1. **PROJECT TITLE:** Is Closed Area I serving as a refuge for haddock? A study of fine-scale behavior through the use of ultrasonic tagging techniques

Subaward # 08-006

2. **PRINCIPAL INVESTIGATOR:**

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4. **MAJOR ACCOMPLISHMENTS AND MILESTONES:**

After sorting out contract and permit details last spring, work for this project began in March of 2007. The work accomplished to date can be divided into four phases: 1) surgery trials (laboratory and field); 2) equipment trials (field); 3) tagging and array deployment; and 4) array monitoring.

1) **Surgery trials:** The first step in our work plan, after purchasing acoustic tags and receivers from Vemco, was to determine whether haddock can survive the internal tagging procedure set forth in the proposal. To test the effect of surgery, 20 haddock were captured in the field (F/V Maine Lady and F/V Special J) and transported to live holding facilities at the University of New England. After fully acclimating to captivity, 9 haddock were surgically implanted with acoustic receivers and the 9 remaining were held as controls. There was no significant effect on survival to 2 months following surgery, although some fish from both treatment groups succumbed to tail rot and other infections. Interestingly, there was a significant effect of surgery on Fulton’s condition factor ($W/L^3$); surgery fish had significantly lower energy reserves (condition) after two months and this was interpreted as the result of the multiple stress of surgery plus captivity (Fig. 1). This sublethal effect is not normally reported in tagging studies of this type and may be grounds for further research. Despite this effect (which was likely an artifact of captivity), the laboratory surgery trials were deemed a success.
Surgeries were also tested in the field over a shorter time period with fish being caught, tagged, and released back into cages that were set back on the sea floor. Our first attempt, resulted in loss of all fish likely due to fish being caged for too long of a period (5 days; weather impeded our ability to return earlier). A second attempt (3 days caging) yielded positive results; 5 of 6 surgery and 6 of 8 control fish survived.

2) Equipment trials: To properly design acoustic monitoring studies, receivers and tags need to be tested in the environment where they will be deployed to come up with proper mooring techniques for receivers and determine the detection range for tags. After consultation with our fishing partners, we decided on a mooring design that complied with whale safe regulations and that would allow for efficient retrieval and redeployment. Range tests for receivers and tags were conducted by drifting away from fixed receivers and determining the distance at which tags are no longer detected; this distance was found to be about 800 m which is near the maximum reported by the manufacturer.

3) Tagging and array deployment: The original proposal envisioned an enclosure type design that would circle off a small portion of the closed area to and from which haddock movements could potentially be monitored. After careful consideration of alternative designs, it was decided that a diffuse, non-overlapping grid design for the limited number of receivers (18) would provide more data and be less risky in terms of potentially missing important centers of aggregation/movement (Fig. 2). 80 haddock were tagged and released into the array at the end of July 2007. All fish released were noted to be in very good condition and readily swam down when released into the water.

4) Array downloading: The array was visited multiple times following deployment and tagging. Unfortunately, our final visit to the array in November of 2007 revealed that all but 3 of the receivers had been lost likely due to Hurricane Noel making a near direct hit on the Great South Channel. Fortunately, we had 2+ good months of array monitoring data from which 23,309 usable (meaningful) detections were made representing 38 individual haddock (an additional 4 haddock, previously not heard from, were detected on a receiver returned to us from a fisherman in April of this year bringing the total number of

![Figure 1](image1.png)  
*Figure 1. Length vs. condition factor for tagged and control haddock 2 months following surgery and held in captivity. Difference in treatment groups is significant (t-test, p < 0.01).*

![Figure 2](image2.png)  
*Figure 2. Chart showing deployment location of 18 receivers (red flags) in northwestern corner of CAI. Blue fish are tagged fish release locations. Green triangle (dashed line) shows extent of early planned enclosure array design.*
haddock ‘relocated’ to 42 or roughly a 50% return rate which we consider to be very high). The patterns of movement and centers of aggregation for August and September appear to support the hypothesis that haddock are resident to CAI (Fig. 3). Most detections were made well away from the edge of the closed area and individual movement tracks appear to indicate a ‘decision’ by haddock to remain in the closed area; multiple tracks showed signs of turning around once the haddock encountered the boundary (this likely reflects differences in food abundance inside and outside of the closed area). Additional interesting biological results were obtained. For example, haddock were more active at night and swimming speeds were well in excess of maximum sustainable suggesting that haddock use tidal currents to move (most movements were in line with the tidal ellipse for the area). All of these results will be presented in the final report.

Figure 3. Number of individual haddock detected by each receiver in the array over the course of two months (Aug – Sep). More haddock were detected on central receivers than receivers near the closed area boundaries.

