Final Report

Submitted to: The Northeast Cooperative Research Partners Program

<u>Project Title</u>: Biological sampling, behavior and migration study of Atlantic Halibut (*Hippoglossus hippoglossus*) and cusk (*Brosme* brosme) in the Gulf of Maine, Year 2

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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):

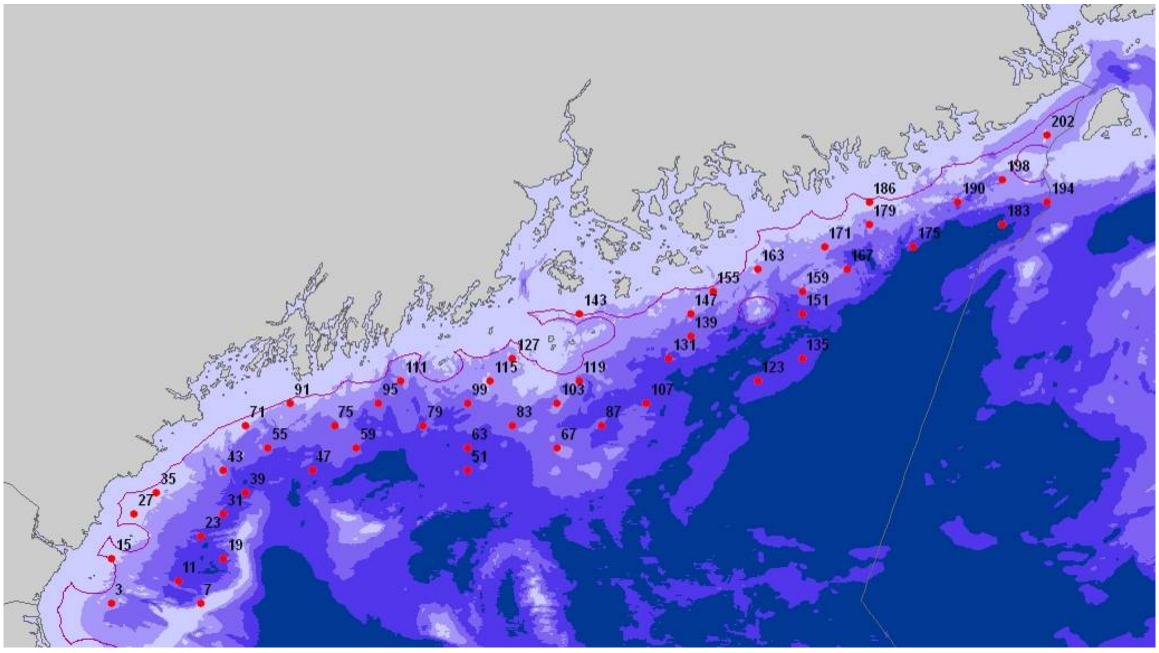
- Process the backlog of halibut otoliths to update age-at-length tables for stock assessment
- Establishment the first digital reference collection for the species in collaboration with DFO and IPHC
- Participate in the 4th International Otolith Symposium held in Monterey, CA in August, 2009

<u>Methods:</u>

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 7^{th} 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.

Figure 2: Diagram depicting otolith removal from a halibut from the top of the head (from IPHC)

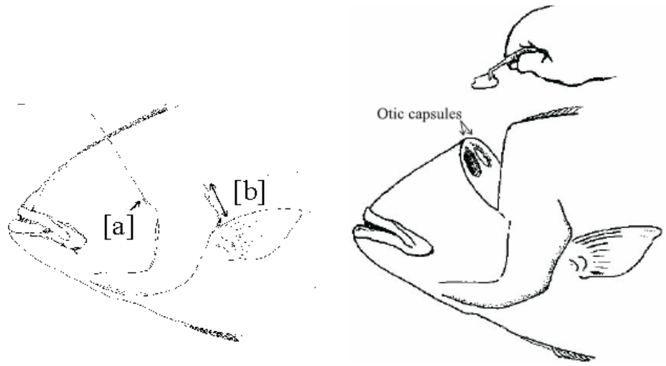
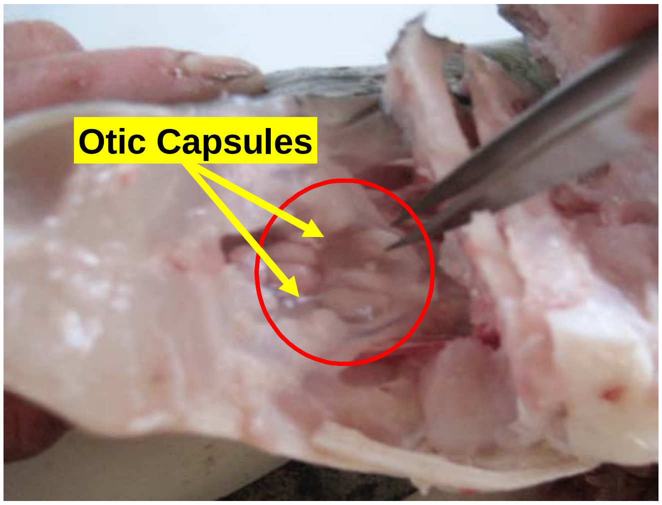


Figure 3: Photo displaying otic capsule and otoliths on either side of brain cavity



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).

Figure 4: Diagram depicting otolith removal from a halibut (from IPHC)

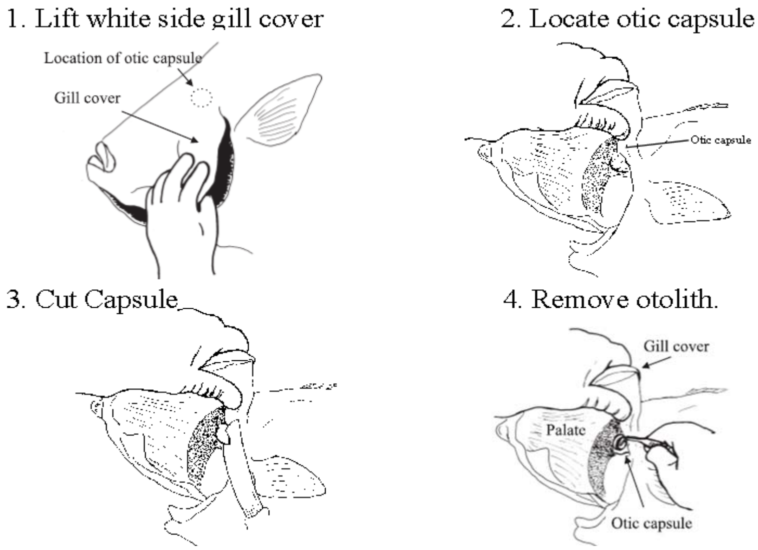
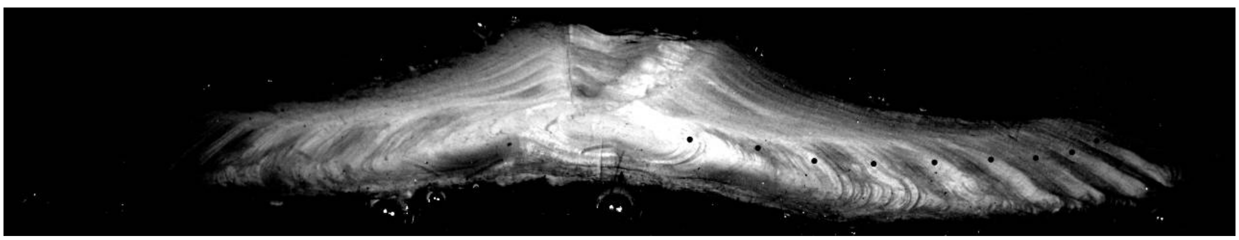


Figure 5: Thin section of a halibut otolith



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.

