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Tagging mortality of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum)

by

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Abstract

Tagging mortality for Greenland halibut was studied under summer and winter conditions. The fish were caught using longlines and tagged with a T-bar tag. The winter experiment was conducted in Cumberland Sound, Canada in May 1997. Air temperatures were below 0°C and cold water-masses were present at 0-300m. Fish were immediately placed in a tub of water after capture and transported by snowmobile to a heated tent for tagging and then placed in cages that were submerged to 300m depth. The summer experiment was conducted in Upernavik, Greenland in August 1998. Air temperatures were above 0°C but intermediate cold water-masses were present at 50-200m. In the summer experiment fish were tagged and released in a holding tank to assess immediate tagging mortality (0 to 18h), placed in specially designed cages and submerged to 200-500m to assess short-term tagging mortality (up to 117h). A total of 155 Greenland halibut were included in the study. Overall tagging mortality was estimated to be 7%. Immediate handling and tagging mortality in both the winter and summer experiments was low (<5%). Several factors were shown to have significant effects on the outcome (level of condition). Fish held in the tanks for longer time periods were in better condition. Moreover, females had a tendency to be in poorer condition than males immediately following tagging. Short-term mortality was 4%. There was no difference in mortality rates between seasons. There was no effect on mortality of the covariates size, time held in the cage and several other factors examined. However, there was a significant correlation between the fish's health and mortality. The study showed that tagging under harsh winter conditions is just as possible as under summer conditions as long as exposure to sub-zero temperatures are minimized. Our study further suggests that holding the tagged fish in an observation tank for a period of 5h or more could reduce the tagging mortality on released fish.

Introduction

The application of external tags is an important tool that has been used in fisheries biology for over 100 years on a population level to determine migration patterns, discriminate between stocks and estimate stock sizes. Tags have also been widely used for studies on the individual level to assess growth, mortality, age and behaviour. A variety of tag types have been used over time –for a review see McFarlane (1990). The prerequisites for a successful tagging program are 1) the fish survive the tagging operation, 2) the tag is not lost and 3) that there is a certain possibility that many of the tagged fish can be recaptured at a later date. In this paper we want to evaluate tagging of the deepwater species Greenland halibut with special attention on tagging mortality.

Greenland halibut are widely distributed over most of the northern circumpolar arctic and sub-arctic oceans in the depth range from 200 down to at least 2200 meters and are found associated with water temperatures of 1 to 6°C

(Bowering, 1999; Jørgensen, 1997) Greenland halibut have in the last decade become an important commercial species (Bowering & Nedreaas, 2000) and as a result there has been an increased demand for studies at both the stock and individual level for management purposes. In many of these studies tagging has been and is an important tool.

To our knowledge the first tagging experiment on Greenland halibut was conducted in West Greenland waters in the 1930's (Hansen, 1949 ref. *in* Smidt, 1969). Since then a number of tagging experiments and programs have been carried out at West Greenland. These are reported in Boje (1994); Boje MS (1999); Riget & Boje MS (1987) and Smidt (1969) and are still ongoing (Simonsen & Boje, MS 2001). In Canadian waters tagging programs have been carried out in 1969, 1971 and 1979 in the Labrador-Newfoundland region (Bowering, 1984) and in Davis Strait / Cumberland Sound in 1994 (Northlands Consulting, MS 1994). In 1997 a tagging program was initiated in the Nunavut region in Cumberland Sound (Stephenson *et al*., MS 1997). In the North Eastern part of the Atlantic tagging has been reported from the Svalbard area by Norway. These experiments were carried out in 1962-64 (Lahn-Johansen 1965 *in* Nedreaas *et al*., MS 1999); 1983-85 (Godø & Haug, 1987); 1995-97 (Nedreaas *et al.*, MS 1999) and 2001 (Å. Høines, pers. com., Marine Research Institute, P. O. Box 1870 Nordnes, N-5817 Bergen, Norway). In the waters around Iceland tagging experiments were conducted in 1971-74 (Sigurdsson, 1981) and have not been conducted since. However, a tagging program is expected to be initiated in autumn 2001 (E. Hjorleifsson, pers. com., Marine Research Institute, Skúlagata 4, 121 Reykjavik, Iceland). In the Gulf of Alaska, Greenland halibut have been tagged on an opportunistic basis in recent years (J. Ianelli, pers. com., Alaska Fish. Science Center, REFM Div., NMFS/NOAA, Bldg 4, 7600 Sand Pt Way NE, Seattle, WA 98115, US). The different programs have used either trawl or longlines to catch the fish. The tags have been Petersen-type discs, T-bar anchor tag, Lea-tag and different kinds of spaghetti or wire tags. None of the studies mentioned have directly studied the first two prerequisites mentioned above namely tagging mortality and tag loss.

The fisheries for Greenland halibut in the Davis Strait and Baffin Bay are continuing to develop both in the inshore and the offshore areas (Jørgensen, MS 2001; Simonsen and Boje, MS 2001; Treble, MS 1999). Tagging programs have been used successfully in the past and are believed to be an important tool to develop a further understanding of Greenland halibut migration and stock bounds in these areas. Tagging programs have been going on for many years in West Greenland waters but tagging mortality and tag loss have never been evaluated. A tagging program was initiated in Canadian Arctic waters beginning with summer tagging (August and September) using otter trawl (Northlands Consulting, MS 1994) and long-line (DFO unpublished report 1995) but the cost to charter these vessels was very high. Mathias and Chiperzak MS (1996) suggested that the most cost efficient method to tag several thousand fish would be to tag during the winter long-line fishery. However, tagging in harsh winter conditions (air temperatures of –10 to –30 C°) was a new approach that could cause severe handling/tagging mortality. In the present paper we examine tagging mortality within our summer and winter tagging programs and review factors of mortality with reference to our results, as well as those from other studies.

Methods

The methods used during the summer and winter experiments had some similarities and differences. The similarities were as follows.

