## Final Report

Submitted to: The Northeast Cooperative Research Partners Program

<table>
<thead>
<tr>
<th><strong>Project Title:</strong></th>
<th>Biological sampling, behavior and migration study of Atlantic Halibut (<em>Hippoglossus hippoglossus</em>) and cusk (<em>Brosme brosme</em>) in the Gulf of Maine, Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Leaders:</strong></td>
<td>Kohl Kanwit &amp; Trisha De Graaf, ME Dept. of Marine Resources Christopher Bartlett, University of Maine Cooperative Extension</td>
</tr>
<tr>
<td><strong>Lead Institution:</strong></td>
<td>Maine Department of Marine Resources</td>
</tr>
<tr>
<td><strong>Primary Partners:</strong></td>
<td>Steve Rosen, Russell Brewer, Jason Alley, Lewis Bishop and Wyatt Beal</td>
</tr>
</tbody>
</table>
Introduction:
This project was first proposed in 2007 as a means of gathering valuable data on Atlantic halibut (*Hippoglossus hippoglossus*) in the Gulf of Maine. This species, while once abundant, is currently considered at historically low levels of biomass. It is managed as a bycatch only fishery in federal waters, meaning that the catch limit of one fish per day precludes any directed fishery. For these reasons, very little data are available describing the life history of Atlantic halibut or the status of the resource in the Gulf of Maine. The work in 2007, funded by a Northeast Cooperative Research Partners Program (NCRPP) grant provided information on the occurrence of halibut, habitat preferences and movement. This survey was done using hook gear rather than trawl gear, an approach adopted by the International Pacific Halibut Commission (IPHC) and the Department of Fisheries and Oceans (DFO) in Nova Scotia. An ancillary benefit of this survey was recognized in 2007, as it also provided an opportunity to collect data on cusk. Cusk (*Brosme brosme*) are being considered for threatened or endangered species listing in both the US and Canada and are therefore of special interest to fisheries biologists, managers and industry members. The project proposal in 2008 equally emphasized both Atlantic halibut and cusk as the target species for this survey. This report covers the second year of the Atlantic halibut and cusk longline survey and an update of the work done in 2007, also funded by NCRPP. Overall, the second year of this survey (2008) was very successful, providing a wealth of information and continuing to develop and expand a partnership between fishermen and researchers.

In addition to the 2008 survey work, NCRPP funding became available to establish a fish aging lab at the Maine Department of Marine Resources (DMR). The DMR has been collecting otoliths for decades from commercially and recreationally important fish species in order to develop length-at-age estimates, however, these otoliths have been backlogged in storage as there was neither staffing nor equipment resources to process and analyze them. The age data used in stock assessments for many species in the Gulf of Maine are in need of updating to be useful in predicting standing stock biomass. During a technical peer review done in 2005, panelists (including National Fisheries Science Center (NFSC) staff at Woods Hole, MA) noted that age-at-length tables for many species, including Atlantic halibut and cusk in the Gulf of Maine are based on data from 30 + years ago. That same year DMR learned that NFSC staff would no longer be able to process otoliths previously sent to them due to insufficient staff resources. Therefore, it became critical that DMR possess the equipment and develop the capability to process these samples in an aging lab at the Boothbay Harbor, ME facility.

Project Goals and Objectives:
The long-term goal of this study is to contribute and expand the knowledge base of Atlantic halibut and cusk population dynamics in the Gulf of Maine that will be directly used in the future assessment and management of these species.

Specific objectives include:
- Provide information on regional stock abundance and distribution of both species
- Estimate seasonal and individual fish movements and migration patterns for Atlantic halibut
- Collect biological information on growth and spawning behavior of Atlantic halibut
- Collect biological information on size, sex, maturity and age of cusk
- Contribute information on bycatch in the bottom longline fishery
- Promote a collaborative partnership between fishermen and researchers

Additional objectives related to the aging lab (added to the contract with an extension of the grant in December 2008):
- Process the backlog of halibut otoliths to update age-at-length tables for stock assessment
- Establishment the first digital reference collection for the species in collaboration with DFO and IPHC
- Participate in the 4th International Otolith Symposium held in Monterey, CA in August, 2009

**Methods:**

**Longline survey**
The survey area included the waters between three and 24 miles along the coast of ME and NH. A random, standard grid design was selected for this survey based on recommendations from Dr. Patrick Sullivan and Dr. Yong Chen. This design seemed to be the best fit since there is virtually no commercial fishery data for either species, the catchability of both species is very low in trawl gear and no stratifying variables could be defined with a high degree of confidence. However, a review of the data from the 2007 survey resulted in dropping stations in waters greater than 100 fm. Figure 1 shows the resulting sampling locations for the 2008 survey.

**Figure 1: Sampling sites selected using a random grid survey design**
A total of 51 stations were fished, each with 300 hooks. This represents a decline in the number of stations fished from 2007 by 16%; a result of funding cuts. Stations were selected in 2008 at the same level as 2007, but then the stations in waters greater than 100 fm were removed and not replaced with stations in shallower waters. These deepest stations were removed on the basis that no fish were caught in them in the prior year and fishermen believed they had unsuitable habitat. The longlines were standardized into 100 hook sets, of 1800 ft total groundline length and 3-ft gangions, collectively called a “skate”. Only frozen mackerel or fresh herring were used as bait in the survey. One set was made through the center point of the grid and the other two sets were made within two nm of the center point. This allowed the fishermen to try and set on more promising bottom if they felt the center point wasn’t located in preferred halibut/cusk habitat. Hook selectivity was explored in 2008 by randomly mixing three sizes of circle hooks on the center point set (33 12/0, 33 14/0 and 34 16/0). Following IPHC protocols, the set times were allowed to range between five and 24 hours. Temperature and depth recorders were attached to the groundlines to collect data from the bottom where the gear was fishing.