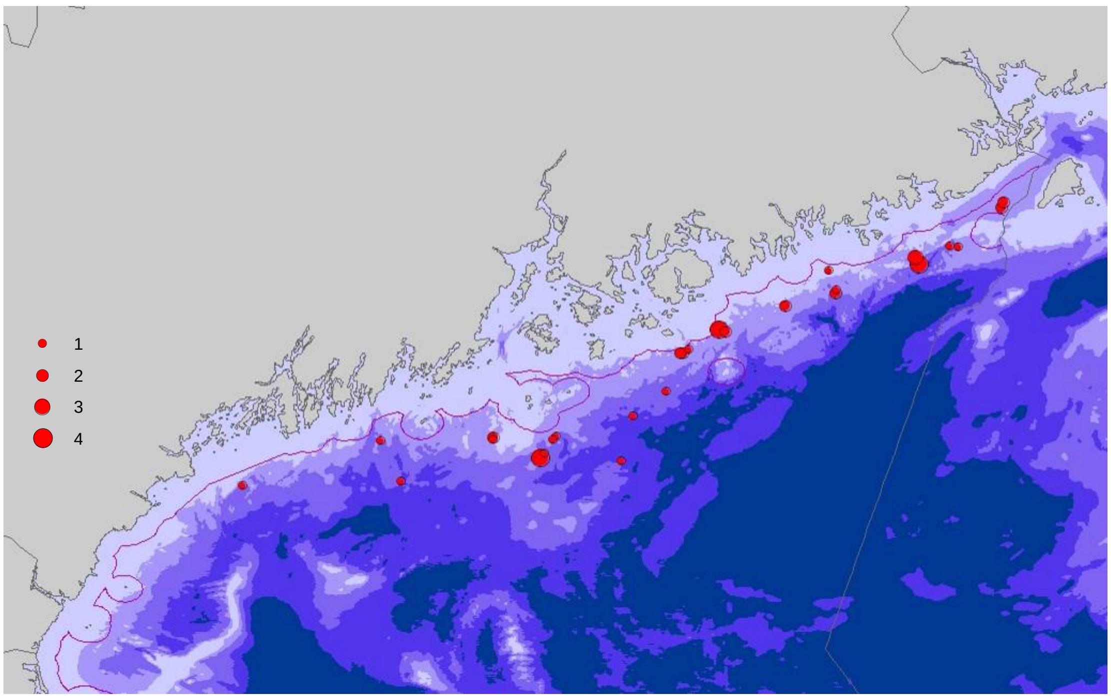
Figure 6: Image analysis equipment including dissecting microscope equipped with a digital camera attached to a PC with a 22" monitor

<u>Results:</u>

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



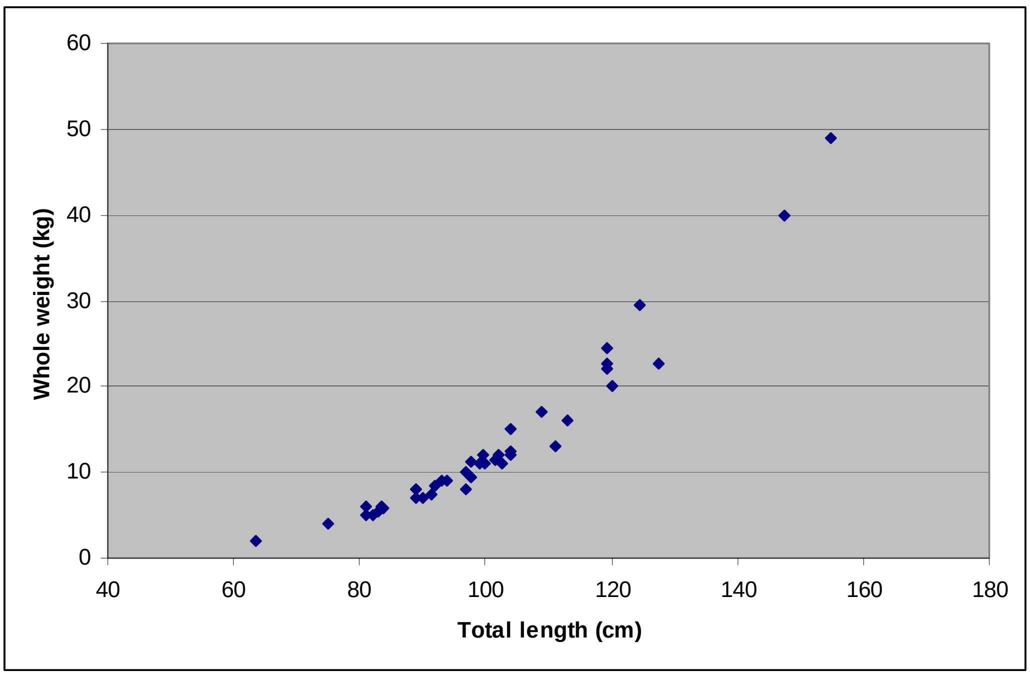
Locations where halibut were captured were explored in relationship with depth, bottom type and time. Depths were binned into four categories: 1=21-40 fm, 2=41-60 fm, 3=61-80 fm, and 4=81-100 fm. The CPUE was highest in the 41-60 fm range and there was a significant difference in the mean depths of sets 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 type). 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^{o}C with an average bottom temperature of 5.7^{o}C. For stations where nothing was caught, the temperature averaged 5.4 ^{o}C, with a minimum of 4.3 ^{o}C and a maximum of 6.7 ^{o}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.

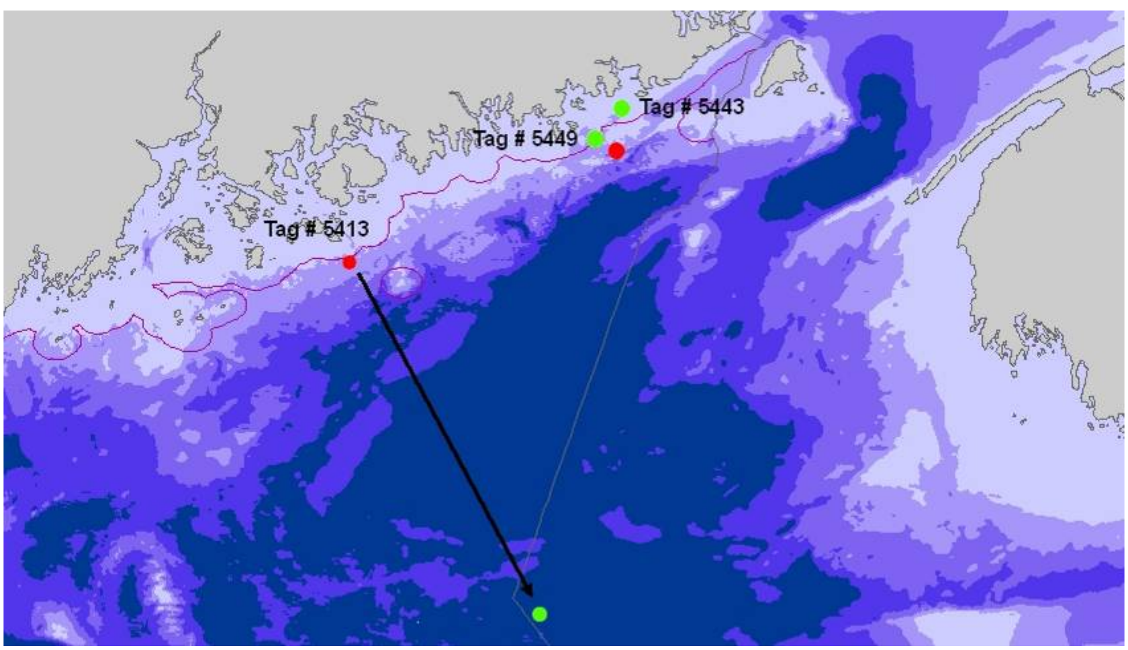
> Tag #5413 was released near Frenchboro, Maine on 6/5/08 on a fish 104 cm in length. This fish was later recaptured on 5/25/09 within 144 km of where it was originally tagged. The fish was at large for 354 days and did not show any growth. Figure 9 shows the release and recapture points.

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

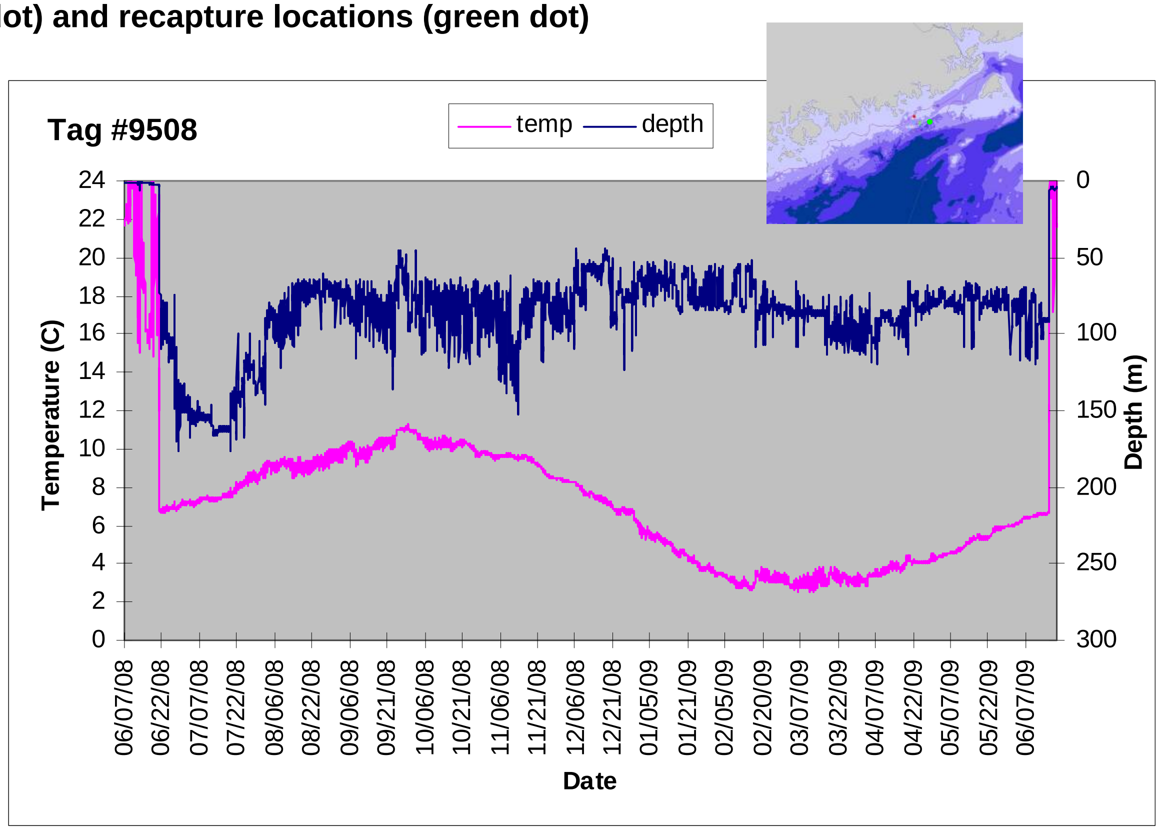


Tags #5443 and 5449 were released in the same location

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.