5. UNEXPECTED DIFFICULTIES AND PROJECT ALTERATIONS:
As mentioned in the previous section, the major alteration to this project compared to what was originally proposed was with respect to array design. The original array design would have had all of the receivers deployed in a “tight” configuration near the northwestern-most corner of the closed area. In the current design, receivers were spread out in a non-overlapping grid pattern to maximize the chance of detecting movements and centers of aggregation. The new design has provided very good results and perhaps may only have been more effective if it had been spread out even more to the east (it’s quite likely that the entire center of aggregation includes the whole deep portion of the area [lightest grey in Fig. 3]).
However, practical limitations, including time to steam between receivers, led us to space receivers at about 3-4 miles apart. It is of note that if the receivers had all been placed in the northwestern-most corner of the closed area as originally planned, we would have seen very few fish (Fig. 3). Another significant setback has been the loss of the array due (likely) to Hurricane Noel. It was hoped that we would be able to download receivers throughout the winter to gain seasonal information on movements. Despite this loss, the one receiver that has been returned to us by a fisherman showed that fish were active within the area throughout the winter months; 8 fish were detected (November to March), 4 of which hadn’t been detected previously. For future studies, we would recommend receivers to be deployed without any surface gear and laid out on the bottom between two anchors laid in such a way so that retrieval could be accomplished by grappling.

6. NEXT STEPS, TASKS FOR NEXT YEAR:
The loss of the array may have been a blessing in disguise. If the array had survived the winter, we would have used up all of our charter days just visiting and downloading receivers. One drawback to the array-only design is that no receivers were placed outside of the closed area because of intense fishing along the outside edge. With charter days freed up (11 total) we can now conduct a proper manual tracking survey. This survey will allow us to expand our coverage further east as well as to points outside of the closed area and will complement well the array results from last year. Thus, we should further be able to test the hypothesis that haddock are more present in the closed area than outside. We are in the process of using up these days and the manual tracking survey results along with the array results will be included in the final report.

7. IMPACTS OF THE PROJECT TO FISHERMEN/FISHING COMMUNITY, AND SCIENTIST/SCIENCE COMMUNITY
Although the analysis is not completed, our results are pointing in the direction of supporting the hypothesis that Closed Area I is serving as a refuge for haddock which should be of major interest to fishermen, scientists and managers. The number of detections seen to date is more consistent with haddock being resident to the area than being transient. Furthermore, the distribution of haddock within the closed area, as revealed by the array, suggests that haddock are avoiding the edge (center of aggregation is well on the inside) and any spillover to the fishery may only represent a small portion of what is available on the inside.

In the larger sense, we at GMRI (particularly Sherwood and Grabowski), are very interested in why some groundfish respond to management measures (like closed areas) while others don’t so well (e.g. haddock vs. cod). In our other NEC funded project, “Exploring the potential inadvertent effects of Gulf of Maine and Georges Bank area closures on cod life-history variation”, we are exploring whether closed areas favor a more resident form of cod (specifically, but not necessarily, red cod). It is premature to say, but on the whole, a picture from these two studies may emerge that supports that hypothesis that closed areas are only effective at rebuilding sedentary groundfish species (e.g. haddock, as seems to be shown by this study) or sedentary types of species (e.g. red cod). We expect that these findings will have a major impact on how we (fishermen, scientists and managers) view, evaluate and design closed areas in the future.

8. PI SIGNATURE AND DATE:
Graham Sherwood  

6/25/08
GMRI Increasing Assistance with Groundfish Sector Management

Fishery management in New England is on the cusp of fundamental change. Many fishermen in the groundfish fishery are considering joining “sectors” which will allow groups of fishermen much greater flexibility in how they fish in return for entering into a binding agreement with one another and the government to limit their catch to a fixed share of the total allowable catch for the fishery. A primary benefit of sectors is exemption from limits on fishing days and daily catch limits on some species that often force fishermen to discard marketable fish.

With generous funding from the Gordon and Betty Moore Foundation, the Gulf of Maine Research Institute (GMRI) is expanding our Community program to provide fishermen with assistance in organizing, developing, and implementing sectors. GMRI has hired a Northern New England sector coordinator and is in the process of hiring a Southern New England sector coordinator who will be based in Gloucester.

Monitoring fishermen's catch by species and area will be a critical component to the success of sector management. To address this issue, GMRI has hired a team of consultants who will work closely with the industry, New England Fisheries Management Council, and the National Marine Fisheries Service to evaluate how monitoring and reporting systems may need to be adapted to support sector management.

GMRI's Community team is working with Dr. Dan Holland, GMRI's resource economist, to provide regional and national leadership in transitioning the fishing industry to sustainable fishing and sustainable fishing communities.

Education

One Laptop Per Child — Many recent publications have featured Nicholas Negroponte, founder of MIT’s Media Lab, and his effort to design, manufacture and market a $100 laptop computer to make modern learning tools available to children around the world. He’s off to a great start, recently offering a very competent laptop, called the XO, that sells for $188.

Through the generosity of friends, GMRI has been able to purchase two of these XOs to better understand whether they might be suitable for use with the Vital Signs program, which engages middle-school students in the search for invasive aquatic species. While every 7th and 8th-grade student in Maine is well-served by having his or her own laptop computer, such is not the case in the rest of the country or around the world.