Otolith Collection and Storage
The DMR collects halibut otoliths from the following sources: the Maine state fishery, a Federal experimental fishery (2001-04), the groundfish port sampling program, industry volunteers (dealers and fishermen), and the NH/ME Inshore Trawl Survey. Cusk otoliths are collected in the groundfish port sampling program and the longline survey. We currently collect both sagittal otoliths when possible from halibut and cusk. Otoliths can be extracted from the head of the halibut by two methods; cutting into the head from the dorsal side or cutting them from under the gill cover. The second method has proven to be preferred for halibut as it does not cause any visual damage to the fish, this being of particular concern for fish that are destined for a display auction or high end restaurant. This method is also a quicker, more efficient and successful way of locating both the otoliths.

For the first method of collecting otoliths, a dorso-ventral transverse cut is made at the 7th spine of the fin above the eyes for halibut and at the beginning of the fin rays of cusk to the top of the first operculum [a], parallel to the edge of the second operculum [b] (Figure 2). The second cut can be at an angle to the first so as to remove a triangle section of the fish tissue and bones if otoliths are not easily located with the first cut, just behind the brain in the otic capsule. The head can be pried open to expose the otic capsules right behind and below the brain and tweezers can be used to extract the otoliths (Figure 3). For cusk, the skull of the fish is particularly thick and a mallet or extra force may be required to get the skull open for extraction.
Otoliths can also be extracted from underneath the gill cover for both species. As demonstrated in Figure 4, the gill cover on the white, or underside of the halibut is lifted. For cusk, the gills are removed while gutting the fish. At the base of where the gills attach to the skull, there are two small bumps which are the otic capsules containing the otoliths. The surface of this capsule is cut, being sure to not exert too much pressure so as to break the otoliths. Using a pair of tweezers or the tip of a knife, the otoliths are carefully removed from each otic capsule. Both otoliths are placed in a folded piece of paper, and then slid into a numbered envelope. The following information is entered on the envelope: collection program, date, name, location, species, length and sex (if known).

**Aging Procedures**

The DMR Fish Aging Lab employs the thin section age determination method, as adopted from the DFO Fish Aging Lab in Dartmouth, Nova Scotia (DFO, 2009). With this method, a thin section is sliced out of the middle of the otolith, revealing a cross-section of the annuli to the age reader (Figure 5).
A dissecting microscope is used to observe the otoliths at 2.5X to 3X power with reflected light from a fiber-optic light source (Figure 6). A digital image is captured and then enhanced using specialized software. From this image, an age estimate is recorded by placing annotations in virtual layers, along with any remarks (such as crystallized, cracked, questionable age, etc.) and entered into an excel spreadsheet.
**Results:**

**Atlantic halibut**

Of the 51 total stations, 49 were fished exactly according to the specified sampling protocols. Two stations had a soak time longer than 24 hours due to an unexpected change in weather conditions. These stations were not re-sampled due to the cost of steaming out and resetting the gear and the fact that fish were present when the gear was hauled after 48 hours. A total of 47 halibut were caught from 17 stations and 27 sets. All but one, which had swallowed the hook, were caught and released in excellent condition. No data were collected from one fish that was lost at the side of the boat, before being brought on board. The maximum number of fish caught in a single grid was seven. Figure 7 shows the locations where halibut were caught.

**Figure 7:** Catch locations of Atlantic halibut represented in numbers

Locations where halibut were captured were explored in relationship with depth, bottom type and time. Depths were binned into four categories: 1=21-40 fm, 2=41-60 fm, 3=61-80 fm, and 4=81-100 fm. The CPUE was highest in the 41-60 fm range and there was a significant difference in the mean depths of sets where halibut were caught compared to sets where they were not caught ($t$-statistic = -3.14; $p < 0.05$; df = 151). There was not a significant relationship between bottom type and halibut catches ($\chi^2 = 3.31; p < 0.05$; df = 2) across three divisions: rock, gravel and mud. The week fished was also not significant in relation to halibut catch ($\chi^2 = 7.02; p < 0.05$; df = 6).

Data from the previous longline survey were analyzed using a generalized linear model (GLM) and a generalized additive model (GAM) to model the relationship between fish density and spatial/environmental variables (location, depth, hook size and bottom...
The GLM performed better for both halibut and cusk. Results from these analyses showed that depth is the most important for halibut distribution.

Although several mini-loggers failed or were lost during the survey, bottom temperature was successfully collected for 92% of the stations. Halibut were caught at temperatures from 4.8 to 6.9°C with an average bottom temperature of 5.7°C. For stations where nothing was caught, the temperature averaged 5.4 °C, with a minimum of 4.3 °C and a maximum of 6.7 °C.

Length data were collected for all halibut and weights were collected unless the tagging procedure took too long and the health of the fish was being jeopardized. The average length of halibut caught was 103 cm, ranging from 64 to 173 cm. The average weight was 13 kg, with a minimum of 2 kg and a maximum of 49 kg. The length/weight relationship can be seen in Figure 8. Sex could not be determined externally, but genetic samples collected might provide these data at a later date. Likewise, no aging could be conducted since all fish were released alive and otoliths were not collected.

Figure 8: Length/weight relationship for Atlantic halibut (weights were not collected for every fish)

With the exception of one dead halibut and one that escaped before being brought on board the vessel, the rest of the fish were tagged (N=45). Most of the fish were marked with a conventional wire spaghetti tag (N=42) and 21 of those fish also received a data storage tag (DST). On two occasions fish were released with only a DST because of concerns for fitness related to time out of water. Three fish received pop-up satellite archival tags (PSAT) which were programmed to collect data for 12 months. Due to
problems experienced last year with half of our PSATs deploying early we opted to turn off the constant pressure trigger in 2008.

To date, seven tags were returned from the 45 halibut tagged and released in the 2008 survey. One fish, marked with a conventional tag only was returned.

Tag #5413 was released near Frenchboro, Maine on 6/5/08 on a fish 104 cm in length. This fish was later recaptured on 5/25/09 within 144 km of where it was originally tagged. The fish was at large for 354 days and did not show any growth. Figure 9 shows the release and recapture points.

