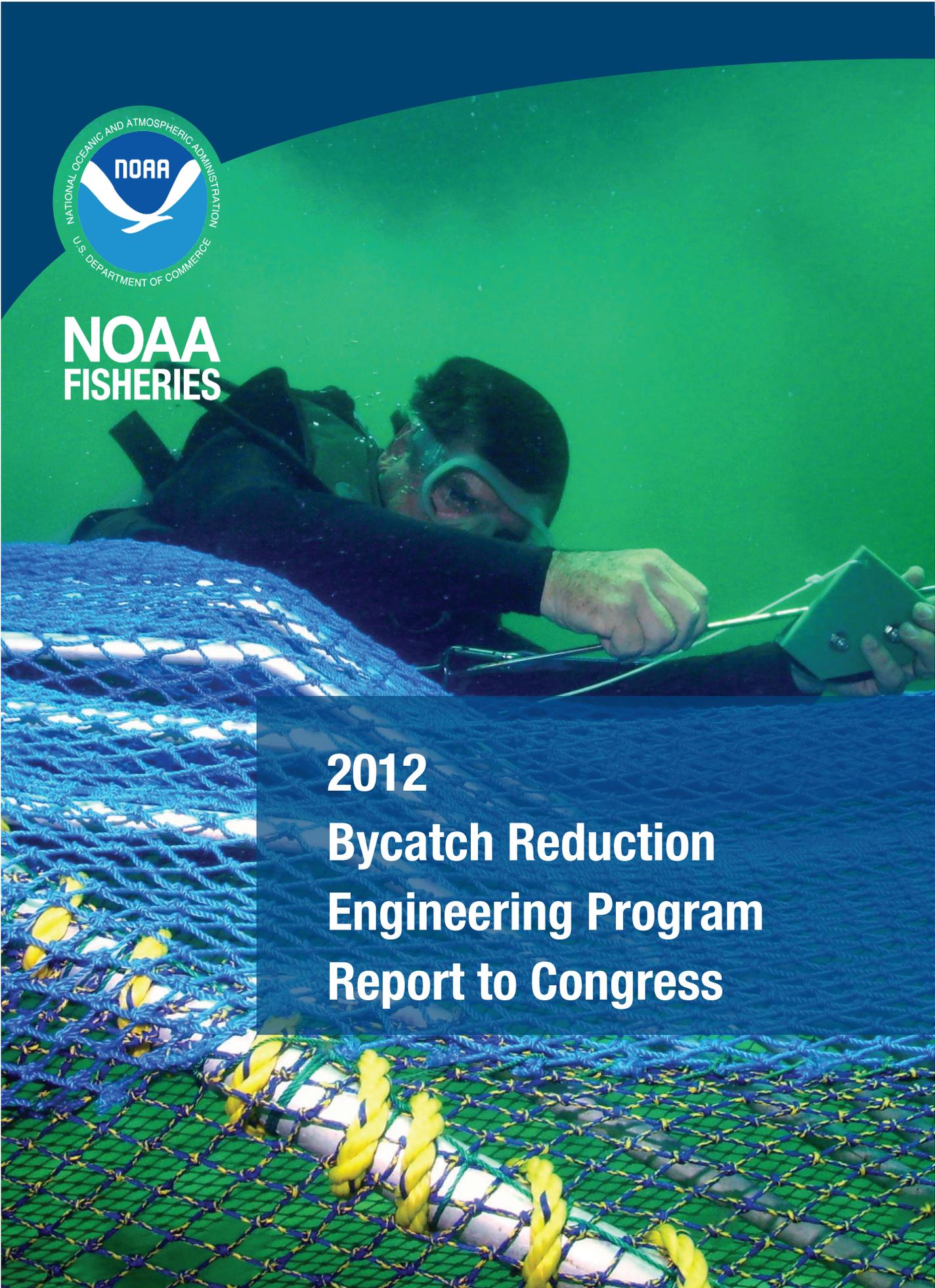




**NOAA
FISHERIES**

A diver in a black wetsuit and mask is working on a blue fishing net underwater. The net is made of blue and yellow mesh and has several white floats with yellow and blue markings. The diver is holding a green electronic device. The background is a clear blue-green water.

