Northeast Consortium Project Annual Progress Report:

Title: Activity and distribution of cod in the Ispwich Bay spawning area
Contract number: 111A22

Project Leader:
W.H. Howell
Dept. of Zoology, UNH, Durham, 03824
Phone: 862-2109
Email: whh@cisunix.unh.edu

Project Participants:
David Goethel, F/V *Ellen Diane*
23 Ridgeview Terrace, Hampton, NH 03842
Phone: 603-926-2165
Email: egoethel@comcast.net

Carl Bouchard, F/V *Stormy Weather*
P.O. Box 219, Exeter, NH 03833
Phone: 603-772-5047

Charles Felch, Sr., F/V *Lady Victoria*
118 Centennial St., Seabrook, NH 03874
Phone: 603-474-7342

Marc Stettner, F/V *Too Far*
91 Fairview Ave., Portsmouth, NH 03801
Phone: 603-431-2577

Pingguo He
OPAL/EOS, Morse Hall, UNH, Durham 03824
Phone: 862-3154

Project Hypothesis and Project Objectives:

The overall goal of the project is to study cod activity and fine scale distribution within the Ipswich Bay spawning area. These data will allow us to determine the spatial use of the spawning habitat, and determine which habitat attributes (e.g. temperature, depth, substrate type, bathymetric features) influence the distribution and spawning of cod. Hypotheses to be tested include:

H_o1: There are no daily patterns of activity (vertical movements) and swimming speeds of cod in Ipswich Bay.

H_o2: Environmental variables such as water temperature, tidal and lunar phase do not influence activity (vertical movements) and swimming speeds.

H_o3: Habitat attributes such as depth, substrate type and bathymetry do not influence the fine scale distribution of cod on their spawning grounds.

To test these null hypotheses, we plan to meet the following objectives:

1. Quantify daily and seasonal (pre-, spawn, post-spawn) changes in activity and depth distribution of spawning cod in the Ipswich Bay spawning area.

2. Relate spawning movements to environmental factors (time of day, water temperature, phases of the moon and tidal cycles).

3. Determine how the spatial distribution of spawning fish relates to attributes of the spawning habitat.

Work Completed to Date:

Letters of Acknowledgement to work in closed area 133 were requested from the National Marine Fisheries Service, and one was obtained for each participating vessel. Prior to initiation of the fieldwork, six cod were implanted with dummy acoustic transmitters and DSTs, and monitored in captivity for three months. All were observed to swim and behave normally and displayed no ill effects from tagging.

Between April 21st and May 17th, 200 adult spawning cod in Ipswich Bay were captured by short bottom tows aboard a commercial vessel and externally tagged with DSTs. Thirty of the fish also had an acoustic transmitter surgically implanted. The DSTs were programmed to record both water temperature and depth of each fish at 12-minute intervals for approximately six months after release, and each was imprinted with information on how to report the recapture of a DST-tagged fish. Monetary rewards ($25) were offered for the return of DSTs so that data could be downloaded from the tags.

Results to Date:

To date, 25 DSTs have been returned by fishermen (12% recapture rate). Each tag creates a data profile of an individual's vertical activity in the water column (depth) and ambient temperature. The data obtained from these tags ranges from 20 days (2,361 measurements for both depth and temperature/tag) to the tags' maximum memory capacity of 176 days (20,936 measurements of depth and temperature/tag). Tagged fish have been at liberty for up to 380 days before recapture, however, and recapture locations range from Platts Bank to Stellwagen Bank.

The DST data from many of the recaptured fish showed an initial dive to the bottom upon being released, and many marked vertical migrations, from the bottom to near the surface, in the 6-10 days following tagging. Following this period of steep vertical movements, the extent of the vertical movements decreased, and the fish remained near the bottom. There was typically a dramatic shift to deeper depths in mid-June onward, showing that individuals have moved out of the study area.