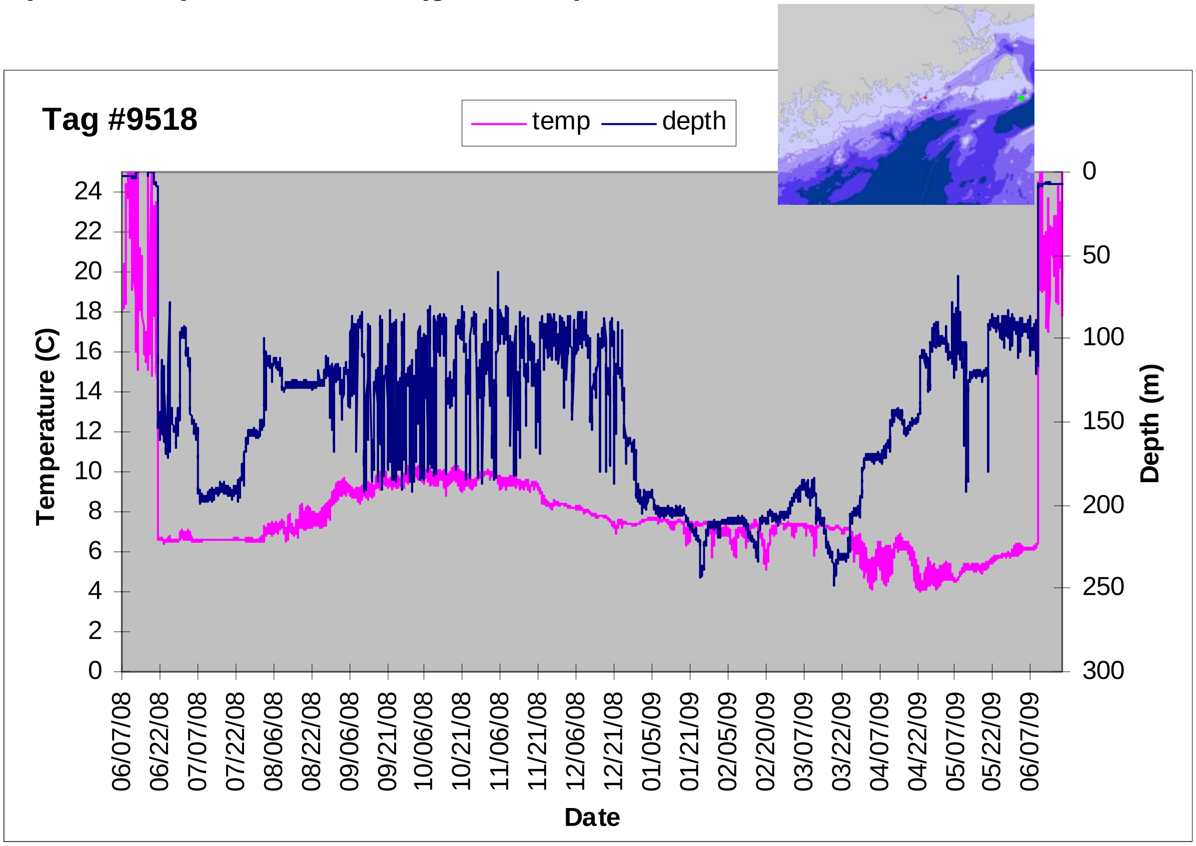
Tag #9508 was released near Jonesport, Maine on 6/21/08 on a fish 113 cm in length. This fish was later recaptured on 6/15/09 within 7 km of where it was originally tagged. The fish grew 6 cm during the 359 days it was at large. Figure 10 shows the release and recapture points and the temperature and 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 ^{o}C and 11.3 ^{o}C, averaging 6.7 ^{o}C.

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



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 ^{o}C and 10.4 ^{o}C, averaging 7.4 ^{o}C.

Figure 11: Temperature and depth profile of tag #9518 with a map of release (red dot) and recapture locations (green dot)



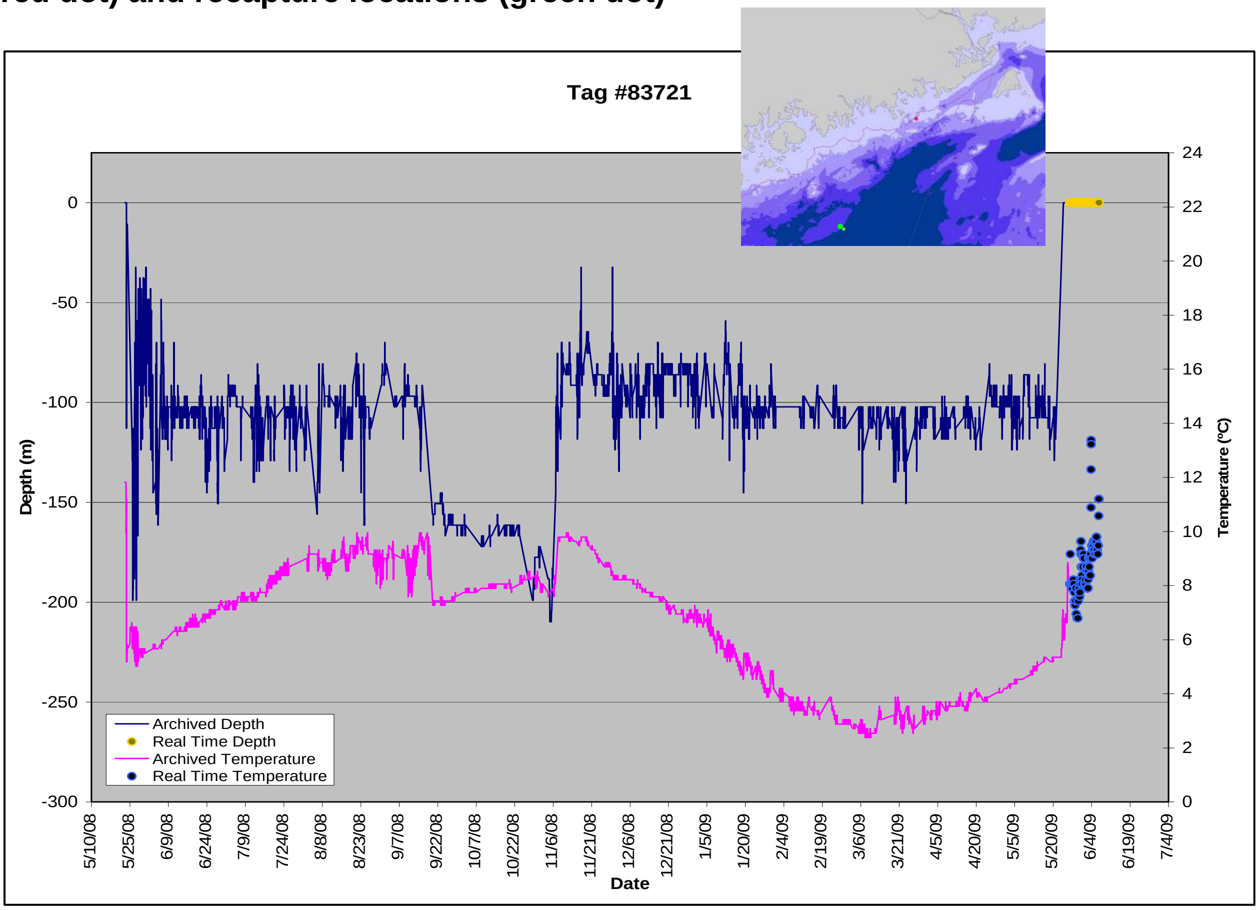
The fates of the three released PSATs were as follows:

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 ^{o}C and 9.9 ^{o}C, averaging 6.5 ^{o}C.