**2012
Bycatch Reduction
Engineering Program
Report to Congress**

Bycatch Reduction Engineering Program

2012 Annual Report to Congress

Issued Pursuant to Section 316(d) of the Magnuson-
Stevens Fishery
Conservation and Management Act
(as Reauthorized and Amended in 2006)

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
2013

2012 Bycatch Reduction Engineering Program Report to Congress

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Executive Summary

Reducing marine fisheries bycatch is an important part of the mission of NOAA's National Marine Fisheries Service (NMFS). Reducing bycatch can help rebuild overfished fish stocks and help recover populations of marine mammals, sea turtles, seabirds, and fish. Reducing bycatch also can increase the economic efficiency of fishing operations by reducing sorting time and damage to gear and bait. Addressing bycatch has biological and economic effects and is required under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), and the U.S. National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries. NMFS' Bycatch Reduction Engineering Program (BREP) is a critical component of NMFS' efforts to identify and foster the development of technological solutions to important bycatch problems in our nation's fisheries.

The MSA was amended in 2007 and required NMFS to establish the BREP and submit an annual report to Congress describing its achievements. The BREP was established in 2008, and this is the fifth annual report to Congress. FY 2012 appropriations language directed NMFS to establish a competitive grant program for non-federal researchers working with U.S. fishermen on the development of improved fishing practices and innovative gear technologies. In response to this direction, NOAA issued a request for grant proposals in 2012. NOAA's request for grant proposals resulted in 64 submissions requesting \$10,939,539. NOAA funded 14 proposals, totaling \$2,440,826.

In terms of bycatch problems addressed, BREP funding through the competitive grant program in 2012 fell into the following categories:

- Marine fish—\$1,545,426
- Marine mammals—\$615,085
- Sea turtles—\$150,272
- ESA-listed fish—\$130,043

On a region-by-region basis, the BREP is funding projects in the following areas:

- Northeast—\$973,591
- Southeast—\$545,518
- Northwest—\$342,930
- Southwest—\$150,272
- Alaska—\$153,953
- Pacific Islands—\$274,562

2012 BREP projects reduce bycatch focus on some of the most important U.S. fisheries:

- Georges Bank large mesh groundfish fishery
- Gulf of Maine recreational hook-and-line fisheries
- Atlantic herring/mackerel mid-water trawl fishery
- Atlantic pelagic longline fishery
- Southeastern shrimp fishery
- U.S. Pacific hake fishery
- Hawaii-based longline fisheries

BREP projects have produced several gear technologies now used by the fishing industry to reduce bycatch. For example, the BREP funded development of weak hooks (now required in the Gulf of Mexico tuna longline fishery), salmon excluders (used widely in Alaska pollock fisheries), and modified sweeps in Bering Sea trawl fisheries (required to reduce damage to the sea bottom and organisms growing there). In addition, NOAA's 2012 BREP investments in weak hooks, excluder devices for trawls, sophisticated underwater video technology systems, and acoustic recorders will help strengthen cooperation and collaboration between NMFS and the fishing industry.

The external 2012 BREP grant projects involved partners from state governments, universities, and the fishing industry. In addition, nine of the 14 BREP grant projects in 2012 included payments to charter commercial fishing vessels as collaborative research platforms.

The NMFS BREP website (http://www.nmfs.noaa.gov/by_catch/bycatch_BREP.htm) provides additional information about 2012 projects, including the National Seabird Program.

2012 REPORT ON THE BYCATCH REDUCTION ENGINEERING PROGRAM
RELEVANT TO SECTION 316(d) OF THE MAGNUSON-STEVENSON FISHERY
CONSERVATION AND MANAGEMENT ACT

Introduction

Section 316(a) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) states:

Not later than 1 year after the date of enactment of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, the Secretary, in cooperation with the Councils and other affected interests, and based upon the best scientific information available, shall establish a bycatch reduction program, including grants, to develop technological devices and other conservation engineering changes designed to minimize bycatch, seabird interactions, bycatch mortality, and post-release mortality in federally managed fisheries.

NOAA's National Marine Fisheries Service (NMFS) established its Bycatch Reduction Engineering Program (BREP) through a NMFS Policy Directive signed January 11, 2008. This Policy Directive (<http://www.nmfs.noaa.gov/op/pds/documents/01/01-107.pdf>) contains terms of reference for the BREP, as well as the following BREP mission:

The mission of the BREP is to develop technological solutions and investigate changes in fishing practices designed to minimize bycatch of fish (including sponges and deep sea and shallow, tropical corals) and protected species (including marine mammals, seabirds, and sea turtles) as well as minimize bycatch injury and mortality (including post-release injury and mortality).