Two tag returns were from fish with a conventional tag that had also carried a DST. The DSTs apparently fell off the fish between their release and recapture as none of the fishermen reported seeing anything other than the conventional tag.

Tag #5443 (lost DST 9498) was released near Jonesport, Maine on 6/21/08 on a fish 100 cm in length. This fish was later recaptured on 6/16/09 within 17 km of where it was originally tagged. The fish was at large for 360 days and did not show any growth. Figure 9 shows the release and recapture points.

Tag #5449 (lost DST 9519) was also released near Jonesport, Maine on 6/21/08 on a fish 100 cm in length. This fish was later recaptured on 5/28/09 within 10 km of where it was originally tagged. The fish was at large for 341 days and grew 7 cm. Figure 9 shows the release and recapture points.

Figure 9: Map of release (red dot) and recapture locations (green dot) for conventional tag returns from the 2008 survey
As of September 30, 2009, two DSTs released in 2008 were returned and data were successfully downloaded. These tags recorded temperature and depth data for almost a complete year.

Tag #9508 was released near Jonesport, Maine on 6/21/08 on a fish 113 cm in length. This fish was later recaptured on 6/15/09 within 7 km of where it was originally tagged. The fish grew 6 cm during the 359 days it was at large. Figure 10 shows the release and recapture points and the temperature and depth data collected by the DST. The fish went to a maximum depth of 177 m with an average of 87 m throughout the year. The fish experienced temperatures between 2.5 °C and 11.3 °C, averaging 6.7 °C.

Figure 10: Temperature and depth profile of tag # 9508 with a map of release (red dot) and recapture locations (green dot)

Tag #9508

<table>
<thead>
<tr>
<th>Date</th>
<th>Temperature (°C)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>06/07/08</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>06/22/08</td>
<td>22</td>
<td>150</td>
</tr>
<tr>
<td>07/07/08</td>
<td>16</td>
<td>140</td>
</tr>
<tr>
<td>07/22/08</td>
<td>12</td>
<td>130</td>
</tr>
<tr>
<td>08/06/08</td>
<td>8</td>
<td>120</td>
</tr>
<tr>
<td>08/22/08</td>
<td>4</td>
<td>110</td>
</tr>
<tr>
<td>09/06/08</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>09/21/08</td>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>10/06/08</td>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>10/21/08</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>11/06/08</td>
<td>4</td>
<td>60</td>
</tr>
<tr>
<td>11/21/08</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>12/06/08</td>
<td>6</td>
<td>40</td>
</tr>
<tr>
<td>12/21/08</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>01/05/09</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>01/21/09</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>02/05/09</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>02/20/09</td>
<td>11</td>
<td>-10</td>
</tr>
<tr>
<td>03/07/09</td>
<td>12</td>
<td>-20</td>
</tr>
<tr>
<td>03/22/09</td>
<td>13</td>
<td>-30</td>
</tr>
<tr>
<td>04/07/09</td>
<td>14</td>
<td>-40</td>
</tr>
<tr>
<td>04/22/09</td>
<td>15</td>
<td>-50</td>
</tr>
<tr>
<td>05/07/09</td>
<td>16</td>
<td>-60</td>
</tr>
<tr>
<td>05/22/09</td>
<td>17</td>
<td>-70</td>
</tr>
<tr>
<td>06/07/09</td>
<td>18</td>
<td>-80</td>
</tr>
</tbody>
</table>

Tag #9518 was released near Jonesport, Maine also on 6/21/08 on a fish 104 cm in length. This fish was later recaptured on 6/8/09 within 57 km of where it was originally tagged. The fish grew 14 cm during the 352 days it was at large. Figure 11 shows the release and recapture points and the temperature and depth data collected by the DST. The fish went to a maximum depth of 249 m with an average of 149 m throughout the year. The fish experienced temperatures between 4.0 °C and 10.4 °C, averaging 7.4 °C.
The fates of the three released PSATs were as follows:

Tag #34251 was released on 6/7/08 and later recaptured by a groundfish trawler in Jordan Basin on 9/23/08. The data were unable to be downloaded due to a software malfunction. The manufacturer replaced the tag, free of charge, for re-deployment in 2009.

Tag #83722 was released on 6/5/08; no data were ever reported from this tag. The cause of the failure is unknown and the manufacturer replaced it with a short-term data recording tag for re-deployment in 2009.

Tag #83721 was released near Jonesport, Maine on 5/23/08 on a fish 147.5 cm in length. The tag released and remotely transmitted data beginning on 5/26/09 within 98 km of where it was originally tagged. Figure 12 shows the release and transmission points and the temperature and depth data collected by the PSAT. The fish went to a maximum depth of 210 m with an average of 106 m throughout the year. The fish experienced temperatures between 2.4 °C and 9.9 °C, averaging 6.5 °C.
Figure 12: Temperature and depth profile of PSAT #83721 with a map of release (red dot) and recapture locations (green dot)

Cusk
A total of 35 cusk were caught from 11 stations and 16 sets. The maximum number of fish caught in a single grid was 14. Figure 13 shows the locations where cusk were caught.

Locations where cusk were captured were explored in relationship to depth. Depths were binned into four categories: 1=21-40 fm, 2=41-60 fm, 3=61-80 fm, and 4=81-100 fm. The CPUE was highest in the 61-80 fm range, but there was not a significant difference in the mean depths of sets where cusk were caught compared to sets where they were not caught (t-statistic = -0.56; p < 0.05; df = 151). There was a significant relationship between bottom type and cusk catches ($\chi^2 = 28.8; p < 0.05; df = 2$) across three divisions: rock, gravel and mud. The highest CPUE in relation to bottom type was for gravel substrate, followed by rock. The week fished also affected the CPUE for cusk with the highest value occurring the first week of June. The week fished was significant in relation to cusk catch ($\chi^2 = 20.1; p < 0.05; df = 6$).
Data from the previous longline survey were also analyzed using a generalized linear model (GLM) and a generalized additive model (GAM) to model the relationship between fish density and spatial/environmental variables (location, depth, hook size and bottom type). The GLM performed better for both halibut and cusk. Results from these analyses showed that bottom type and depth are the first and second most important factors for cusk distribution.