Greenland halibut were caught using longlines. The longlines were set in 400-850 meters and soaked for 5-12 hours. Fish were gently landed. In general, if the hook was placed in the outer mouthparts and the fish was undamaged, it was used for tagging. In some cases a few fish that were clearly damaged were used to evaluate the influence of physical damages. The fish were measured (total length) and tagged using a Dennison tagging gun. The tag was placed slightly posterior to the line of maximum body depth, and approximately 1-2 cm (depending on the size of the fish) below the insertion of the dorsal fin. The external portion of the tag protruded from the right (dorsal) side of the fish, angled posteriorly. No anaesthetic was used. The fish were first released in an observation tank to assess immediate mortality. The condition of the fish was then quickly evaluated and those still alive were re-released in a cage for a study on short time mortality. In order to make the conditions as comparable as possible to a normal tagging operation the tagged fish were submerged to 200-500 meters (approximately the depth of capture) and left untouched. At the end of the experiment the cages were retrieved, the fish examined and tag loss registered.

Summer

The experiment was carried out in August 1998 at three different locations in a fjord system in Upernavik district at the West coast of Greenland (Fig. 1, Table 1). The longlines were set from the RV "Adolf Jensen" during a longline survey (Simonsen *et al*., MS 2000). The hooks were baited with squid and the hook type was Mustad no. 8, type 7255D. The Greenland halibut caught on the hooks were gently netted as the line was retrieved and brought on board. The fish were immediately measured and tagged with Floy tags, type FD-68B. Every second fish had a dose of 50-mg/kg oxytetracycline (OTC) injected into the body cavity. The OTC is known to mark otoliths and was being tested for use in Greenland halibut for age validation purposes. The observation tank was equipped with continuous water flow to maintain saturated oxygen levels. Temperature in the tank was around 3.0 °C (mean 3.02, min. 0.9, max 5.5°C). After 1 to 18 hours the fish's condition was evaluated according to Table 2 and re-released in cages. The temperature profile at the location for the cage release was determined using a temperature probe lowered through the water column. The cage was a modified box-type snowcrab pot. The cage consisted of an outer metal frame, with a fine meshed net (black, mesh size 10 mm, knot free) stretched inside the frame (Fig. 2). An opening device at the top of the cage allowed the fish to be added and removed. The cage volume was approximately 0.9 m^3. A metal pipe (diameter 10 cm) was situated in the middle of the cage in order to secure the cage to the anchor rope. The lower cage was equipped with buoys so that the setting had positive buoyancy and was suspended in the water column. Each cage was held beside the ship as fish were transferred from the tank to the cage. A total of 8 to 18 fish were put in each cage (density 8.9 to 20.0 fish m^{-3}). The cage was then lowered (sinking rate was ~30 meter per minute) to the desired depth and left untouched until termination of the experiment. Water temperature at the cage settings was monitored with an attached temperature probe and found to be around 1.3 °C (mean 1.26; max. 1.45; min. 0.6 °C). A total of 11 cage settings were carried out at three different locations (Table 1).

Winter

The experiment was carried out in May 1997 within Cumberland Sound, Southeast Baffin Island (Fig. 1, Table 1). The longlines were set from the land fast sea ice. The hooks were baited with arctic char (*Salvelinus alpinus*) and the hooks used were Milward circle (Kirbed) No. 2. Fish were removed from the hook as quickly as possible and put into a 70 L fish tub, containing 0 to 4^o C water, which was lashed to a sledge and pulled by a snowmobile. The fish tub was covered with plywood to limit exposure to sunlight and heat loss. When all the fish were removed from the ground line they were transported back to a tent and placed in an observation tank where they were measured, tagged and held prior to placing them in the cage. Compared to the summer experiment the holding time in the tank was short, only 10-20 minutes. The tags used were Floy tags, model FD-94. They had a 9 mm T-bar, 64 mm total length (16 mm monofilament with 48 mm expanded yellow plastic label). The outside air temperature varied from -12.0^o C to $+2.0^o$ C during the day. Wind-chill was a factor, particularly when removing fish from the unprotected fishing holes, but we were able to limit the fish's exposure to sub-zero air temperatures by tagging inside a heated tent. A hole was cut in the ice just inside the open end of the tent to accommodate the deployment and retrieval of our holding cage. Water was heated on an iosol stove and added to the water in the tagging tank in order to keep it above 0^oC. It was difficult to maintain a constant temperature and it ranged from 1^oC to 5^oC over the experiments. The water in the tagging tank was partially or completely changed at least two to three times a day to maintain clean, well-oxygenated water conditions.

Short term tagging mortality was assessed using a cage to hold fish at depth, below the cold water layer, where temperature was similar to that found on the bottom. A conductivity, temperature, and depth (CTD) sound was taken in order to determine the exact conditions for our tagging site. The cage was made from 2 cm diameter PVC pipe and measured 0.54 m^3 (Fig. 2). It was covered with fine mesh (6mm) seine netting with a zipper sewn into one end of the netting to provide an opening for adding and removing the fish. Ten to eleven fish were placed in the cage (density 18.5 – 20.4 fish m^{-3}) on three different occasions and held for 5, 10.5, and 56.5 h. A 20 kg weight was attached to lower the cage into the water (sinking rate ~9m per minute) and to keep it suspended in the water column on a line secured to the ice above. The temperature of the tagging and transport tanks was recorded and notes made on the condition of the fish before and after being held in the cage.

Data analysis

We have divided the analysis of our results into two parts. First, we considered the tank experiment. For the summer experiment only the Greenland halibut were held in observation tanks immediately following tagging. The stay in the tank lasted from 1 ½ to 18 h. The outcome examined was the fishes condition, assessed using a five point scale (Table 2). The influence that explanatory variables such as *fish length, time in tank, station* and *sex* had on fish condition were evaluated by univariate and multivariate linear regression.