Figure 12: Temperature and depth profile of PSAT #83721 with a map of release (red dot) and recapture locations (green dot)

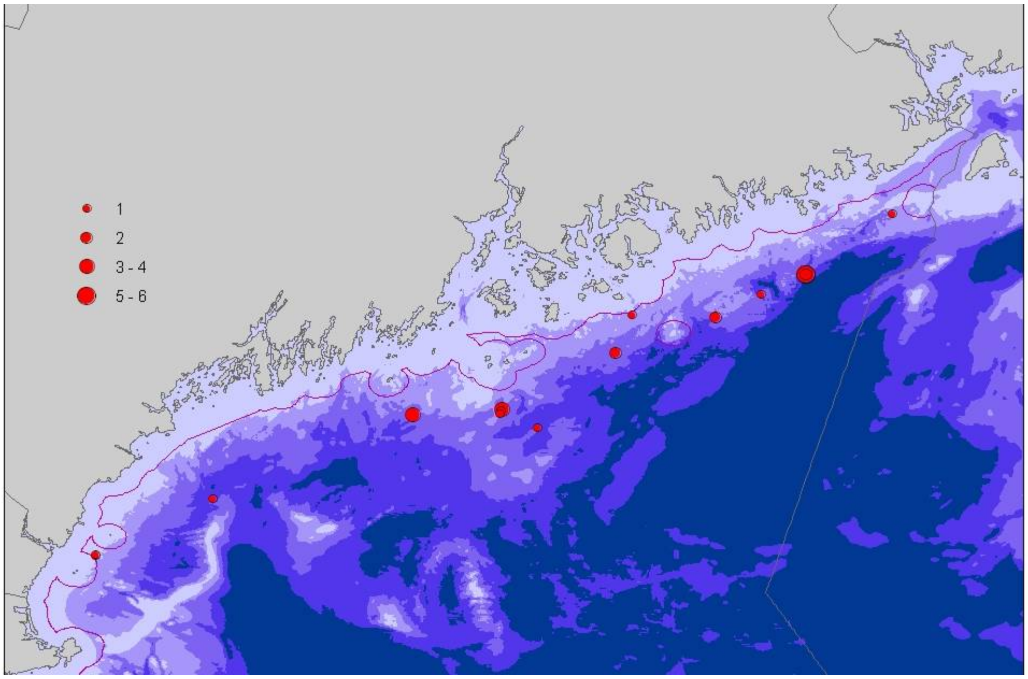


Cusk

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).

Figure 13: Catch locations of cusk represented in numbers

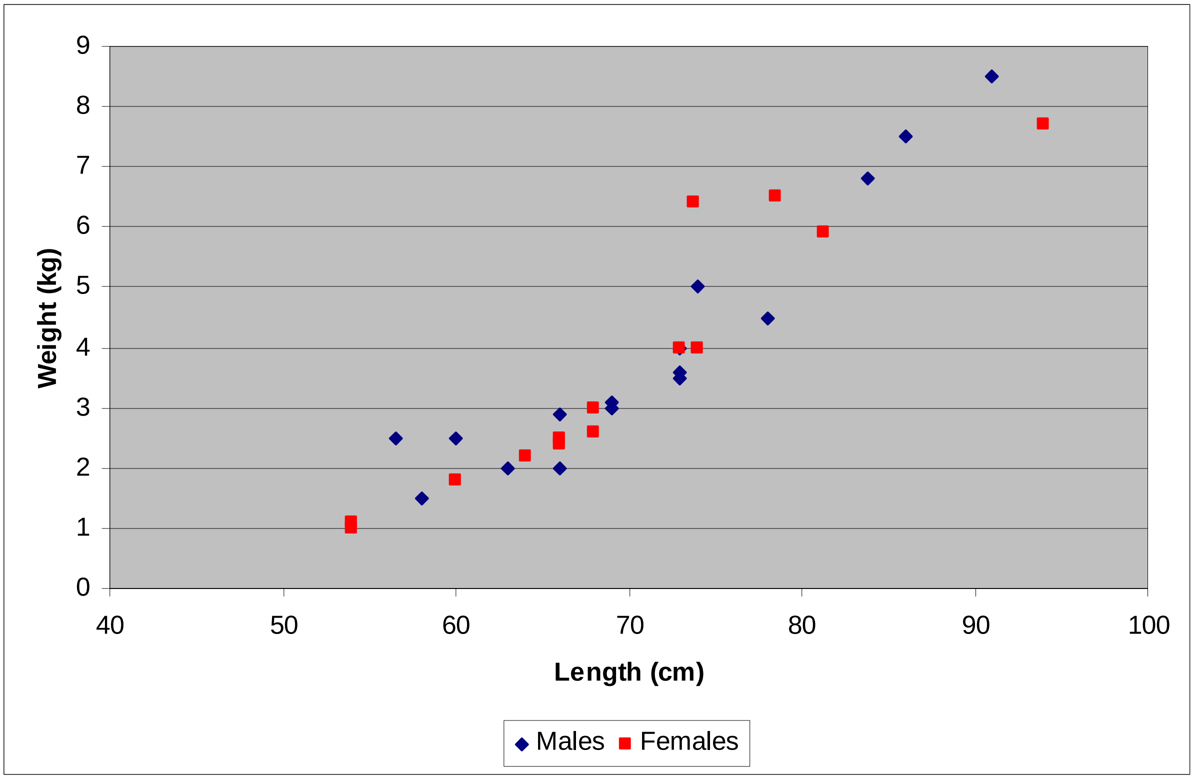


Data from the previous longline survey were also analyzed using a generalized linear model (GLM) and a generalized additive model (GAM) to model the relationship between fish density and spatial/environmental variables (location, depth, hook size and bottom type). The GLM performed better for both halibut 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^{o}C with an average bottom temperature of 5.9^{o}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/o 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

SPECIES	TOTAL
cod atlantic	2
dogfish spiny	1150
haddock	1
hake atlantic red	5
hake white	5
lobster american	2
sculpin longhorn	1
skate little	2
skate thorny	31
wrymouth	26
GRAND TOTAL	**1225**

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 radiocardon 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

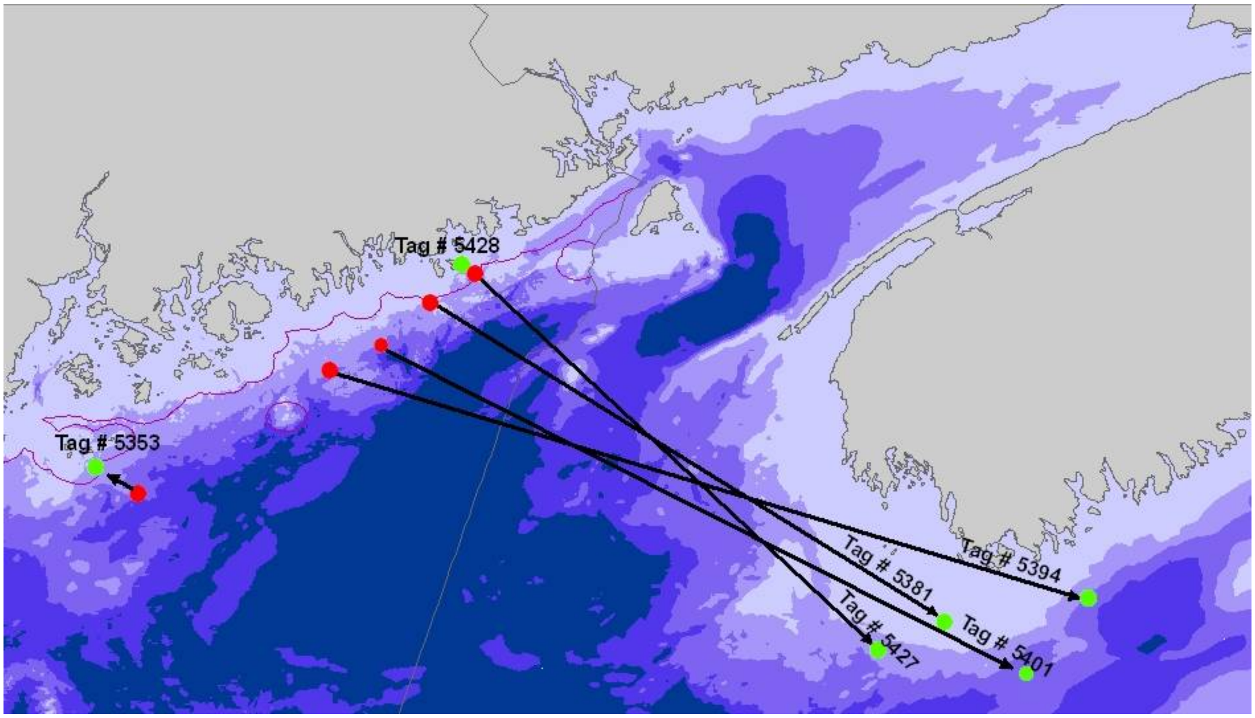


Figure 16: Temperature and depth profile of tag #8823 with a map of release (red dot) and recapture locations (green dot)