Cusk were caught at temperatures from 4.8 to 6.5°C with an average bottom temperature of 5.9°C.

While gonads, otoliths and genetic samples were collected from almost all of the cusk caught, only sex data are available at this time in addition to length and weight information. Of the 31 cusk sexed, 45% were female and 55% were male. The average weight of males was 3.9 kg with a minimum of 1.5 kg and a maximum of 8.5 kg. The average weight of females was 3.7 kg, with a minimum of 1.0 kg and a maximum of 7.7 kg. The average length of males was 71 cm, with a minimum of 57 cm and a maximum of 91 cm. The average length of females was 70 cm, with a minimum of 54 cm and a maximum of 94 cm. Figure 14 shows the length/weight relationship of male and female cusk.
Figure 14: Length/weight relationship for male and female cusk

Hook selectivity
Different sized hooks were deployed in the 2008 survey to assess size selectivity. On 41 of the 51 stations fished, the set that crossed the center point of the grid consisted of 1/3 size 16/0, 1/3 size 14/0 and 1/3 size 12/0 circle hooks. The size hook was noted each time a fish was caught regardless of species.

Results from the GAM and GLM showed hook size having no effect on the catchability of cusk while larger hooks caught more halibut. Furthermore, there was no difference in the size distribution of cusk in relation to the hook size. The smallest halibut in the study (64 cm) was caught with a 14/0 hook; the next largest halibut was 75 cm suggesting there might be a size selection issue.

Bycatch
A total of 10 different marine species were recorded as bycatch in this survey. Spiny dogfish accounted for 94% of the total bycatch in number. The sizes ranged from 54 cm to 106 cm, with an average of 83 cm and the weights ranged from 0.4 kg to 5.2 kg with an average of 2.6 kg. Of the 1126 individuals sexed, males made up 20% while females made up 80%. Other species were <1% of the bycatch in number. The species and numbers of individuals documented as bycatch in the halibut survey can be seen in Table 1.
### Table 1: Bycatch information

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>cod atlantic</td>
<td>2</td>
</tr>
<tr>
<td>dogfish spiny</td>
<td>1150</td>
</tr>
<tr>
<td>haddock</td>
<td>1</td>
</tr>
<tr>
<td>hake atlantic red</td>
<td>5</td>
</tr>
<tr>
<td>hake white</td>
<td>5</td>
</tr>
<tr>
<td>lobster american</td>
<td>2</td>
</tr>
<tr>
<td>sculpin longhorn</td>
<td>1</td>
</tr>
<tr>
<td>skate little</td>
<td>2</td>
</tr>
<tr>
<td>skate thorny</td>
<td>31</td>
</tr>
<tr>
<td>wrymouth</td>
<td>26</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td><strong>1225</strong></td>
</tr>
</tbody>
</table>

**Aging lab**

The majority of samples from the port sampling, survey and industry volunteer programs are from halibut between the ages of 5 and 10 years old. The minimum age of 5 is due to the legal minimum size of 38” for halibut landed in Maine. The maximum age observed for an Atlantic halibut captured along the coast of Maine is 19 years. This fish was a male, 137 cm and was captured in the federal experimental halibut fishery.

To date, DMR has processed and performed 'consensus ageing' to get known ages (performed by DMR, DFO and IPHC staff) for approximately 100 otoliths samples. A good reference collection needs to be large enough to not be easily memorized; therefore ideally the collection would be large enough to select 50-75 samples randomly for accuracy exercises. These initial 100 samples are the basis of an adequate collection with two- to three-hundred as a long-term goal. The aim is to have digital images for each age group, with both male and female samples in each age group represented.

A portion of this grant was used to provide funding for the DMR fish aging lab coordinator to present some of the preliminary results from the effort to establish a digital reference collection for Atlantic halibut otoliths at the 4th International Otolith Symposium in Monterey, CA. With more than 270 oral and poster presentations on otolith research from around the world, this symposium offered a valuable learning experience on the most up-to-date techniques and areas of applied research that could potentially be conducted on our collection. In addition, indispensable networking opportunities and relationships were established with fish age-readers from the Fish Biology Program at Woods Hole to NMFS labs on the west coast, DFO in Canada as well as other international institutions around the world. Feedback received during the poster presentation session from members of the international aging community was not only informative, revealing more opportunities for in-depth research that could be done on the reference collection, but also encouraging, as expert age-readers endorsed the methodology used to process and establish this collection. Potential future research could include: microchemistry characterization, elemental fingerprinting, morphology/shape analysis, stable isotope analysis, the use of otoliths as environmental loggers, biochronology, bomb radiocarbon dating and dendrochronology.
These methodologies and applications could reveal information about habitat shifts/use, life history diversity, stock structure discrimination, population ecology, age and growth, trophic positions, evaluating environmental change/climate variability & change and larval dispersal. In all, attendance at this symposium not only allowed DMR and NCRPP to broadcast some of the research being undertaken on Atlantic halibut along the coast of Maine to the international community, but it was also an opportunity to attain the knowledge, skills and experience needed to foster research opportunities at the DMR Aging Lab.

**Update from 2007 Longline survey:**
To date, ten tags were returned from the 42 halibut tagged and released in the 2007 survey. This number does not include the two PSATs that deployed early and transmitted data in 2007 (Kanwit and Bartlett, 2007), nor does it include two DSTs called in but never mailed. Of the ten returns, two were from fish that were tagged with a conventional wire tag only.

Tag #5427 was released near Jonesport, Maine on 5/26/07 on a fish 99 cm in length. This fish was later recaptured on 7/8/08 within 181 km of where it was originally tagged. The fish was at large for 409 days. Figure 15 shows the release and recapture points.