Secondly, we considered the cage experiment. After an assessment of immediate effects, the fish were placed in cages and held for relatively longer periods of time to assess short-term tagging effects. The total time the fish were held in captivity varied between 4 ½ and 119 hours. Fish were pooled in 6 time intervals based on weighted mean values for each cage. Here the outcome was the binary result dead or alive. Investigation of the relationship between the probability of dying and the explanatory variables was done using Generalised linear models. McCullagh & Nelder (1989) chapter 4, provided an appropriate transformation of the probabilities (link function). Then, the each of the estimated coefficients were tested using linear regression, and the goodness-of-fit was evaluated via analysis of deviance given a sequence of nested models (for details see McCullagh and Nelder, (1989), chapter 2).

Results

The weather conditions during the winter experiment in May (WINTER) were relatively warm for the season –12.0 to +2.0 °C and thus excellent for tagging. The air-temperature was not monitored directly during the summer experiment (SUMMER), but was in the range +2 to +10° C (normal for the Upernavik area in August). The temperature conditions in the water column at each location are illustrated in figure 3. Both WINTER and SUMMER locations had a cold, sub-zero, water layer present. In WINTER it extended from the surface down to ~300 m. However, between 100 to 300 m. temperature gradually rose to 0 °C. Below 350 m. water temperature was homogeneous at approximately + 0.2 °C. In SUMMER a cold intermediate water layer was present from 57 to 198 m. Below 200 m. the temperature again rose and began to stabilize around +1.35°C at 300 m. As a consequence the Greenland halibut were exposed to sub zero temperatures when the longlines were retrieved and when the cages were lowered and raised.

A total of 155 fish were included in the study (Table 1). Of these 11 fish died during the tagging experiment suggesting an overall mortality of 7.1%.

Immediate mortality & condition

A total of 105 fish were included in the analysis of immediate mortality and fish condition. Five fish were assigned to level IV (dead), which corresponds to a mortality of 4.8%. We looked at the covariates *fish length, time in tank, station* and *sex* in order to see if they could explain condition (Fig. 4). First we looked at each factor separately by general linear regression (GLM); secondly we examined additive and interaction effects using multivariate models.

<u>Fish length:</u> Fish lengths ranged from 35 to 73 cm but the majority were between 40 and 60 cm. Observations were pooled in 10 cm length intervals. Death only occurred in length interval 40-50 cm and 50-60 cm. Condition level-I was observed for all length groups and was most abundant. There was a small trend that the bigger fish were in better condition but it was not significant (p=0.16). <u>Time:</u> Time in the tank was grouped in 3 time intervals 0-5h, 5-10h and 10-20h. There was no positive correlation between condition and time spent in the tank. On the contrary we observed that the fish that were in the tank for the shortest period (0-5h) were the only ones that were classified as level III and IV (p=0.008). <u>Station:</u> The five fish that died originated from two stations (*d* & *i*). The number of fish from these stations was limited and these sample sizes could be influencing the significant result for these stations on condition (p=0.01; p=0.03). At the same time station *n* almost exclusively produced fish of condition level1 and was thus also significant (p=0.03). <u>Sex:</u> After termination of the experiment a random selection of 48 fish was sampled for sex. We found that only female fish were classified as condition level III to IV. Sex was thus a significant factor (p=0.03).

Test models with additive as well as interactive effects were also carried out:

*time+length; time+sex; length+sex; length*time; sex*time; length*sex*

Even though many of the models also were statistically significant, the amount of variation explained was generally low (R^2 values 0.08 to 0.19) and not significantly better than the univariate approach. As our primary goal was to estimate which covariates that contributed the most to HC we used the univariate models in interpretation of the data.

Short-time mortality

A total of 150 fish were included in the cage-experiment to assess short-time mortality, 118 for the summer experiment and 32 for the winter. The proportions of fish that died are shown in table 3 and figure 5. Overall six fish died during the experiments (4.0%). Results of the covariate analysis of the explanatory variables *season, fish size, time, condition, tag, sex, cage* and *OTC* are given below.

Season: Mortality for the winter cage experiment was 6.3% and for the summer it was 3.4%. The difference was not significant (p=0.48). Fish size: Fish were in the size range 35 to 73 cm (total length). All deaths happened in the 40 to 60 cm length interval with the highest mortality in the 40 cm length group. There was no evidence of size dependent mortality (p=0.43). Time: Mortality varied between 0 and 10.3%, highest in the 31h interval lowest in intervals above 60 h. There was no correlation between time held and the proportion of fish that died (p=0.20). Condition: The fish's condition after the tank stay was used to evaluate the dependence of condition on mortality. None of the HC-I fish died while the mortality of the HC-IV was 100% (2 fish). These data showed a significant dependence between the fish's health condition and mortality (p=0.02). Tag: The Floy-tag itself or the additional handling due to attachment of the tag could introduce higher mortality. In the summer experiment a total of 9 fish in one cage setting were not tagged with a Floy-tag, but were otherwise treated equally. None of the untagged fish died while 4.3% of the tagged fish died. However, the groups were very unbalanced (9 vs. 141) and the difference was not significant (p=0.77). Sex: 53 of the Greenland halibut were sexed after termination of the experiment. The mortality for both sexes were around 5% and thus, sex had no influence on the mortality (p=0.92). Cage: 15 cages were used. One cage did stand out with mortality at 27%. However, statistically the chance of dieing in that cage was not significantly different from the rest (p=0.8). Mortality was not significantly influenced by any of the other cages. OTC: Only one of the OTC treated fish died compared to 5 in the untreated group. Therefore, there is no evidence that the OTC injection increased mortality or had a significant positive effect on survival (p=0.26).

Additive as well as interactive effects were then tested for the following combinations of variables:

*condition + otc; otc*condition; time*sex; length*sex; condition+otc+otc*condition;*

In general, the explanatory variable *condition* had a strong influence and it seemed to drive most of the multivariate models when it was included (as additive or interactive effect). All the models where *condition* was included were thus significant, but none of them were significantly better than the univariate model (ANOVA, p>0.3). An additive effect of OTC and fish condition was observed. Fish in poor condition that were treated with OTC had a significantly lower chance of dieing (p=0.04).