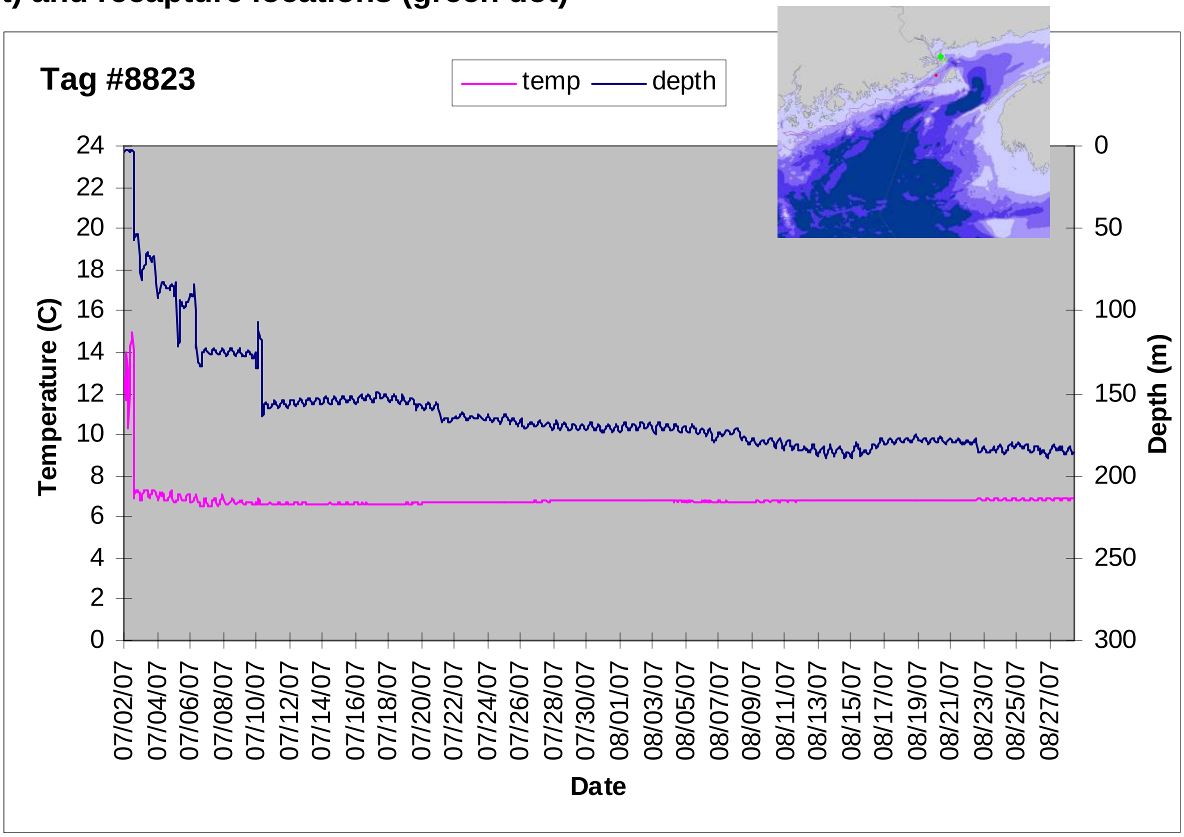


Figure 17: Temperature and depth profile of tag #8808 with a map of release (red dot) and recapture locations (green dot)