Tag #5428 was also released near Jonesport, Maine on 5/26/07 on a fish 76 cm in length. This fish was later recaptured on 5/13/09 within 6 km of where it was originally tagged. The fish was at large for 718 days and grew 28 cm. Figure 15 shows the release and recapture points.

Three tag returns were from fish with a conventional tag that had also carried a DST. The DSTs apparently fell off the fish between their release and recapture as none of the fishermen reported seeing anything other than the conventional tag.

Tag #5394 (lost DST 8792) was released near Stonington, Maine on 7/3/07 on a fish 113 cm in length. This fish was later recaptured on 10/29/08 within 229 km of where it was originally tagged. The fish was at large for 484 days. Figure 15 shows the release and recapture points.

Tag #5381 (lost DST 8802) was released near Vinalhaven, Maine on 6/12/07 on a fish 102 cm in length. This fish was later recaptured on 5/21/09 within 207 km of where it was originally tagged. The fish was at large for 709 days and grew 5 cm. Figure 15 shows the release and recapture points.

Tag #5353 (lost DST 8827) was released near Jonesport, Maine on 6/7/07 on a fish 86 cm in length. This fish was later recaptured on 10/8/08 within 211 km of where it was originally tagged. The fish was at large for 489 days. Figure 15 shows the release and recapture points.
Another return reported from the 2007 longline survey was from a fish still carrying a PSAT tether. This fish, like all the PSAT fish was triple tagged with: 1. the PSAT; 2. the PSAT tether that stays in the fish after the tag deploys; and 3. a conventional wire tag. This was a very interesting return because the PSAT attached to this fish had failed to report any data.

Tag #5401 (PSAT #34278) was released near Jonesport, Maine on 6/23/07 on a fish 106 cm in length. This fish was later recaptured on 9/12/09 within 224 km of where it was originally tagged. The fish was at large for 812 days. Figure 15 shows the release and recapture points.

Four DSTs were returned from fish tagged and released as part of the 2007 longline survey. The times at large varied from a few months to almost two years. Unfortunately, the tags were set to record data in small time increments and the memory of all tags filled up within two months. The tag settings were changed in 2008 so that a longer time series of data could be collected (see pages 9 and 10).

Tag #8823 was released near Jonesport, Maine on 7/2/07 on a fish 142 cm in length. This fish was later recaptured on 10/17/07 within 211 km of where it was originally tagged. The fish was at large for 107 days. Figure 16 shows the release and recapture points and the temperature and depth data collected by the DST.

Tag #8808 was released near Jonesport, Maine on 6/25/07 on a fish 99 cm in length. This fish was later recaptured on 9/10/08 within 24 km of where it was originally tagged. The fish was at large for 443 days and grew 20 cm. Figure 17 shows the release and recapture points and the temperature and depth data collected by the DST.

Tag #8831 was released near Vinalhaven, Maine on 6/12/07 on a fish 113 cm in length. This tag was later recovered on 11/24/08 by an individual walking on the beach in Millbridge, ME. Because of the temperature and depth profile it is assumed that the fish lost the tag after the memory filled and it stopped recording data. Figure 18 shows the temperature and depth data collected by the DST.

Tag #8833 was released near Vinalhaven, Maine on 6/12/07 on a fish 107 cm in length. This fish was later recaptured on 5/21/09 within 17 km of where it was originally tagged. The fish was at large for 709 days. Figure 19 shows the release and recapture points and the temperature and depth data collected by the DST.

There were also two other DSTs that were called in, but never mailed to DMR despite follow up efforts and the promise of a $250 reward.
Figure 15: Map of release (red dot) and recapture locations (green dot) for conventional tag returns from the 2007 survey

Figure 16: Temperature and depth profile of tag #8823 with a map of release (red dot) and recapture locations (green dot)
Figure 17: Temperature and depth profile of tag #8808 with a map of release (red dot) and recapture locations (green dot)

Tag #8808

Temperature (°C) vs. Depth (m) over time.

Figure 18: Temperature and depth profile of tag #8831

Tag #8831

Temperature (°C) vs. Depth (m) over time.
Figure 19: Temperature and depth profile of tag #8833 with a map of release (red dot) and recapture locations (green dot)

Discussion:
The results from this survey have contributed a great deal to our knowledge of Atlantic halibut and cusk distribution and habitat preferences. The limited time series (two years) and geographic coverage of these data preclude any contribution of quantitative data to an estimate of stock abundance for either species. However, the data do provide a relative index that can be compared to future surveys. The abundance and distribution data collected for cusk were used descriptively in a recent report on the status of cusk. This report is still being complied in response to a request for NMFS to review cusk for potential endangered species listing.

The survey was successful in contributing to our knowledge of seasonal and individual halibut movements as well as broader migration patterns. Conventional tag returns continue to support the findings of earlier work (Kanwit, 2008) that revealed short distance movements contrasted with long distance eastward migrations. A total of 87 halibut were marked with one or more type of tags in the two years of this program. To date, 17 tags were recovered for a 20% return rate. This includes the PSATs that do not require manual recovery for data collection. If the PSATs that transmitted data remotely are removed from the returns, the recovery rate is 16%. This is still considered a high return rate for a marine fish tagging project. We do not know the reason(s) for this high return rate, but it is consistent with other halibut tagging programs in the US and Canada. Another interesting aspect of the tag returns is the percent
recovered in Canadian waters. Almost half of the tag returns (41%) were reported from Canada, clearly indicating trans-boundary movements. This finding may have implications for future management and assessment of stocks.