Discussion

We believe tagging mortality may be caused by several factors: 1) capture method; 2) handling (capture, tagging, tag type); 3) increased risk of predation; and 4) environment (changes in temperature and pressure). In addition, variables such as size, fitness (condition) of the fish, and the type of tag used may also have an influence on mortality.

Our cage experiments provide data on tagging mortality that was previously unavailable for Greenland halibut. The results suggest that if care is taken to minimize physical trauma and stress during the capture and tagging process then mortality can be minimized, even under severe winter tagging conditions. Our experiments did not address predation or tag type, however, we have chosen to include observations and studies made by others in the following discussion on the factors that can influence tagging mortality.

The Capture Method

Greenland halibut in the present study were all caught on longlines. If we assume that our study design did not influence mortality rate, the overall mortality rate for Greenland halibut caught on longline and tagged with t-bar anchor tags is around 9 %. To our knowledge this is the first estimation of mortality rate for tagged Greenland halibut and possibly for any tagged flatfish.

The literature suggests tag return rates for tagging programs using longline (LL-fish) differ compared to otter trawl (OT-fish). In West Greenland the return rate was 16% for LL-fish and only 3% for OT-fish (Riget & Boje, 1989). In a tagging program in the waters of Newfoundland, Bowering (1984) observed a return rate from LL-fish of 17.2 to 38.9 % while it was as low as 0.1 to 1.7% for OT-fish. Data from Iceland showed that Greenland halibut caught using longline had consistently higher tag return rates (Sigurdsson, 1981). Even though some of the difference could be caused by variability in effort the uniform results strongly indicate that tagging mortality on OT-fish are several times higher than for LL-fish. Black (1958) argues that line caught deep-sea fish have a very high mortality if released. He suggests the hooked fish are hyperactive and thus build up a deadly level of lactic acid (or other metabolic products) in the blood. This might be true for some deep-sea fishes but Greenland halibut are usually very passive on the line and it has a bad reputation among sports fishermen for not being a big fighter. Therefore, we believe that for Greenland halibut, the optimal gear in a tagging operation is longline.

Handling and Tagging Methods

In the present study we were not able to estimate the influence of handling or tag type directly. Many of the fish (5 out of the 9 death in total) in the summer experiment died in the holding tank within 10 hrs of capture. One of the two fish that died in the winter experiment had obvious physical damage and died within 5 hrs. This compares to an experiment that was similar to ours that the short-tem mortality (5 days) for northern pike (*Esox lucius*) held in net pens was 2.4% (Pierce & Tomcko, 1993). All deaths occurred within two days of tagging and fish that were in poor condition (not able to swim upright prior to tagging) had a much higher mortality rate (73 %). We did not observe higher (or worse) condition for the Greenland halibut that stayed longer in the tanks. Therefore, holding the fish in observation tanks for 5h or more could reveal fish with internal damage or high levels of lactic acid, thereby reducing mortality for released Greenland halibut. This is contrary to what Black (1958) found for sockeye salmon (*O. nerka*). He observed that salmon held in tanks had much higher lactic acid compared to fish that had just been caught using hook and line. He therefore concluded that holding fish in tanks for extended periods could increase lactic acid level and may have a negative effect on survival. The level of lactic acid is correlated with behavior and activity. As Greenland halibut are observed to behave very calmly in the tanks, species specific behavior could explain the difference.

Schreck (1981) suggests that physical handling or psychological disturbance can lead to increased mortality. The longer the handling time and the longer it takes to apply the mark the greater the chance of mortality, according to McFarlane *et al*. (1990). Different tag types have different handling time and may therefore have different mortality rates associated with their use. The effects of tag and tag type have primarily been examined for fish smaller (10-30 cm) than the Greenland halibut used in our experiments. The following authors all found a significant negative effect on survival for small fish with external tags: Mourning *et al*. (1994), *Oncorhynchus mykiss,* 14-24 cm; Whitelaw & Sainsbury (1986), *Lutjanus carponotatus,* avg. 16 cm; Stobo *et al*. (1992), *Clupea harengus,* juvenile fish). Others found that mortality for larger fish was not significantly affected (Pierce & Tomcko (1993), *Esox lucius* 38-73 cm; Eames & Hino (1983), *Oncorhynchus tshwytscka,* 2 year old smolt). We believe that the time it takes to apply the tag and the tag size in relation to fish size are important contributions to overall tagging mortality. For example Godø and Haug (1987) noted that the recapture rate from Greenland halibut tagged with Lea-tags (fish size 20 to 30 cm) was nil compared to 2% for larger Greenland halibut. The same size-dependent recapture rate was also observed in a tagging experiment with 0-group cod (*G. morhua*) (Svaasand *et al*., MS 1987). This leads us to conclude that small and easy to apply tags like Floy-tag and Lea-tag can be used on Greenland halibut down to about 35 cm without introducing size-dependent handling or tagging mortality.