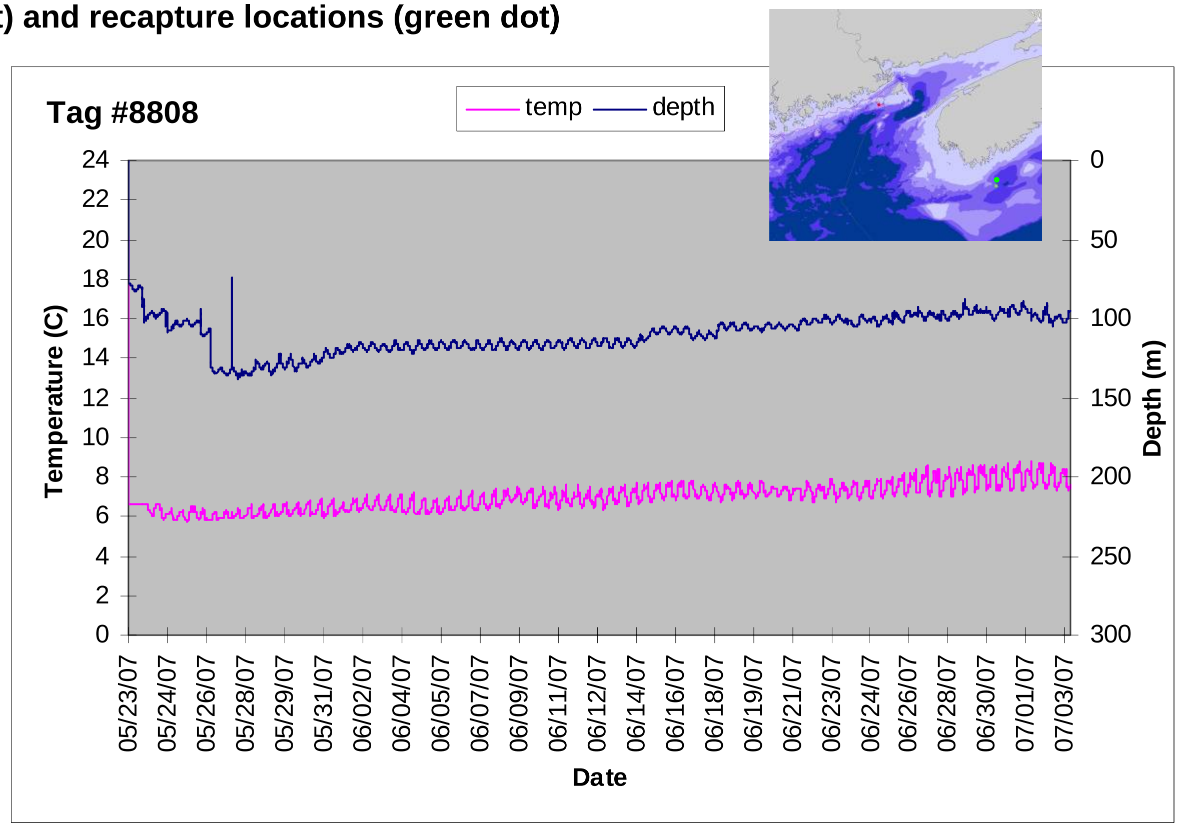


Figure 18: Temperature and depth profile of tag #8831

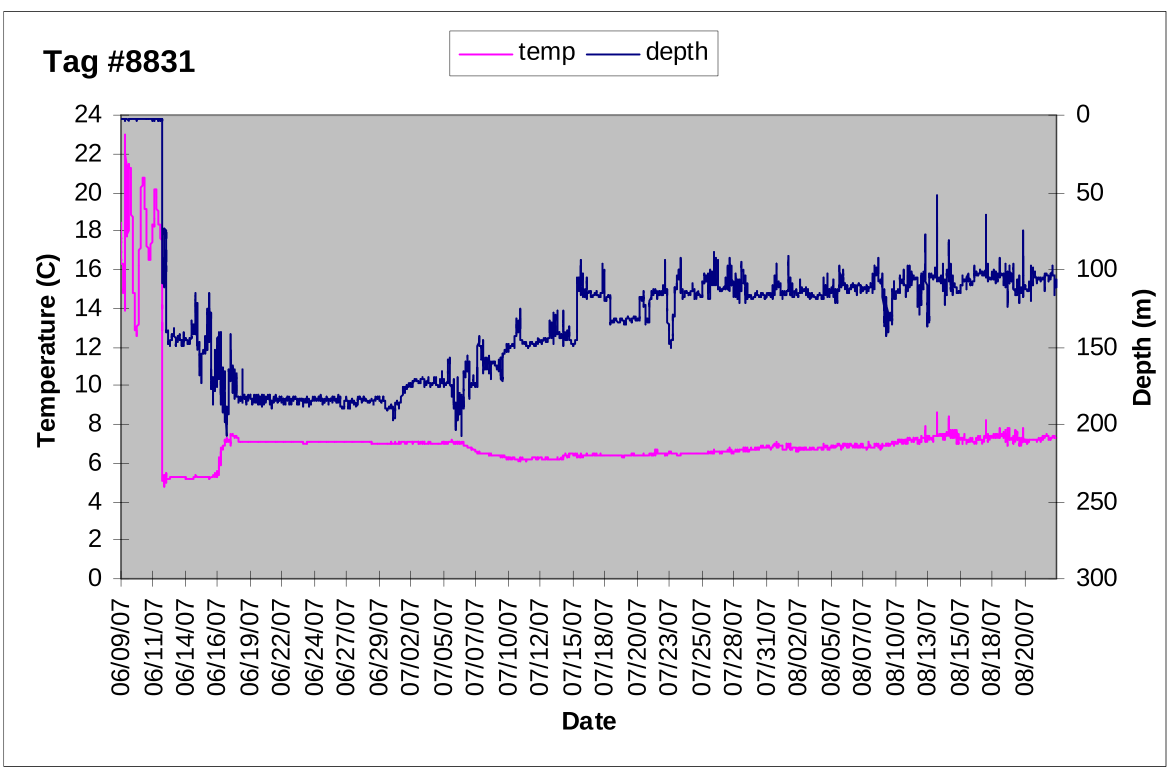
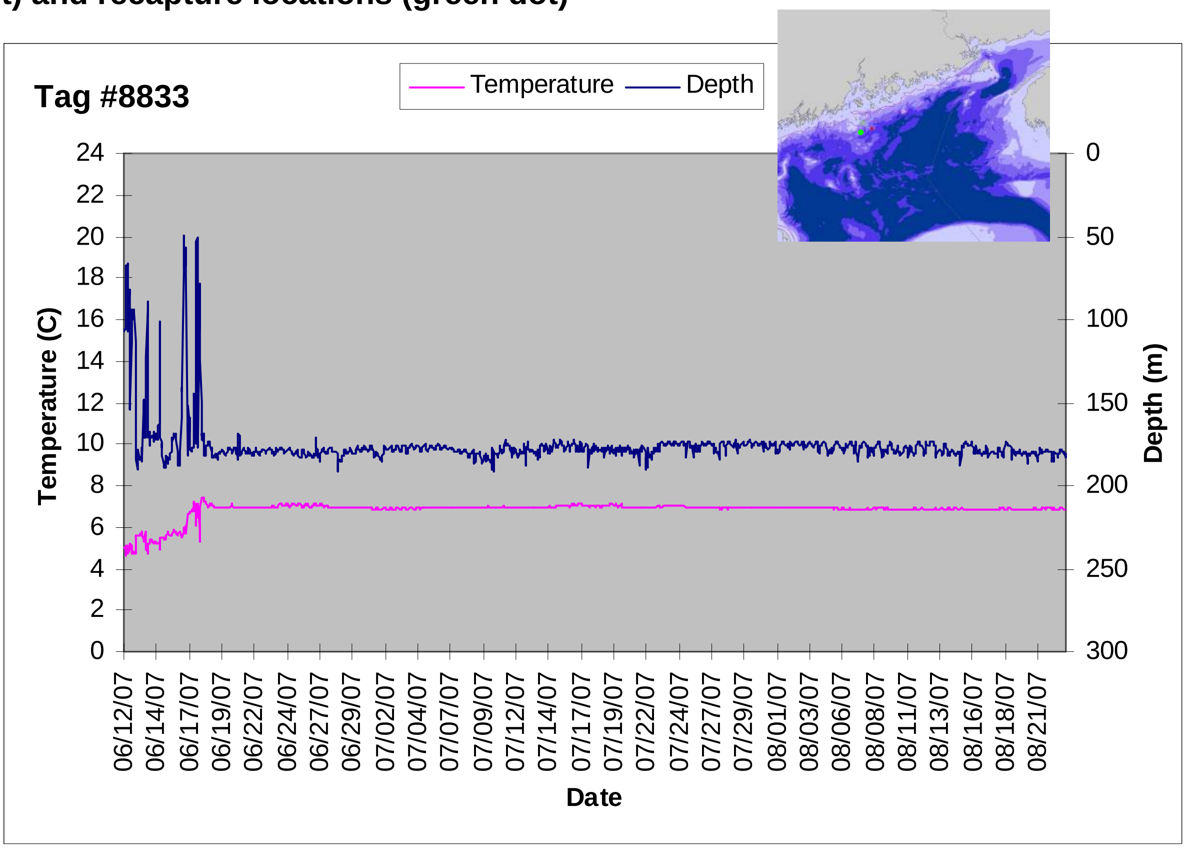


Figure 19: Temperature and depth profile of tag #8833 with a map of release (red dot) and recapture locations (green dot)



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 form 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 2: Cost analysis for PSATs versus DSTs applied to Atlantic halibut

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

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:

Department of Fisheries and Oceans (2009) Preparation of Thin Sections. Available online. http://www.marinebiodiversity.ca/otolith/english/thin_sections.htm. Accessed 29 Sept 2009

Kanwit, J.K. and C. Bartlett, 2007. Maine Department of Marine Resources Research Reference Document: RRD #07/17, available from ME DMR PO Box 8 West Boothbay Harbor, ME 04575

Kanwit, J.K., 2008. Tagging results from the 2000-2004 Federal Experimental Fishery for Atlantic Halibut (Hippoglossus hippoglossus) in the Eastern Gulf of Maine. J. Northw. Atl. Fish. Sci. Vol. 38, 37-42.

Attachment 1: Poster presented at the Regional Tagging Symposium in Durham, NH.

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

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Funding for the electronic tagging was provided by the Northeast Cooperative Research Partners Program

INTRODUCTION:

Since 2000, the Maine Department of Marine Resources (DMR), Maine Sea Grant and participating fishermen have been tagging Atlantic halibut (*Hippoglossus hippoglossus*) in the near-shore Gulf of Maine waters. Three types of tags were deployed on Atlantic halibut; conventional wire tags, data storage tags (DSTs) and pop-up satellite archival tags (PSATs). Electronic tags were incorporated into this study in order to collect data on the temperature and depth preferences of Atlantic halibut throughout their annual movements. Tagging results indicate both localized movements within the Gulf of Maine and long-distance emigrations of juveniles to Canadian waters, demonstrating an interchange between fish in the Gulf of Maine and those considered part of the Scotian Shelf/Southern Grand Banks stock unit. The methods developed for the application of the electronic tags, preliminary results from a DST and PSAT and tag return locations are discussed.

METHODS:

TAG RELEASES & ATTACHMENT

Since 2000, 1561 halibut have been tagged and released off the coast of Maine through the Federal Experimental Fishery, Cod Tagging Program, Maine state waters fishery, NH/ME Inshore Trawl Survey or the DMR/ Northeast Cooperative Research Partners Program Halibut Longline Survey.

Figure1: Halibut after being measured and marked with conventional tag.

CONVENTIONAL TAGS

All halibut were tagged with a conventional wire tag and a subset of fish also received a DST or PSAT. The attachment methods for both types of archival tags were first tested on a dead halibut to determine the best placement. Fish were tagged in the wild without anesthetic or specialized restraining systems.

All tagged fish were measured and marked using a plastic coated wire tag inserted through the first operculum by a specialized stainless steel needle (Figure 1). This "wire spaghetti" tag and application method were adopted from the International Pacific Halibut Commission (IPHC) tagging program due to the tag's low shedding rate and high visibility. The tags were 16.0 cm long with a 7.5 cm yellow plastic section inscribed with: "H00001 Return to DMR // PO Box 8 W Boothbay Hbr, ME 04575 PH: 207-633-9535". Tags were manufactured by Floy Tag Inc. and/or Hallprint Pty Ltd. . Fishermen were trained on proper tagging techniques and handling protocols before the start of each fishing year for the Maine state waters fishery.

DST TAGS

The DSTs were attached to the fish using a "harness" system originally developed for Greenland halibut (*Reinhardtius hippoglossoides*) by Tone Vollen, Ole Thomas Albert (both of the Institute of Marine Research, Norway) and staff at Star Oddi. Star Oddi Milli tags were first attached to a plastic plate, backed with a silicone pad. This plate was then attached to the fish on the upper edge of dorsal side toward the head (Figure 2). Large, hollow, stainless needles (16 gage, 10 cm long) were used to puncture the fish from the underside and the attachment wires were then threaded into the needles and drawn through the body of the halibut. A back plate with a silicone pad was also applied on the underside of the fish and the wires were secured by tightly twisting the two ends together. The fish were released as quickly as possible and the procedure generally took less than two minutes.

Figure 2: Atlantic halibut with DST and conventional tag (through first operculum), INSERT: DST "harness" and applicator needles.

PSAT TAGS

The PSAT tethers were based on the designs developed for bluefin tuna (*Thunnus thynnus*) in the Northwestern Atlantic (Molly Lutcavage, per. comm.). These tethers were constructed using an umbrella dart, developed by Michael Domeier of the Marine Conservation Science Institute, attached to Microwave Telemetry's X-Tag by 400 pound test monofilament secured with stainless steel crimps. This tether, along with a conventional wire tag with return information was sealed in surgical grade silicone tubing to create a smooth, uniform surface from the point of attachment to the tag. These tags were applied to the fish using a stainless steel tagging harpoon specifically designed to fit the umbrella dart. The darts were inserted directly below the apex of the dorsal fin on the topside of the halibut at approximately a 45º angle (Figure 4). Only fish larger then 106 cm were tagged due to information from the IPHC indicating that if the antenna touches the tail it can interfere with swimming behavior (Tim Loher, per. comm.).

Figure 3: Atlantic halibut with PSAT, tether and conventional tag, to the right is PSAT tag with magnet.

RESULTS:

TAG RETURNS

A total of 226 tagged halibut were recovered representing an 11% unadjusted return rate. The distribution of recoveries ranged from along the cost of Maine to the west coast of Newfoundland and the Grand Banks (Figure 4). The recaptures were made by Federal Experimental Fishery participants (33%), the Maine state waters fishery (35%), the US commercial trawl fishery (2%) and the Canadian hook and gillnet fisheries (30%). Tagged and released fish were in the 30 - 185 cm size range, while recaptured fish averaged 96 cm.