The results from the electronic tags are very informative, contributing to our knowledge of temperature and depth preferences throughout an annual cycle. The DSTs performed very well in relation to data retrieval, but the harness system needs to be improved. We know that six of the DSTs were lost from fish that were later recovered with only a conventional tag. This represents a 12% shedding rate. Results from a tag retention study conducted in 2007 also indicated there was an issue with DST shedding, one of four fish (25%) lost its DST after four months in captivity. We have started discussions on ways to improve the attachment method with the tag manufacturer (Star Oddi) and biologists from Norway who originally developed the harness for Greenland halibut. These results reinforce the importance, in any tagging program, of double tagging fish to estimate tag shedding rates.

During the two years of this study seven PSAT tags were released on halibut. One tag performed to specification, two tags released and transmitted data early and four tags completely failed (this includes the one PSAT that was physically recovered, but the data could not be retrieved due to a software malfunction). No geolocation data were collected in the datasets that were transmitted; therefore the PSATs functionally collected exactly the same information as the DSTs, temperature and depth. Although PSATs have the advantage of not requiring physical recapture to obtain the data, their failure rate is too high to justify their cost when the recapture rate for DSTs is currently 12%. Theoretically, if we improve our DST shedding rate we could have returns as high as 24%. A simple cost analysis reveals why PSATs are not cost effective for this project (Table 2).

<table>
<thead>
<tr>
<th>TAG TYPE</th>
<th>COST PER UNIT</th>
<th>DATA</th>
<th>NUMBER</th>
<th>EXPANDED COST</th>
<th>RETURN RATE</th>
<th>TAG RETURNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSAT</td>
<td>$4,200</td>
<td>DEPTH/TEMP</td>
<td>10</td>
<td>$42,000</td>
<td>0.14</td>
<td>1.4</td>
</tr>
<tr>
<td>DST</td>
<td>$260</td>
<td>DEPTH/TEMP</td>
<td>10</td>
<td>$2,600</td>
<td>0.12</td>
<td>1.2</td>
</tr>
<tr>
<td>DST W/ NEW HARNESS</td>
<td>$260</td>
<td>DEPTH/TEMP</td>
<td>10</td>
<td>$2,600</td>
<td>0.24</td>
<td>2.4</td>
</tr>
</tbody>
</table>

The data collected from both the DSTs and the PSATs will be explored further and summarized in a manuscript for submission to a scientific journal in the winter of 2009/2010.

Another important advancement that has come from this project is the creation of an aging lab at DMR. This lab was put together in cooperation with staff from the ME/NH Inshore Trawl Survey and finding from the NCRPP. Some of the current projects that are using the aging lab are: Atlantic Halibut Otolith Aging - Reference Collection and Commercial Fishery Monitoring, Rainbow Smelt Scale Aging and Winter Flounder Otolith Aging. The establishment of this lab is a significant advancement for the whole region as it expands the expertise, capability and volume of samples that can be
processed. Aging data are becoming more important in fisheries management as scientists struggle to develop effective stock models and explain the physiological changes in fish size at age and maturity at age.

The creation of a digital reference collection for Atlantic halibut is also a significant achievement. This reference collection can be used throughout the region to train new aging technicians as well as evaluate consistency between labs. This is a new and highly cost effective method of training agers and transferring otolith images.

This project contributes valuable data for two species of concern in the Gulf of Maine. Traditional methods of surveying (e.g. groundfish trawl) are not effective in monitoring these species due to their preferred habitat and in the case of large halibut, their ability to out swim a trawl net. It is critical that traditional survey methods be augmented by other means including hook surveys. While there was no funding for this project in 2009, a proposal was submitted for an improved and expanded hook survey in 2010.

**Acknowledgements:**
We would like to thank the Northeast Cooperative Research Partners Program for providing funding for this project. We would also like to thank the project participants: Steve Rosen, Jason Alley, Rusty Brewer, Lewis Bishop and Wyatt Beal. Thanks to Dr. Yong Chen for technical advice and data analysis.

**Citations:**


Preliminary results for two types of electronic and conventional wire tags used to study Atlantic halibut (Hippoglossus hippoglossus) in the Gulf of Maine

J. Kohl Karnwit1, Trisha Cheney De Graaf2, Christopher Bartlett2, and Timothy Bennett1

1 Maine Department of Marine Resources, PO Box 6, West Boothbay Harbor, ME 04576 USA
2 Maine Sea Grant/University of Maine Cooperative Extension, 16 Deep Cove Road, Eastport, ME 04631 USA

INTRODUCTION

Since 2003, the Maine Department of Marine Resources (MDMR)’s Sea Grant and partners have been tagging Atlantic halibut (Hippoglossus hippoglossus) in the nearshore Gulf of Maine with electronic and conventional wire tags. Data on the movements of these tagged halibut provide important information for the management of this species, which is a major commercial target in the Gulf of Maine. The tagging was conducted as part of the Northeast Cooperative Research Partners Program (CERP). The methods developed during the first phase of this project were the basis for subsequent research. The results from the first and second phases of this project are presented here.

METHODS

TAG ATTACHMENT

Since 2003, 295 halibut have been tagged and released in the NE Gulf. The electrical equipment used in the first phase of the project was provided by the Northeast Cooperative Research Partners Program (CERP). The methods developed during the first phase of this project were the basis for subsequent research. The results from the first and second phases of this project are presented here.

CONVENTIONAL TAGS

All halibut were tagged with conventional wire tags in the first phase of the project. The tags were attached to the fish using a knotless wire tag. The first phase of the project was conducted from 2003 to 2006. The method used to attach the tags was similar to that used in the first phase of the project. The tags were attached to the fish using a knotless wire tag.

RESULTS

A total of 295 tagged halibut were recovered from the NE Gulf. The proportion of halibut recovered was 11%, and the number of fish recovered was 295. The average length of the fish was 23 cm. The average weight of the fish was 0.2 kg. The number of fish recovered was 295.

DISCUSSION

The results from this study indicate that the conventional wire tags are effective in tagging Atlantic halibut in the NE Gulf. The conventional wire tags are expected to be effective in tagging Atlantic halibut in the NE Gulf. The results from this study indicate that the conventional wire tags are effective in tagging Atlantic halibut in the NE Gulf. The conventional wire tags are expected to be effective in tagging Atlantic halibut in the NE Gulf.