Predation

There is the possibility that tagging could make the fish more vulnerable to predation as an external tag may act as an attractant to predators such as sea birds (Svaasand *et al*., 1987). Seagull attacks have been observed both in the Davis Strait and NE Atlantic when tagged Greenland halibut has been released from otter trawlers (J. Macpherson, pers. com., 18 Argus Drive, Dartmouth, Nova Scotia, B3A 4Y1, Canada; Godø & Haug, 1987). However, seagull attacks have never been registered in the tagging program off West Greenland using longlines (J. Boje, pers. com., Greenland Institute of Natural Resources, P. O. Box 570, DK-3900 Nuuk, Greenland). One reason for the difference could be that fish caught using otter trawl are smaller and weaker following tagging compared to fish caught using long-lines. These fish may remain at the surface longer during recovery from tagging and are therefore at greater risk of attack by sea birds. Several tags from Greenland halibut have been recovered from stomachs of seal (Godø & Haug, 1987), cod (Bowering, 1984) and shark (in Cumberland Sound, a tagged Greenland halibut was found in the stomach of a shark 3 days after it had been released). Otterå *et al*. (1998) examined predation on tagged and untagged Atlantic cod (*G. morhua*) in the size range 20-41 cm and found that neither predation from other fish or by birds were higher for the tagged fish. As illustrated from the seagull predation on tagged Greenland halibut, we find it likely that fish that have just been released, are easier prey for a predator than a normal fish and thus mortality due to predation could be higher immediately following tagging (especially for smaller fish). However, it does not seem likely that a relatively small tag on a fish like Greenland halibut should increase mortality rate after the first few days.

Environment

Changing environmental conditions (e.g. water temperature and pressure) may injure or increase stress in the fish. Some fish species may be able to survive these stresses better than others. For example most flatfish do not have swim bladders and are thus not as affected by pressure changes with depth as other species. Pressure is of special concern when tagging deep-water fishes. Greenland halibut are probably one of the few deep-water species that can be tagged at the surface and released with success.

Temperature is another factor that is known to be crucial, probably because temperature differences induce thermal shock (leading to death). Exposure to subzero temperatures has been reported to be lethal for fish (Clay, 1990; Carline & Brynildson, 1972). In March 1993, a first attempt was made by DFO to tag Greenland halibut during the winter fishery. However, the fish were exposed to -20^{o}C air temperatures, the tagging tank was placed on a sledge and a pump was used to circulate surface water (-1.9^{o}C) through it. All the fish were dead or moribund as soon as they were transferred to the tagging tank and never regained their composure. Two attempts were made with about 10 fish in each trial. No fish survived the capture and handling process. (Dan Pike, pers. comm., North Atlantic Marine Mammal Commission, University of Tromsø, 9037 Tromsø, Norway). Also, under the winter tagging conditions there is a chance some fish may be trapped in the cold water layer below the ice surface if they are not strong enough to swim free of tidal currents running below the ice. These currents vary in strength throughout the day (tidal). On one occasion a fisherman found a tagged Greenland halibut dead in his fishing hole 12 days after it had been tagged. Godø and Haug (1987) also showed that temperature could affect tagging mortality on Greenland halibut. They found during a 3 year tagging program on Greenland halibut (1983-85), that recapture rate was much higher (16.5%) in 1984 when bottom temperature was the highest (2.2^o to 3.2^o C) compared to recapture rates below 1% in years with lower bottom temperatures (0.8^o to 2.7^o C).

Results from the winter tagging experiment show that tagging from the sea-ice at subzero temperatures is possible and does not result in tagging mortality that is higher than that found in the summer period. Until now there has been 5 re-captures (0.3%, but low fishing effort) from the winter tagging (design as described in this study) in Cumberland Sound.

Tag loss:

Tag loss or shedding is a common problem in many tagging program (see e.g. Pierce & Tomcko, (1993); Waldman *et al*. (1990); Whitelaw & Sainsbury (1986). In the summer experiment we had 6 fish (5%) that lost their tag during the cage stay while the winter experiment had none. A reason for the relatively high tag loss in the summer experiment, could be that the net type used in the summer cages had wider mesh sizes (10mm mesh in summer vs. 6mm mesh in winter) and thus the t-bar of the Floy tag easier caught in the meshes. Further studies with double tagging are needed to clarify the tag loss for Greenland halibut. However, the observed tag loss is within the range reported from other species tagged with anchor tags. For Atlantic cod (20-41 cm) double tagged with anchor tags suggest that tag loss rate could be as high as 11% (Otterå, et al., 1998). For tropical fish (16 cm avg. length), tag loss was calculated at 6.1 % after 55 days (Whitelaw and Sainsbury, 1986). Chinook salmon (20 cm avg. length), tagged using anchor tags, experienced tag loss of 2-5 % (Eames & Hino, 1983).

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Table 1. Overview of experiments.

	date	Location	Position		cage	depth of cage (m)	time in tank (h)	time in cage (h)	fish in cage (n)
Summer	August 1998	1	73º20N	55º20W	A	310	2 ½	32	9[a]
					B	310	2 ½	27	9
		2	73º12N	55º31W	A	450	2 ½	39	9
					B	450	2 ½	39	9
					C	450	3	29	11
		3	72º52N	54º43W	A	260	10	101	11
					B	260	18	101	10
					C	260	3	86	8
		4	72º52N	54º43W	A	310	13 ½	62	14
					B	310	5	36	14
					C	310	10	36	14
		fish died in	tank						5
		total							**123**
Winter	May 1997	1	65º59N	66º43W	A	200	< ½	4 ½	1
					B	200	< ½	5	11
					C	300	< ½	10 ½	10
					D	300	< ½	56 ½	10
		total							**32**
Combined		**Grand total**							**155**

[a] Fish were not tagged.

Table 2. Condition factor (health- condition). Evaluated after tank experiment.

Condition factor	Description
I	Very good condition. Fish lively swimming, deep-red gills
II	Good condition. Fish swimming, deep-red gills
III	Reasonable condition. Fish slowly swimming, red gills
IV	Bad condition. Fish hardly swimming, pink gills.
V	Dead

Table 3. Observations in the tagging experiment. The variable *"Health-condition"* has fewer observations because the winter experiment did not apply the five point scale used in the summer experiment.