Section 316(d) of the MSA requires the Secretary of Commerce to transmit an annual report to the Senate Committee on Commerce, Science, and Transportation and the House of Representatives Committee on Resources that:

1. Describes funding provided to implement this section (see pp. 6–7).
2. Describes developments in gear technology achieved under this section (see pp. 8–42).
3. Describes improvements and reduction in bycatch associated with implementing this section (see pp. 8–42), as well as proposals to address remaining bycatch or seabird interaction problems (see pp. 43–54).

This report responds to the requirements of Section 316(d) of the MSA. This report also provides updates concerning BREP projects funded in 2011 for which results were not available in time for the 2011 Report to Congress (pages 43–54). The NMFS BREP website (http://www.nmfs.noaa.gov/by_catch/bycatch_BREP.htm) includes additional information about NMFS efforts to address remaining bycatch or seabird interaction problems.

Summary of Funding Provided to Implement the BREP in 2012

In FY 2012, funding to implement the BREP external grants totaled \$2,440,826. This funding came from a NOAA budget line item entitled Reducing Bycatch. FY 2012 appropriations language directed NMFS to establish a competitive grant program for non-federal researchers working with U.S. fishermen on the development of improved fishing practices and innovative gear technologies. In response to this direction, NOAA issued a request for grant proposals in 2012. NOAA’s request for grant proposals resulted in 64 submissions requesting \$10,939,539. NOAA funded 14 proposals, totaling \$2,440,826.

Table 1 lists the projects funded to implement the external BREP grants in 2012. The individual projects are described on pages 8–42. The external grant projects involved partners from other federal agencies, state governments, nongovernmental organizations, universities, and the fishing industry. In addition, nine of the 14 external grant projects included payments to charter commercial fishing vessels as collaborative research platforms.

Table 1. Projects funded to implement the BREP in 2012

<i>Project Title</i>	<i>Funding Provided</i>	<i>Recipient</i>	<i>Subject Matter</i>
EXTERNAL GRANT PROJECTS			
Elucidating Post-Release Mortality and “Best Capture and Handling” Methods in Sublegal Atlantic Cod Discarded in Gulf of Maine Recreational Hook-and-Line Fisheries	\$248,659	New England Aquarium Corporation	Fish
Enhancing the Visibility of Fishing Ropes to Reduce Right Whale Entanglements	\$231,079	New England Aquarium Corporation	Marine Mammals
Testing of a Modified Groundgear to Reduce Yellowtail Flounder and Juvenile Cod in the Large Mesh Groundfish Fishery on Georges Bank	\$184,674	University of Massachusetts, Dartmouth	Fish
Maine Fishing Industry Monitoring Program	\$181,530	Gulf of Maine Lobster Foundation	Marine Mammals
Testing In-Trawl Image Collection and Analysis to Quantify and Record Bycatch in the Atlantic Herring/Mackerel Mid-Water Trawl Fishery	\$127,649	Gulf of Maine Research Institute	Fish
Performance of a Long-Lasting Shark Repellent Bait for Bycatch Reduction during Commercial Pelagic Longline Fishing	\$234,311	Florida Keys Community College	Fish
Geospatial Preference Modeling and Real-Time Catch Reporting in Support of an Atlantic Bluefin Tuna Avoidance System	\$227,636	GeoEye Imagery Collection Systems, Inc.	Fish
Enhancing Proof of Concept Procedures of Potential Bycatch Reduction Devices in the Southeastern Shrimp Fishery	\$83,571	Texas A&M University	Fish

Testing Modified Deep-Set Buoy Gear to Minimize Bycatch and Increase Swordfish Selectivity	\$150,272	Pfleger Institute of Environmental Research	Sea Turtles
Reducing the Bycatch of Overfished and Rebuilding Rockfish Species in the U.S. Pacific Hake Fishery	\$144,598	Pacific States Marine Fisheries Commission	Fish
Use of Artificial Light to Enhance the Escapement of Chinook Salmon when Used in Conjunction with a Bycatch Reduction Device in a Pacific Hake Midwater Trawl Net	\$130,043	Pacific States Marine Fisheries Commission	Endangered Species Act (ESA) Fish
Field Validation of the RAMP Approach for Determining Crab Bycatch Mortality	\$68,289	Oregon State University	Fish
Using Combined Video/Acoustic Recordings of Marine Mammal/Fishing Gear Interactions to Evaluate Utility of Passive Acoustic Monitoring	\$202,476	University of California, San Diego	Marine Mammals
Estimating Post-Release Mortality in Istiophorid Billfish	\$226,039	Queen's University, Ontario, Canada	Fish
TOTAL	\$2,440,826		

