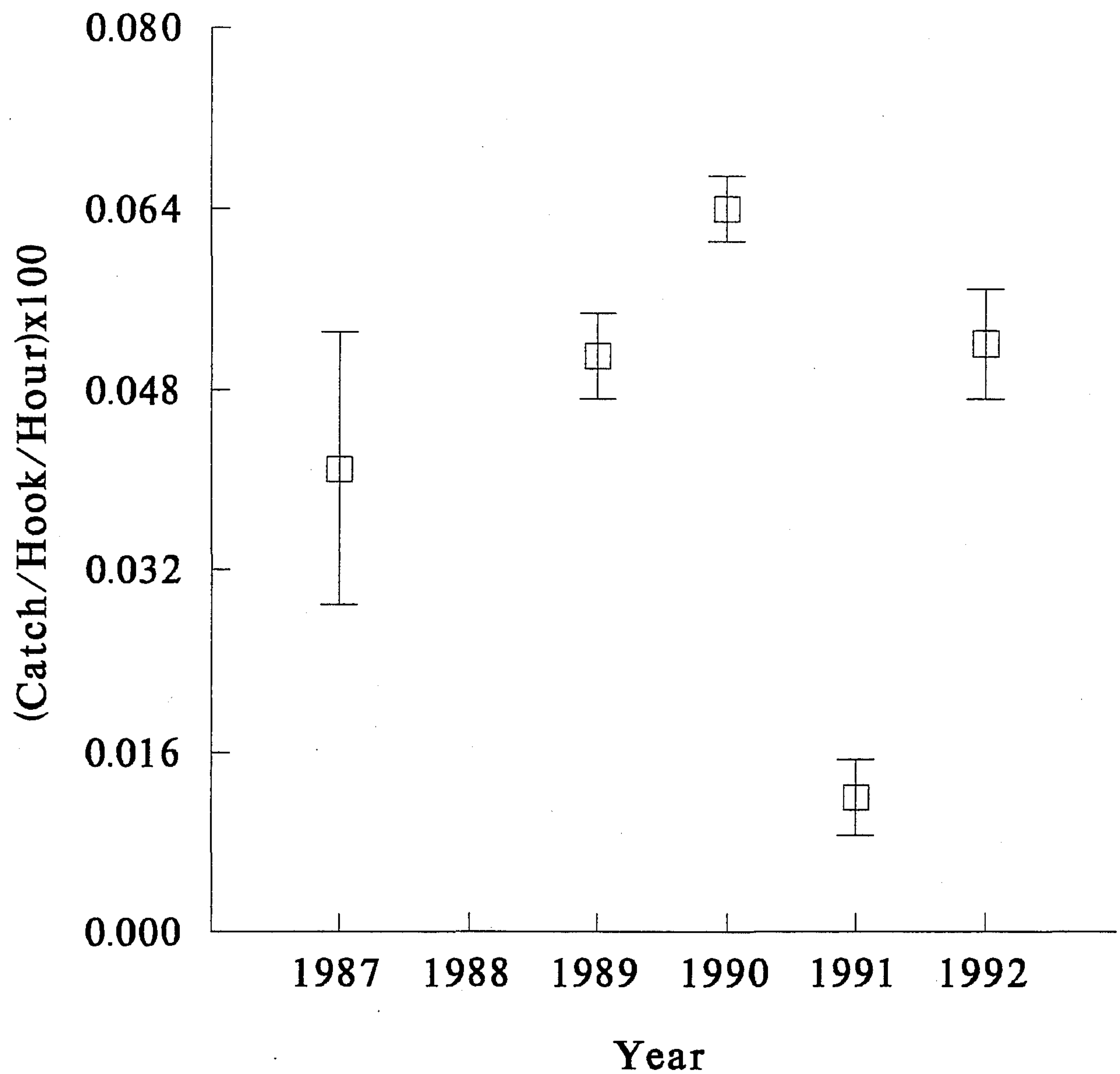

Fig. 11. Mean annual catch per unit effort of thorny skate in Cumberland Sound, 1987-1992. Error bars are 95% confidence intervals.