	Variable	ALIVE (n)	DEAD (n)	Grand Total
SEASON	summer	114	4	118
	winter	30	2	32
	total	144	6	150
SIZE (cm)	30	3	0	3
	40	26	2	28
	50	57	2	59
	60	52	2	54
	70	6	0	6
	total	144	6	150
TIME (hour)	8	21	1	22
	31	26	3	29
	42	45	1	46
	60	14	1	15
	80	17	0	17
	117	21	0	21
	total	144	6	150
HEALT-CONDITION	1	71	0	71
	2	23	2	25
	3	2	0	2
	4	0	2	2
	total	96	4	100
TAG	NO	9	0	9
	YES	135	6	141
	total	144	6	150
CAGE	1	1	0	1
	2	10	1	11
	3	10	0	10
	4	9	1	10
	5	9	0	9
	6	9	0	9
	7	9	0	9
	8	8	3	11
	9	11	0	11
	10	10	0	10
	11	8	0	8
	12	14	0	14
	13	14	0	14
	14	13	1	14
	15	9	0	9
	total	144	6	150
SEX	Male	18	1	19
	Female	32	2	34
	total	50	3	53
OTC	NO	84	5	89
	YES	60	1	61
	total	144	6	150

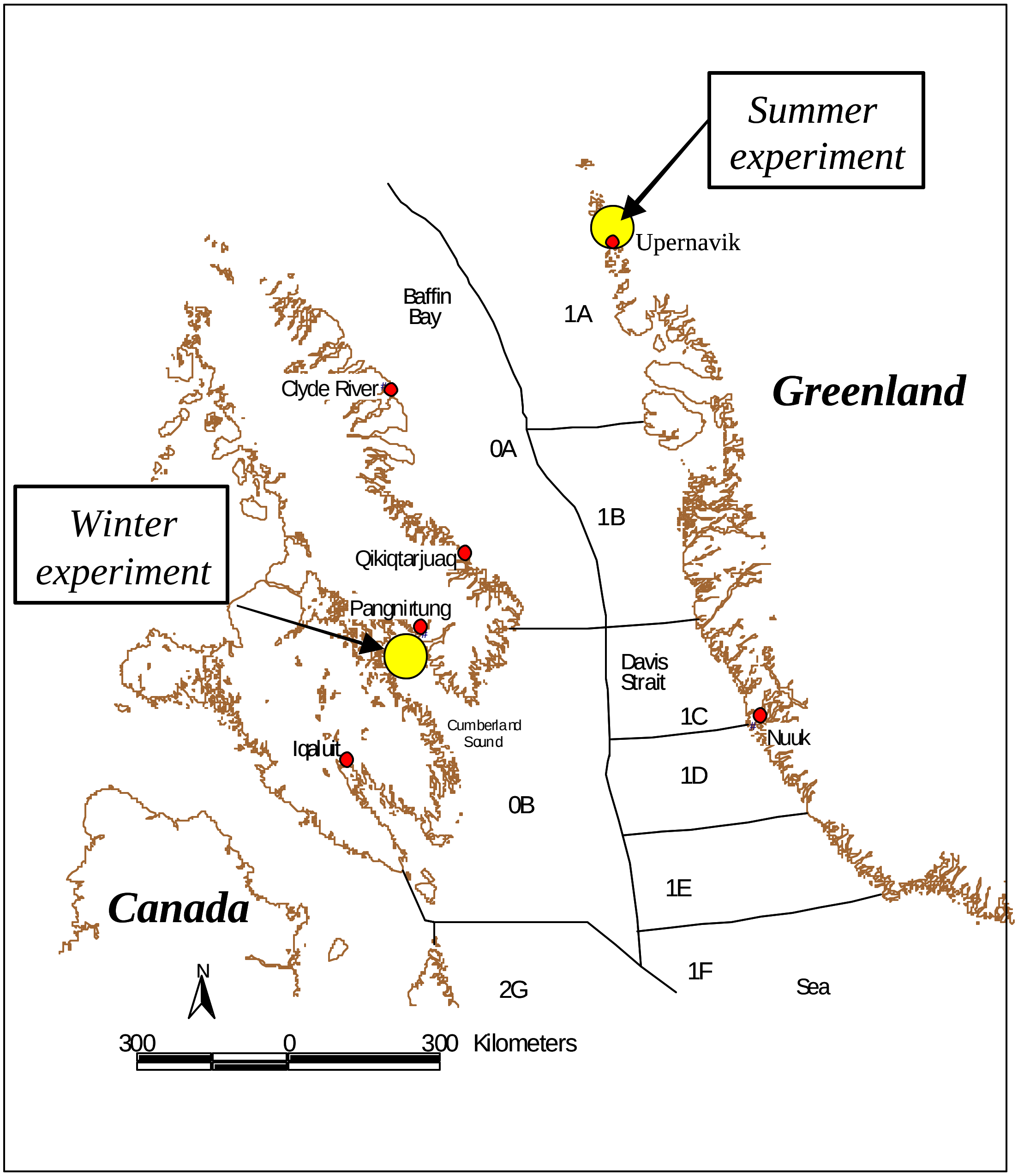

Figure 1. The winter and summer experiment sites in Canada and Greenland respectively. The exact position is shown in Table 1.