Northeast Grant Project Summaries

Project Title

Elucidating Post-Release Mortality and “Best Capture and Handling” Methods in Sublegal Atlantic Cod Discarded in Gulf of Maine Recreational Hook-and-Line Fisheries

BREP Funding Provided

\$248,659

Recipient

New England Aquarium Corporation

Resource Challenge

Held as the most economically and culturally important fish species in New England waters, Atlantic cod (*Gadus morhua*) has experienced heightened fishing-induced mortality and associated western North Atlantic stock declines in recent years. During the past 5 years, recreational fishing (see Figure 1) has been responsible for approximately 35 percent of cod removed by weight in the Gulf of Maine (GOM), where discards (by number) are presently twice that of landings. The survivorship of these recreational discards has major implications for the status as well as the management of the GOM cod stock. However, no study to date has estimated cod post-release mortality after capture by recreational angling. Moreover, assuming that at least some cod post-release mortality occurs, no study has sought to determine “best angling and handling practices” that minimize injury/stress and reduce mortality in this species.

Project Summary

This project is designed to estimate (30-day) post-release mortality using ultrasonic telemetry and to determine and disseminate best angling and handling practices that minimize injury/stress and enhance survival in sublegal (and barely legal) cod discarded in GOM recreational hook-and-line fisheries.

The work will first evaluate the condition of approximately 400 cod (both sublegal and, for comparison, sizes slightly above that threshold that were formerly sublegal) immediately following capture by recreational angling during the summer of 2013. Prior to release, acoustic transmitters equipped with depth sensors will be affixed to a subsample of 150 individuals (see Figure 2) to detect any delayed fatalities for approximately 30 days post-release. Through pilot work, this project’s researchers have field-tested the application of this technology to estimate mortality in cod and have found a clear disparity in acoustically transmitted depth profiles between live and dead specimens monitored over a ~2-week period (see Figure 3).

These initial findings, coupled with the generally small-scale movements of juvenile cod, indicate that, with careful placement of an array of acoustic receivers, this technology can reliably estimate post-release mortality for this species and size class. This study will introduce additional acoustic receivers to bolster a vast set of arrays manned by study collaborators at the Massachusetts Division of Marine Fisheries, enhancing spatial coverage in Massachusetts Bay/Gulf of Maine for detecting tagged specimens.

By retrospectively evaluating the physical, biological, and other variables from the capture and handling process, this project's researchers hope to establish a set of guidelines to reduce post-release mortality. This project's best angling and handling practices will be disseminated to management sources and the recreational angling community through outreach to angling groups, journal articles, and internet and social/traditional media dissemination. The research team assembled for this work represents a diverse array of skill sets and stakeholders, which should help strengthen the study's design, maximize its applicability, and ensure broad dissemination of the resulting data.

Developments in Gear Technology Achieved

This project is presently in its experimental planning stages and will begin in 2013. Therefore, this project has not yet achieved any developments in gear technology.

Improvements and Reduction in Bycatch Associated with This Project

Because fieldwork and data collection have not yet started, this project has not yet achieved improvements or reductions in bycatch.



Figure 1. Recreational hook-and-line fishing for Atlantic cod.



Figure 2. Ultrasonic transmitters will be attached externally to help estimate the post-release mortality of angled and released Atlantic cod.