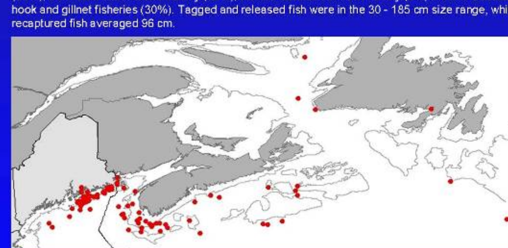

Figure 4: Atlantic halibut tag recapture locations along the North Atlantic coast.

DST DATA

DSTs No. 8823 was deployed in July of 2007 and the fish was recaptured 3 months after being at large, although the memory filled up after 2 months. Upon release, the fish swam down to a depth of 55 m, then gradually kept swimming deeper, eventually remaining within a 20 m depth range (between 150 and 175 m) (Figure 5). Once the fish reached the bottom, the temperature remained within a 1ºC range (between 6.5 and 7.5ºC).

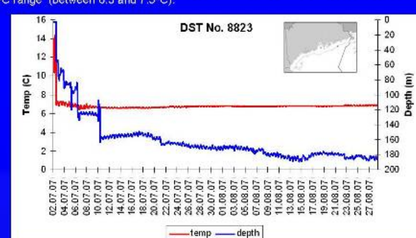

Figure 6: Temperature and depth profile for DST number 8823

PSAT DATA

PSATs No. 34256 was deployed in June of 2007 and released after one month at large. The fish went to a depth of 70 m within the first day after release and remained in comparatively shallow water between 59 and 75 m (Figure 6). Throughout the month long period, the halibut remained within a 1.5 degree temperature range (between 6.2 and 7.7°C).

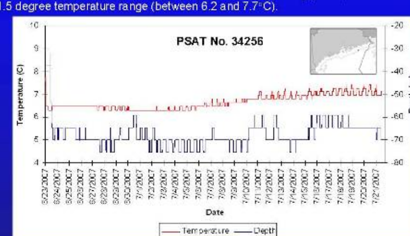

Figure 6: Temperature and depth profile for PSAT number 34256

CONCLUSIONS:

- Data storage tags may contribute significantly to understanding of Atlantic halibut habitat preferences and movement.
- Tagging results provide insight into the movement patterns for Atlantic halibut found off the eastern coast of Maine.
- Data indicate a pattern of both long distance emigrations and local seasonal migrations.
- Data demonstrates an interchange between fish in the Gulf of Maine and those considered part of the Scotian Shelf/Southern Grand Banks stock unit.
- Dispersal pattern of juveniles are to the northeastward in contrast to the southwestward drift of eggs and larvae originating from the Scotian Shelf/Southern Grand Banks stock unit.
- Pattern supports that found in previous study (Kanwit, 2007) where 26 of the 92 recaptures (28%) exhibited large-scale northeasterly emigrations into Canadian waters.
- No evidence of halibut returning to the Gulf of Maine after undertaking emigrations

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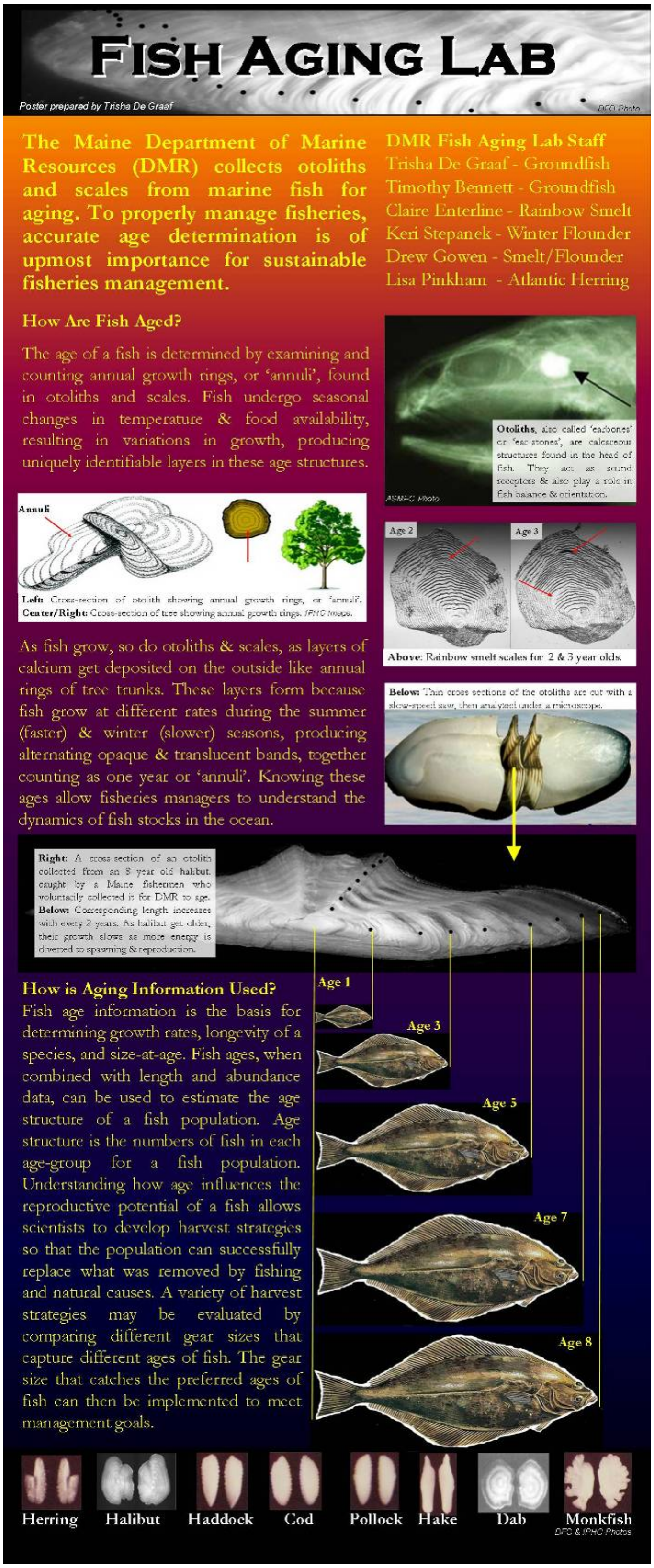
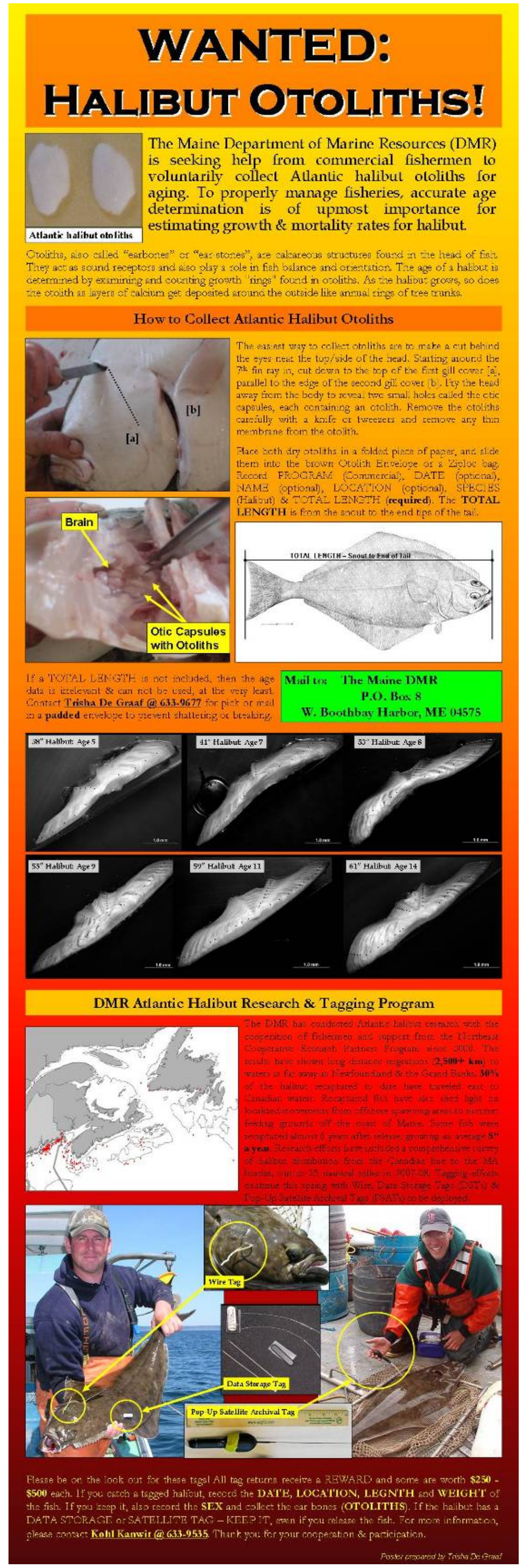
Attachment 2: Education poster and Otolith request poster presented at the Maine Fishermen's Forum.