GMRI’s partners in the Republic of Ireland, for instance, are also interested in exploring a laptop computer-based invasive species identification program. By testing a pair of XO laptops here, GMRI will be able to determine whether the XO is a suitable hardware choice for use in the European Union. The Education Group at GMRI straddles an interesting line between delivering marine education programs to broad audiences on a daily basis and exploring new solutions that may improve these programs.

Research

Evaluation of closed areas: Cashes Ledge as juvenile cod habitat — Dr. Jonathan Grabowski, GMRI’s benthic ecologist, is leading a collaborative team of scientists and fishermen to investigate if the Cashes Ledge Closed Area is helping to rebuild cod populations in the Gulf of Maine. Over the past two years, this team has collected acoustic data that will be used to develop bottom habitat maps and has conducted surveys of juvenile and adult cod on Cashes Ledge. By comparing these recent surveys to historic records of the abundant cod populations in this area during the 1980’s, Dr. Grabowski and his team will determine if the closure of Cashes Ledge has been an effective management tool.

Evaluating the efficacy of closed areas requires an understanding of how closing off areas to fishing activity influences key fish species. On Cashes Ledge, the GMRI team is finding that cod are most abundant in the summer when dogfish are scarce. In the spring and fall, more dogfish and fewer cod are caught, suggesting that dogfish could be influencing how cod use Cashes Ledge.

“Hopefully our results will help managers evaluate whether the Cashes Ledge Closed Area is an important habitat for cod and will facilitate shifting to an ecosystem approach to fisheries (management) in the Gulf of Maine,” said Grabowski. “The success of this project has hinged upon bringing together fishermen who know a lot about Cashes Ledge and a wide range of scientists from GMRI, the University of New Hampshire, the Gulf of Maine Mapping Initiative, the University of Maine, and the University of Ulster in Northern Ireland.”
Spyball camera will be purchased for Cohen Center – In preparation to launch Lobsters: Untold Tales, the next generation of education content for the Sam L. Cohen Center for Interactive Learning, GMRI will make major renovations to all of its LabVenture! stations to allow students to delve into the science mysteries of lobsters. As part of this renovation, the schooling tank will be getting an extreme makeover. To transform this exhibit from one that focuses on mid-water fish (like herring) to bottom dwelling species (like lobsters), artisans in Arizona will craft a custom fiberglass insert that will look exactly like a slice from the bottom of the lobster habitat in the Gulf of Maine—craggy granite rocks with mussels, barnacles, algae, and other encrusting life. This station will allow students to use scientific tools to make measurements on the size of the lobsters in the tank. GMRI will install Spyball, a state-of-the-art underwater camera, in the top of the tank, which students can control with a joystick. The camera is equipped with two laser points that project a pair of red dots into the tank that are always 10 centimeters apart. By taking snapshots of the lobsters in the tank with the camera, students will be able to estimate the size of the lobsters in the tank.

Research

Surfing haddock? – When Demersal Ecologist Dr. Graham Sherwood joined GMRI in 2005, he was excited to learn of a thriving local surfing community. Through his research, GMRI has learned that it’s not just humans who enjoy catching a few waves. Haddock, once one of our most valuable groundfish, and recently on the rebound, may also be making use of underwater currents to get around. This unlikely discovery came after a summer of monitoring haddock behavior in Closed Area 1, an area closed to fishing about 60 miles southeast of Cape Cod. Haddock were surgically implanted with transmitters, and their movements were monitored by an array of submerged detectors.

“We started noticing swimming speeds two to three times faster than expected. Our first thought was, these fish can really swim!” explains Sherwood.

But the supercharged haddock theory soon fell to a more likely explanation.

“It turns out that haddock are more like the sea turtles in Finding Nemo – if they want to move a few miles, they just pop into tidal current and go for the ride.” The challenge is to now find out what this all means for haddock biology and management. “Sound fisheries management is based on biological observations, and any insight into the underwater lives of fishes can only enhance our ability to manage effectively. On one level, this is a really cool discovery. On another, this may end up helping the fishery.”

Public Lecture Series

Sea State 3.0: Changing Currents, Changing Communities

Please join Dr. William-Christy Ingmanson for a public lecture on the changing current of our coastal areas:

March 13: Charting Fishing Communities at Sea: Laying the Foundations for Community-Based Marine Resource Management
Kevin St. Martin, Rutgers University

March 20: Sea Lice: Do They All Come From Fish Farms?
Ian Bricknell, University of Maine

April 10: River Herring in the Gulf of Maine: Challenges for Research and Management
Karen Wilson and Theo Willis, University of Southern Maine

May 1: Marine Bioinvasions in the Gulf of Maine: A Story of Maritime History, Marine Science and Environmental Policy
James Carlton, Williams College, Williams-Mystic Program

June 1: Stormy Subjects: Hot Topics from Cold Waters
George LaPointe, Maine Department of Marine Resources