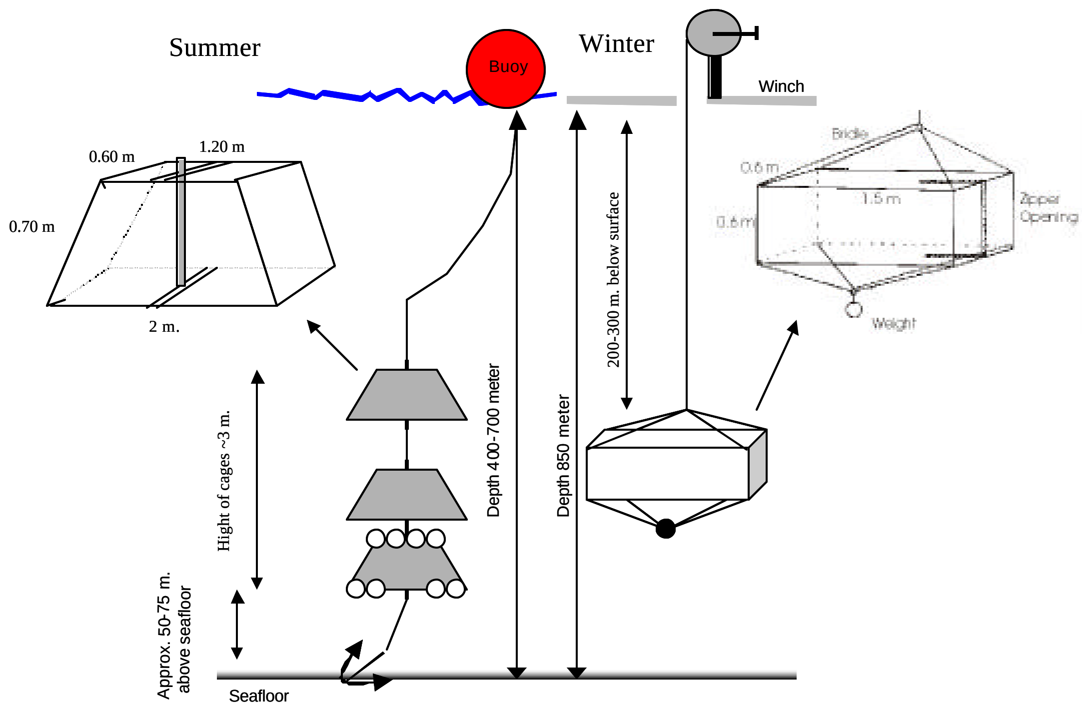

Figure 2. Schematic presentation of the design and set-up in the summer and winter experiment.

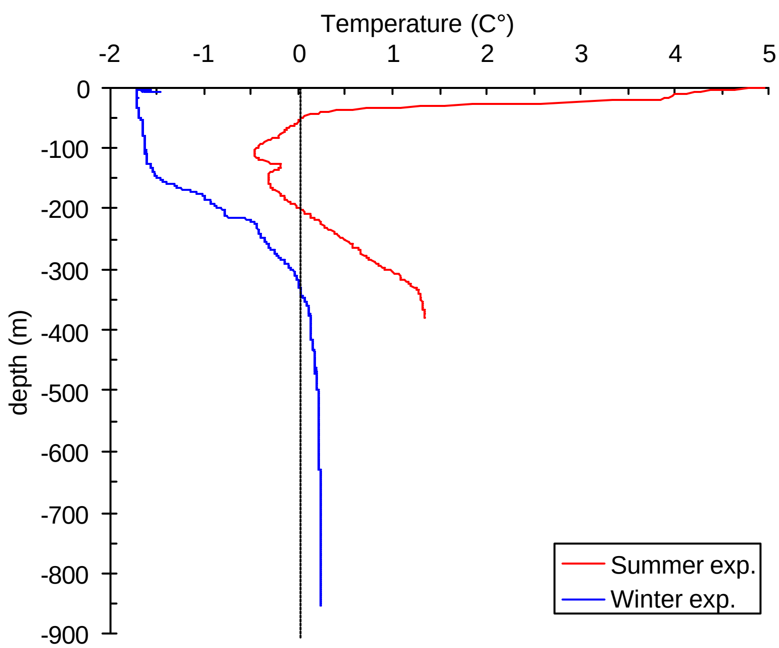

Figure 3. Temperature profiles at the summer and winter locations. The summer experiment was conducted in August in Upernavik Icefjord, West Greenland and the winter experiment in May in Cumberland Sound, Canadian Eastern Arctic (see Table 1).

