Northeast Consortium Project Annual Progress Report 2008:

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

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Project Goal:

The overall goal of the project is to study the activity and fine scale distribution of cod in the Ipswich Bay spawning area, using a combination of data storage tags (DSTs) and acoustic telemetry.

Methods and fieldwork (completed):

Letters of Acknowledgement to work in the closed area 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.

The cod tagged with an acoustic transmitter were tracked to determine their movement during their residence in Ipswich Bay in 2006. 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.

Results to date:

Ongoing tag returns:
As of June 2008, 28 DSTs have been returned by fishermen (14% recapture rate). Each tag creates a data profile of an individual's vertical activity in the water column (depth) and ambient temperature. The data profiles from recaptured tags range in length from 20 days (2,361 measurements for both depth and temperature/tag) to 174 days (20,880 measurements of depth and temperature/tag). Several DSTs were at liberty longer than the tags' memory life, and have been recaptured as recently as May of 2008 (757 days at liberty). Recapture locations span Platts Bank to Cape Cod, up to 171 km from their release site.

DST results:
Trends in DST data include the occupation of relatively uniform and consistent depths in May and early June, sometimes punctuated by brief ascents to much shallower depths, which may reflect spawning events. There is typically a dramatic shift to deeper depths in mid-June, showing that individuals have moved offshore and out of the study area. This depth change coincides with the initiation of a wide-ranging vertical movement in the water column, indicating a change in behavior as well as location. Cod that traveled to the same areas before recapture displayed similar vertical movement patterns, indicating that local environment and bathymetry influence fine-scale behavior. The depth ranges occupied by cod between release and recapture suggest pathways cod move along after leaving the spawning ground, and many appear to have followed basins and trenches during their migration. Most cod show strong diel vertical migration patterns after leaving the spawning ground, in which they ascend to shallower depths at night and descend at dawn. We believe these 24-cycles are a result of feeding behavior and movement onto shallow banks at night.

Acoustic tracking results:
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 20 recaptured DSTs, 4 DSTs came from cod that contained acoustic transmitters (13% 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 2007-2008:
No major obstacles or alterations were encountered in the past year.

Summary of completed and unfinished work:
All fieldwork, tagging, and acoustic tracking are complete. The majority of DST analysis is complete, although we are currently collaborating with a statistician to pursue more advanced models for movement analysis for both DST and tracking data. DSTs continue to be recaptured and incorporated into our data set.

We are still working to relate positional history of each tracked cod with physical and environmental features of the area: bathymetric features, sediment type, weather patterns,

diel cycles, and temperature. Having collected a sizeable data set of movement information, we are examining what relationships exist between fine-scale spawning behavior and habitat, and what associations are statistically significant. We are also working to improve our habitat data for the Ipswich Bay spawning ground and have been conducting multibeam acoustic surveys of the seafloor in our study area. This data should be available to us and incorporated into our movement analysis later this year.

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.

Presentations:
Laughlin Siceloff and Hunt Howell presented results from this study at the 2nd International Symposium on Tagging and Tracking Marine Fish with Electronic Devices on October 8, 2007, in San Sebastian, Spain.

Hunt Howell presented findings from this study at a fishery management meeting in May 2008 concerning the formation of sector-based groundfishing regulations and potential changes in rolling closures in the western Gulf of Maine.

Related projects and collaborations:
We began collaboration in the summer of 2008 with a colleague at Simon Fraser University, who specializes in statistical modeling of fishery population dynamics and movement. He will be constructing analytical models for this project's data that will be incorporated into future publications.

Project data was used to inform and advise a grant proposal submitted by researchers at the Gulf of Maine Research Institute, University of Massachusetts-Dartmouth, and UNH in 2008. This proposal is for a large-scale ecological connectivity study of known cod spawning grounds in the Gulf of Maine, including Ipswich Bay.

We have also been coordinating with UNH's Center for Coastal Ocean Mapping (CCOM) to conduct multibeam acoustic surveys of the seafloor and cod spawning aggregations in the Ipswich Bay spawning ground, in order to improve on the low-resolution habitat and bathymetry data currently available for this area. Cod tracking data

was used to design a survey plan for acoustic mapping work, and will become part of our future publications and CCOM's Gulf of Maine mapping database.

Partnerships:
All fishers named as project participants were involved in the tagging and tracking work in 2006. None have been actively involved in the project in the past 12 months but have been regularly updated and consulted by researchers during the data analysis process, and have recaptured and returned some of the project's tags in the past year.

Student participation:
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