Extensive vertical movements in the days following capture and release have also been observed in Pacific cod (Nichol and Chilton 2006), and were attributed to barotrauma (rupturing of the swimbladder). This trauma resulted in the inability of the fish to maintain themselves at constant depths. To determine if the extensive vertical movements we observed were associated with barotraumas, or with equally likely spawning or feeding vertical movements, we are presently conducting a short study of DST tagged cod in a submersible cage. In this, we captured 13 cod on July 4, 2007, equipped each with a DST, and released them into a 4 x 4 x 6 m submersible cage. A DST was also attached to both the top and bottom of the cage to serve as vertical reference points. The cage was then submerged to 50 m. The caged fish will remain at this depth until July 15, 2007. The cage will then be brought to the surface, the fish recaptured, and their DSTs downloaded. If, as we expect, the fish have undertaken rapid vertical movements within the cage, it will suggest the fish have experienced barotrauma.

The cod tagged cod with an acoustic transmitter were tracked to determine their movement during their residence in Ipswich Bay. Tracking was achieved in two ways. In the first, a series of 6 submerged stationary hydrophones were deployed in the area. These recorded the unique acoustic signal from any fish that came within 800m of the hydrophone. In the second tracking method, fish were located using a manually operated directional hydrophone aboard commercial vessels involved in the project. We undertook both day and night manual tracking trips, 10-12 hours long, in the spawning area from May 6th through June 30th. The project utilized 47 days of boat time for tracking. Of the 30 fish tagged with transmitters, 29 were relocated on at least one day, and 20 were relocated on more than 5 days. Tracking data from both the stationary and manual hydrophones were used to create a positional history of each fish during the spawning period. All relocated transmitters (fish) were found to aggregate around a small number of elevated, hard bottom features of Ipswich Bay, and frequently moved back and forth between these landmarks during the tracking period.

A gradual eastward movement was observed for several cod in June until they appeared to leave the area entirely. For some transmitters, tracking efforts captured abrupt and rapid eastward movement out of Ipswich Bay, indicating the exact date and time that a fish left the spawning area and moved offshore, and the approximate swimming speed and heading. By the last week of June, just before commercial fishing opened in the area on July 1st, only six transmitters could be relocated. The disappearance of tracked fish in mid-June was concurrent with the shift in vertical activity and depth seen in most recaptured DSTs, and supports the idea that most tagged fish moved out of the spawning area by mid-June. Out of the 25 recaptured DSTs, 5 DSTs came from cod that contained acoustic transmitters (17% recapture rate for the 30 acoustically tracked fish). The

positional tracking data of these individual cod can be combined with the vertical profiles of their DSTs to create a three-dimensional history of their behavior and location during the spawning period.

Obstacles and Project Alterations:

Tagging and tracking goals were met in full, and no major setbacks were encountered. Few fish were found when tagging attempts began April 21st, but by April 30th, adults had moved into the area in large numbers. During the tagging period, females were less abundant than males, and more males were tagged with DSTs as a result (78 females and 122 males total). A 1:1 sex ratio was maintained when implanting acoustic transmitters (15 males, 15 females). Our most significant obstacle was weather, as expected, and storms in mid-May interrupted manual tracking and prevented some tags from being deployed until May 17th.

Plans for next 6 months:

We are currently overlaying the positional history of each tracked cod with physical and environmental features of the area: bathymetric features, sediment type, weather patterns, tidal and lunar cycles, and temperature. Having collected a sizeable data set of movement information, the next goal is to determine what relationships exist between fine-scale spawning behavior and habitat, and what associations are statistically significant. For the cod that we have both tracked and recovered DSTs for, we are working to integrate their DST vertical activity data and positional history.

Impacts for fishing and science communities:

Detailed information about the spatial distribution and habitat utilization of spawning cod in Ipswich Bay allows fishery managers to better assess the importance of the study area as a spawning ground, what features are critical to spawning populations each year, and how to most effectively preserve the population and regulate the area. Fine-scale data indicating the exact timing of cod entry and exit from the inshore spawning ground can improve rolling closure regulations. Depth profiles can improve the accuracy of survey trawling in spawning areas and efficiency of commercial trawling when spawning areas open. Depth profiles, tracking data, and recapture locations increase our knowledge of where cod disperse from spawning grounds, and what linkages exist between this spawning ground and fishing grounds elsewhere in the Gulf of Maine. Depth, timing, and exact location of spawning events can be used in modeling larval transport and recruitment, and thus determining the significance of this spawning population to New England cod stocks.