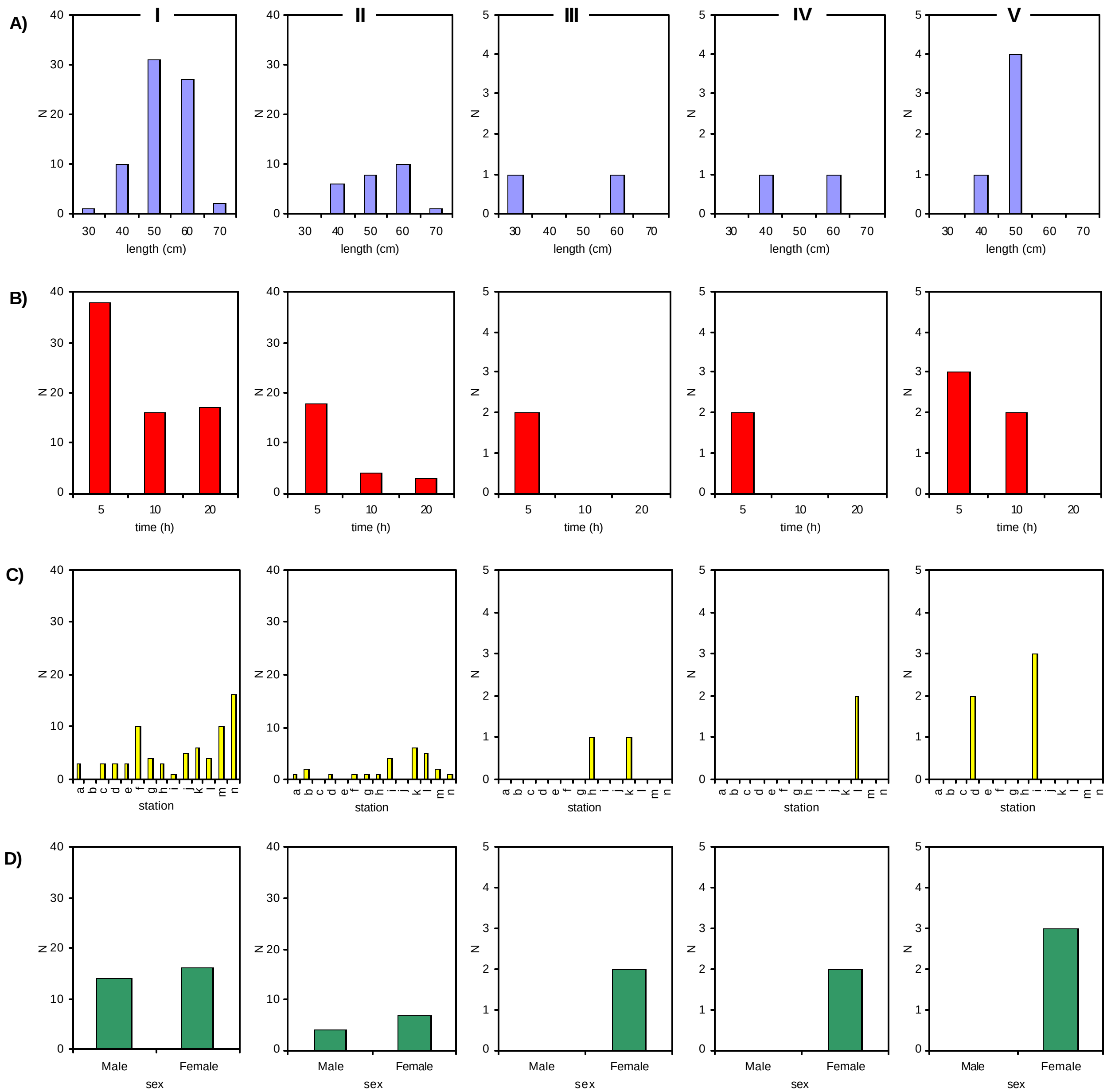

Figure 4. The influence on fish condition (left panel level I to right panel level IV) on Greenland halibut in the tank-experiment from: A) fish length, B) time in tank, C) station or longline they originated from, and D) sex .

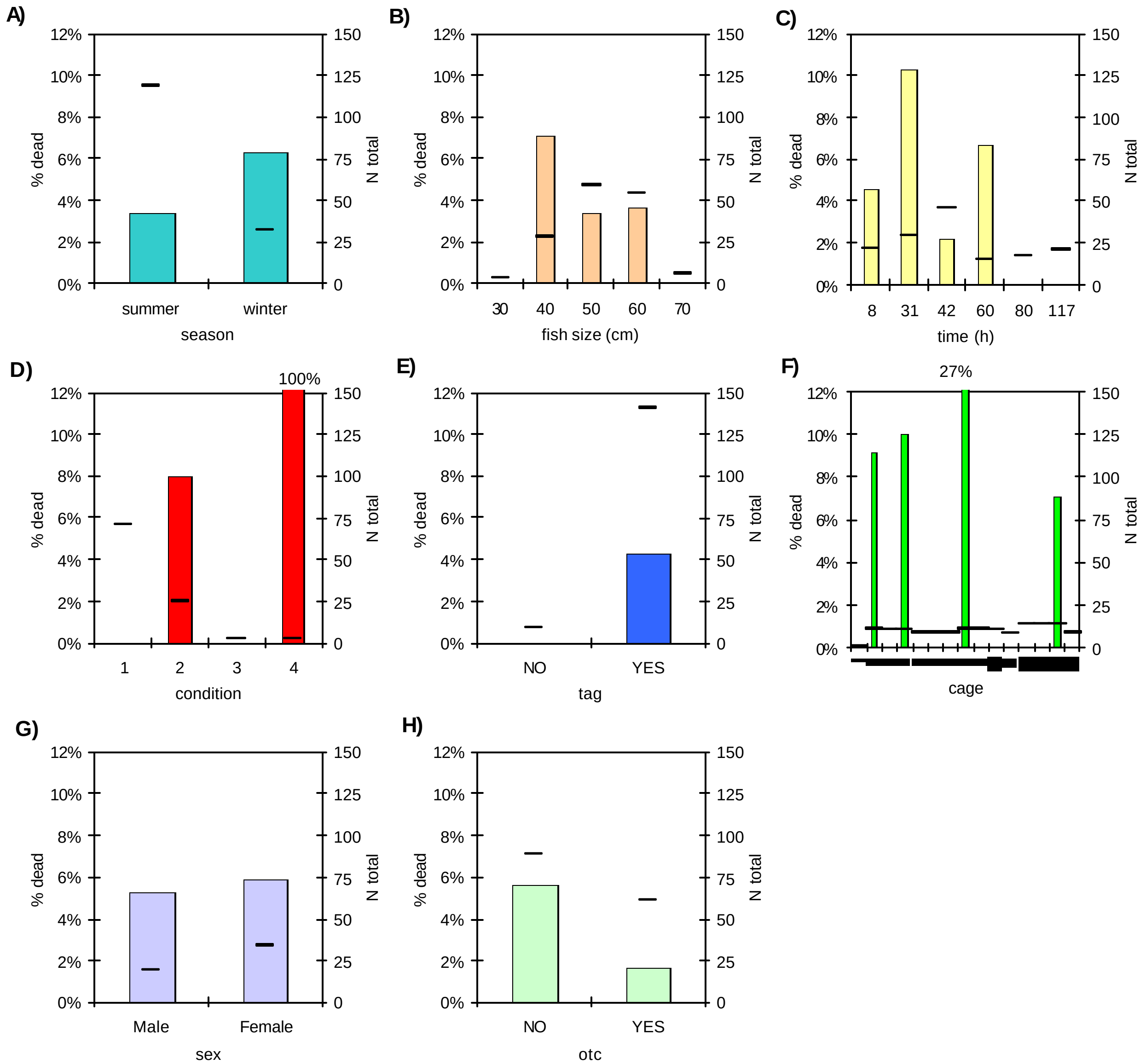

Figure 5. Mortality (proportion dead) broken down by the variables A) SEASON B) FISH SIZE (total length, cm) C) TIME (total time, h) D) CONDITION (se table 2) E) TAG (presence of Floy-tag F) CAGE G) SEX andH) OTC (oxytracycline, se Methods). Actual observations in total in each interval are indicated with –. See also Table 3.