REFERENCES


Attachment 2: Education poster and Otolith request poster presented at the Maine Fishermen’s Forum.

**Fish Aging Lab**

The Maine Department of Marine Resources (DMR) collects otoliths and scales from marine fish for aging. To properly manage fisheries, accurate age determination is of utmost importance for sustainable fisheries management.

**How Are Fish Aged?**

The age of a fish is determined by examining and counting annual growth rings, or “annuli”, found in otoliths and scales. Fish undergo seasonal changes in temperature & food availability, resulting in variations in growth patterns when uniquely identifiable layers in these age structures.

**Otoliths**

Otoliths, also called “ear stones”, are small, dense structures embedded in the brain of fish. They are found inside the ear and play a vital role in hearing and balance. The age of a fish can be accurately determined by examining and measuring the annuli found in otoliths.

**How to Collect Atlantic Halibut Otoliths**

The Atlantic Halibut’s otoliths are located in the head of the fish. To collect otoliths, make an incision into the head of the fish, near the eyes. Gently remove the otoliths and place them in a labeled bag for future analysis.

**DMR Fish Aging Lab Staff**

- Tonha De Guzain
- Groundfish
- Timothy Bennett
- Groundfish
- Claire Lande
- Rainbow Smelt
- Keil Spevak
- Winter Flounder
- Dave Grenier
- Smelt
- Founder Lisa Pilkham
- Atlantic Herring

**How is Aging Information Used?**

Fish age information is the basis for determining growth rates, longevity of a species, and size-at-age. Fish ages, when combined with length and abundance data, can be used to estimate the age structure of a fish population. Understanding how age influences the reproductive potential of a fish allows scientists to develop harvest strategies that ensure the sustainability of the fish population.

**WANTED: HALIBUT OTOLITHS!**

The Maine Department of Marine Resources (DMR) is seeking help from commercial fishermen to voluntarily collect Atlantic halibut otoliths for aging. To properly manage fisheries, accurate age determination is of great importance for estimating growth & mortality rates for halibut.

**DMR Atlantic Halibut Research & Tagging Program**

DMR is interested in collecting Atlantic halibut otoliths and scales from commercially caught fish. If you have freshly caught Atlantic halibut, please contact the DMR’s Atlantic Halibut Research & Tagging Program. Your participation can help us better understand the life history of Atlantic halibut.

**Mail to:**

The Maine DMR

W. Brooklin Harbor, ME 04677

**DMR Fish Aging Lab**

The Maine Department of Marine Resources (DMR) collects otoliths and scales from marine fish for aging. To properly manage fisheries, accurate age determination is of utmost importance for sustainable fisheries management.

**How Are Fish Aged?**

The age of a fish is determined by examining and counting annual growth rings, or “annuli”, found in otoliths and scales. Fish undergo seasonal changes in temperature & food availability, resulting in variations in growth patterns when uniquely identifiable layers in these age structures.

**Otoliths**

Otoliths, also called “ear stones”, are small, dense structures embedded in the brain of fish. They are found inside the ear and play a vital role in hearing and balance. The age of a fish can be accurately determined by examining and measuring the annuli found in otoliths.

**How to Collect Atlantic Halibut Otoliths**

The Atlantic Halibut’s otoliths are located in the head of the fish. To collect otoliths, make an incision into the head of the fish, near the eyes. Gently remove the otoliths and place them in a labeled bag for future analysis.

**DMR Fish Aging Lab Staff**

- Tonha De Guzain
- Groundfish
- Timothy Bennett
- Groundfish
- Claire Lande
- Rainbow Smelt
- Keil Spevak
- Winter Flounder
- Dave Grenier
- Smelt
- Founder Lisa Pilkham
- Atlantic Herring

**How is Aging Information Used?**

Fish age information is the basis for determining growth rates, longevity of a species, and size-at-age. Fish ages, when combined with length and abundance data, can be used to estimate the age structure of a fish population. Understanding how age influences the reproductive potential of a fish allows scientists to develop harvest strategies that ensure the sustainability of the fish population.

**WANTED: HALIBUT OTOLITHS!**

The Maine Department of Marine Resources (DMR) is seeking help from commercial fishermen to voluntarily collect Atlantic halibut otoliths for aging. To properly manage fisheries, accurate age determination is of great importance for estimating growth & mortality rates for halibut.

**DMR Atlantic Halibut Research & Tagging Program**

DMR is interested in collecting Atlantic halibut otoliths and scales from commercially caught fish. If you have freshly caught Atlantic halibut, please contact the DMR’s Atlantic Halibut Research & Tagging Program. Your participation can help us better understand the life history of Atlantic halibut.

**Mail to:**

The Maine DMR

W. Brooklin Harbor, ME 04677

**DMR Fish Aging Lab**

The Maine Department of Marine Resources (DMR) collects otoliths and scales from marine fish for aging. To properly manage fisheries, accurate age determination is of utmost importance for sustainable fisheries management.

**How Are Fish Aged?**

The age of a fish is determined by examining and counting annual growth rings, or “annuli”, found in otoliths and scales. Fish undergo seasonal changes in temperature & food availability, resulting in variations in growth patterns when uniquely identifiable layers in these age structures.

**Otoliths**

Otoliths, also called “ear stones”, are small, dense structures embedded in the brain of fish. They are found inside the ear and play a vital role in hearing and balance. The age of a fish can be accurately determined by examining and measuring the annuli found in otoliths.

**How to Collect Atlantic Halibut Otoliths**

The Atlantic Halibut’s otoliths are located in the head of the fish. To collect otoliths, make an incision into the head of the fish, near the eyes. Gently remove the otoliths and place them in a labeled bag for future analysis.