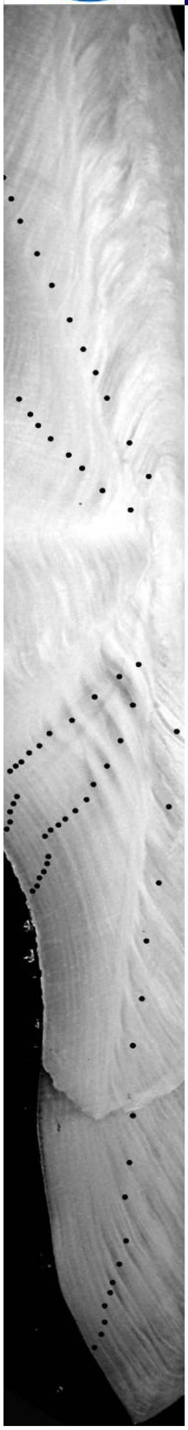


Attachment 3: Poster presented at the 4th International Otolith Symposium in Monterey, CA

Establishment of a Digital Reference Collection for Gulf of Maine Atlantic halibut (*Hippoglossus hippoglossus*)

Trisha Cheney De Graaf[1] and J. Kohl Kanwit[1]

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



ABSTRACT:

Since 2000, the Maine Department of Marine Resources (ME DMR), Maine Sea Grant and participating fishermen have been collecting Atlantic halibut (*Hippoglossus hippoglossus*) otoliths in the near-shore Gulf of Maine waters. Recently, ME DMR established a Fish Aging Laboratory through funding provided by the NOAA Northeast Cooperative Research Partners Program with its first task being to process Atlantic halibut otoliths and establish a digital reference collection. The primary purpose of this reference collection was to train DMR staff. This was a collaborative effort by staff from the Canadian Department of Fisheries and Oceans at the Bedford Institute of Oceanography (DFO BIO) and the International Pacific Halibut Commission (IPHC). Otoliths were embedded, sectioned, and digitized, aged by ME DMR's new ager, then electronically distributed to other aging laboratories for their estimates. DFO BIO and IPHC staff aged the collection and returned it to ME DMR with digital annotations and comments. The ME DMR ager 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 agers. The result was an improved % agreement between the new ager and experienced agers estimates from 30.7% to 63.6% agreement. This methodology may prove beneficial to state, federal and other aging laboratories with limited budgets, restricting them from allowing staff members to travel to receive training at other institutions as the digital format can be easily uploaded and downloaded through ftp websites or mailed as digital format. These methods and procedures will be discussed in this poster.

METHODS:

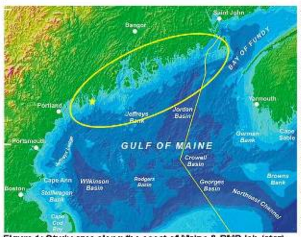


Figure 1: Study area along the coast of Maine & DMR lab (star).

ALANTIC HALIBUT OTOLITH SAMPLES

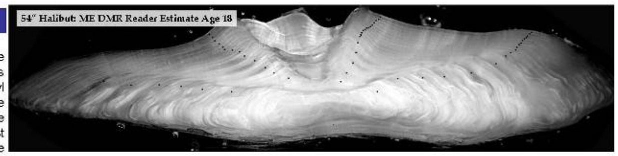
Sagittal otoliths were collected off the coast of Maine through the Federal Experimental & ME State Waters Fishery, Port Sampling and the NH/ME Inshore Trawl Survey. While 88 were chosen as an initial basis for the digital reference collection, with both a male and female sample for each age group, the goal is to have at least 300 samples, so individual images cannot be memorized. Age comparisons were conducted as part of a training exercise for ME DMR's new age reader through a collaboration with DFO BIO and IPHC experienced age readers. All agers interpreted annuli counts from otolith cross sections images independently. None of the age interpretations were validated, however the age determination protocols of DFO & IPHC have been validated through radiocarbon bomb chronometer work (Piner & Wischniowski, 2004).

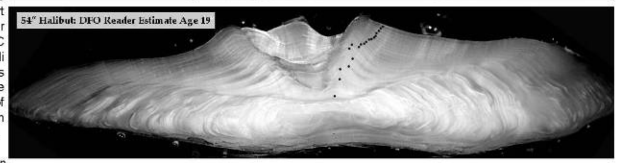
HARDWARE & SOFTWARE:

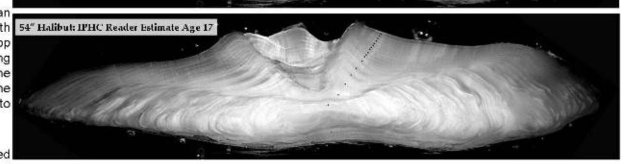
The digital image analysis system consisted of an Olympus SZ6145 dissecting microscope equipped with an Olympus DP71 digital camera connected to a PC with a 22" Planar color monitor. Digital images of otolith cross sections were captured using Olympus' DP Manager software and imported into Adobe Photoshop 7.0.1 for image enhancement and analysis. The software allowed the ager to clearly identify by annotating each annulus. The annotations were saved in separate layers in which the visibility can be hidden, so the following ager had no knowledge of the previous agers selections. This gave the ME DMR 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.

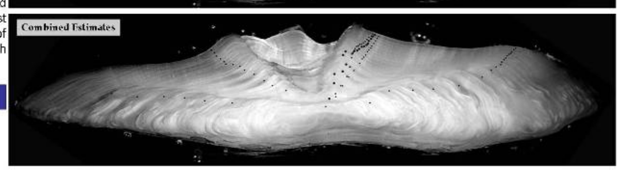
ACCURACY & PRECISION:

To track the progress of the new DMR age reader while being trained by the DFO BIO and IPHC experienced agers remotely, 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.nefsc.noaa.gov/fbi/age-prec/#bow. This 'two-reader' approach tested whether the new ager had applied ageing criteria in the same way as the experienced reader.









RESULTS:

Inter-Reader Precision Tests were run on age estimates between labs. The trainee's ages are presented in terms of the experienced (DFO & IPHC) reader's ages. The ME DMR age reader improved their percent agreement with the DFO age reader from 30.7% to 63.6% (Figure 2), while the percent agreement only increased slightly with the IPHC age reader from 39.8% to 40.9% (Figure 3). This slight increase is due in part to the fact that the DMR age reader has yet to study the annotations and comments provided by the IPHC reader, and it is expected that a once completed and the collection again re-aged, the percent agreement will increase.

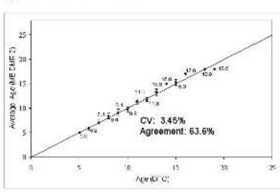


Figure 2a. Age Bias Plot, showing the average age attained by the DMR reader versus the ages generated by the DFO age reader. Error bars indicate 95% confidence intervals.

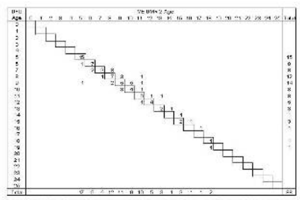


Figure 2b. Age-frequency table, showing each reader's ages. Numbers in the outlined boxes indicate agreement between the two ages. Numbers above the diagonal indicate fish which were given higher ages by the ME DMR ager; those below the outlined boxes were given higher ages by the DFO age reader, Total age frequencies are given by age for both readers.

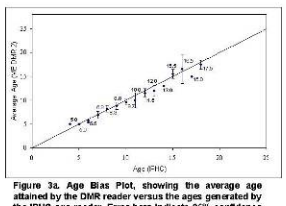


Figure 3a. Age Bias Plot, showing the average age attained by the DMR reader versus the ages generated by the IPHC age reader. Error bars indicate 95% confidence intervals.

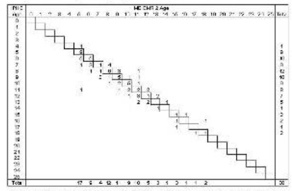


Figure 2b. Age-frequency table, showing each reader's ages. Numbers in the outlined boxes indicate agreement between the two ages. Numbers above the diagonal indicate fish which were given higher ages by the ME DMR ager; those below the outlined boxes were given higher ages by the DFO age reader, Total age frequencies are given by age for both readers.

ONGOING & FUTURE EFFORTS:

Figure 3: ME DMR Fish Aging Lab's primary equipment.

This work is ongoing and it 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 agers to learn from and identify aging errors more efficiently; otolith images in digital format, allowing for ease of transfer between different aging labs (state, federal, academic, etc…); reduced aging biases resulting from aging by microscope only; a reflection the current oceanographic and climatic conditions that affect fish growth; as well as a basis for other future research studies (onset of maturity, stock 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 agers to learn from as aging errors can be identified more efficiently and what adjustments need to be made, but it provides a permanent image that can then be easily transferred to other aging laboratories at a minimal cost in terms of time, storage space and funding that would otherwise be used for personnel travel.

AKNOWLEDGEMENTS:

- Stephen Wischniowski from IPHC (aging)
- Jay Burnett at NFSC, Woods Hole, MA (direction)
- NE Cooperative Research Partners Program (funding)
- Tania Davignon-Burton from DFO BIO (aging)
- Steve Campana at DFO BIO (direction)

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