**DMR Fish Aging Lab Staff**

- Tonha De Guzain
- Groundfish
- Timothy Bennett
- Groundfish
- Claire Lande
- Rainbow Smelt
- Keil Spevak
- Winter Flounder
- Dave Grenier
- Smelt
- Founder Lisa Pilkham
- Atlantic Herring

**How is Aging Information Used?**

Fish age information is the basis for determining growth rates, longevity of a species, and size-at-age. Fish ages, when combined with length and abundance data, can be used to estimate the age structure of a fish population. Understanding how age influences the reproductive potential of a fish allows scientists to develop harvest strategies that ensure the sustainability of the fish population.
Establishment of a Digital Reference Collection for Gulf of Maine Atlantic halibut (Hippoglossus hippoglossus)

Trisha Cheney De Graaff and J. Kohl Kanwit

*Maine Department of Marine Resources: PO Box 8, West Boothbay Harbor, ME 04575 USA

ABSTRACT:

Since 2000, the Maine Department of Marine Resources (MDMR), Maine Sea Grant and participating fishermen have been collecting Atlantic halibut (Hippoglossus hippoglossus) otoliths in the near-shore Gulf of Maine waters. Recently, MDMR established a Fish Aging Laboratory through funding provided by the NOAA Northeast Cooperative Research Partners Program with the goal being to store Atlantic halibut otoliths and establish a digital reference collection. The purpose of this reference collection is to train MDMR staff. This was a collaborative effort by staff from the Canadian Department of Fisheries and Oceans at the Bedford Institute of Oceanography (DFO BIC) and the International Pacific Halibut Commission (IPHC). Otoliths were embedded, sectioned, digiized and aged by MDMR's new age reader, then electronically transmitted to other aging laboratories for their estimates. DFO BIC and IPHC staff aged the collection and returned it to MDMR with digital annotations and comments. The MDMR age reader compared their estimates and studied comments, then re-aged the collection. An Inter-reader Precision Test, provided by the National Marine Fisheries Service (NMFS), was applied to the age estimates to compare the fish ages between the different readers. The result was an improved % agreement between the new age and experienced ages estimates from 30.7% to 65.6% agreement. This methodology may prove beneficial to state, federal and other aging laboratories with limited budgets, reducing them from allowing staff members to travel to receive training at other institutions as the digital format can be easily updated and downloaded through ftp websites or mailed as digital format. These methods and procedures will be discussed in this poster.

METHODS:

ATLANTIC HALIBUT OTOLITH SAMPLES

Segalts otoliths were collected off the coast of Maine through the Federal Experimental & MEE State Waters Fishery, Port Sampling and the NMFS Shape Trawl Survey. While all were chosen as an initial batch for the digital reference collection, with both a male and female sample for each age group, the goal is to have at least 500 samples, as individual images cannot be measured. Age comparisons were conducted as part of a training exercise for MDMR's new age reader throughout a collaboration with DFO BIC and IPHC experienced age readers. All ages interpreted annual counts from cross sections images, independently. Some of the age interpretations were validated, however the age determination protocols of DFO & IPHC have been validated through a dissection bomb chromatogram work (Pinner & Wishart, 2004).

HARDWARE & SOFTWARE:

The digital image analysis system consisted of an Olympus SZX16 dissecting microscope equipped with an Olympus DP71 digital camera connected to a PC with a 22" Plasma color monitor. Digital images of otolith cross sections were captured using Olympus DP Manager software and imported into Adobe Photoshop 7.0.1 for image enhancement and analysis. The software allowed the age to clearly identify by counting each annulus. The annotations were saved in separate layers in which the utility can be held, so the following year had knowledge of the previous ages collected. This gave the MDMR age reader the ability to re-age the collection, then observe where errors were being made and what adjustments needed to occur while developing an aging technique.

ACCURACY & PRECISION:

To track the progress of the new MDMR age reader while being trained by the DFO BIC and IPHC experienced age readers, fish age estimates were tested using an Inter-reader Precision Test. A Precision Test template was provided by Jay Burnett from the Fishery Biology Program at the Woods Hole Laboratory of NMFS and can be found online at http://www.srre.noaa.gov/abiage.

Results:

Inter-reader Precision Tests were run on age estimates between labs. The trainee's ages are presented in the terms of experienced (DFO & IPHC) reader’s ages. The MDMR age reader improved test percent agreement with the DFO age reader from 32.7% to 65.6% (Figure 2), while the percent agreement only increased slightly with the IPHC age reader from 39.9% to 43.0% (Figure 3). The slight increase is due in part to the fact that the DFO age reader has not yet to study the annotations and comments provided by the IPHC reader, and is expected that a once completed and the collection re-aged, the percent agreement will increase.

ONGOING & FUTURE EFFORTS:

This work is ongoing and is hoped that the establishment of this digital reference collection will provide a useful reference tool for future aging of halibut otoliths; a valuable training tool for new ages to learn from and identify aging errors across more efficiently, otolith images in digital format, allowing for easy sharing of different aging labs (state, federal, academic, etc.) reduced aging time resulting from aging by microscope only; a reflection of the current oceanographic and climatic conditions that affect their growth; as well as a base for other future research studies (maturity, age identification, microchemistry work, etc.)

CONCLUSIONS:

The advancements of technology over the past decade can be taken advantage of by aging labs. Digital images not only provide a valuable training tool for new ages to learn from as aging errors can be identified more efficiently and what adjustments need to be made, but also provides a permanent image that can then be easily transferred to other aging laboratories at a minimal cost in terms of space, storage space and funding that would otherwise be used for personnel travel.

ACKNOWLEDGEMENTS:

- David Weidler (DFO BIC) for providing otoliths.
- Tania Danigrosn from NMFS BIOC for providing otoliths.
- Jay Burnett at NESIC, Woods Hole, MA (director).
- Anne Campagna at DFO BIC (director).
- NOAA Cooperative Research Partners Program (funding).

REFERENCES:


Correspondence: (trisha.degraff@maine.gov, 207-633-8577, P.O. Box 8, W. Boothbay Harbor, ME 04575)

25