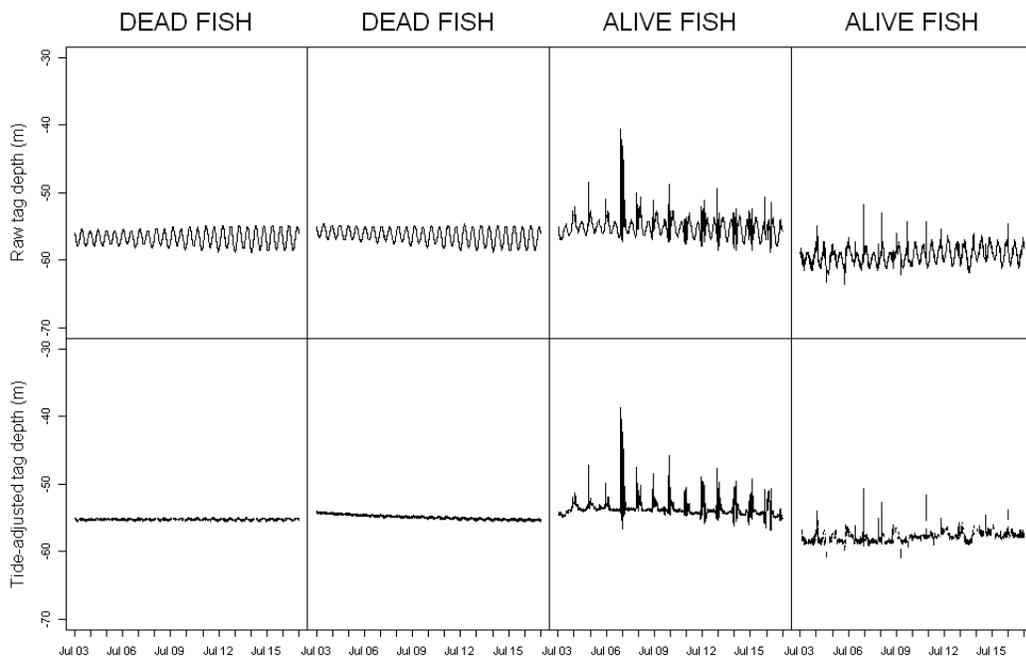


Figure 3. Depth profiles of ($n = 2$) dead versus ($n = 2$) live cod as conveyed via depth sensor data from acoustic transmitters to be used in the study. Differences in magnitude of oscillations clearly distinguish activity levels between the two groups over a span of about 2 weeks.

Project Title

Enhancing the Visibility of Fishing Ropes to Reduce Right Whale Entanglements

BREP Funding Provided

\$231,079

Recipient

New England Aquarium Corporation

Resource Challenge

The North Atlantic right whale (*Eubalaena glacialis*) is the most endangered large whale in the north Atlantic, with less than 500 alive today. Population growth is impaired by high levels of human-caused mortalities. At least half of all deaths in this population are caused by human activities, primarily ship collisions and entanglements in fisheries gear. Changes in the speed regulations for ships should reduce mortality from that source, but entanglement rates remain high and claim one to three right whales annually along the east coast of North America. More than 82 percent of the animals in the Right Whale Catalog have scars caused by ropes or nets. Fixed fishing gear is distributed very broadly along the coast of North America and, although all types of fixed fishing gear have been recovered from entangled right whales, rope entanglements appear to be the most dangerous. Failure to solve the right whale gear entanglement problem jeopardizes the viability of several fixed gear fisheries, especially the lobster fishery.

Project Summary

This project is designed to determine whether changing the color of fishing ropes will enhance their detectability underwater by whales, therefore allowing the animals to avoid entanglements. This study includes three integrated components:

1. Laboratory work will be conducted to directly determine right whale sensitivity to light and color through DNA analysis. This sensitivity will determine the colors used in the field trial rope mimics in order to maximize the detection distance underwater by the whales.
2. Field trials will take place in Cape Cod Bay in spring 2013. Rope mimics will be placed in front of right whales that are skim-feeding at the surface, so that changes in behavior can be easily detected and documented. Rope mimics will be made from rigid PVC pipe, which will be colored or illuminated based on right whale spectral sensitivity, and mechanically scored so they will shatter on contact. Researchers will deploy rope mimics by weighting one end and attaching a float at the other end, so the whale is presented with the equivalent of a vertical buoy line as it swims near the surface. These “ropes” will be placed along the trajectory of whales feeding in straight lines, and changes in behavior will be recorded, including respiration rates, submergence times, and turning angles.
3. To determine the operational applicability of these findings, we propose to test similarly colored ropes in the Maine lobster fishery with regard to fouling characteristics, handling, and safety concerns. Fishermen will be provided with ropes of colors that appear to be effective on right whales, and compensated to report back to us on their experience with the experimental rope.

Developments in Gear Technology Achieved

Preliminary data collected with support from the Wildlife Bycatch Consortium showed shorter distances for behavioral responses by right whales confronted with black and green ropes ($n = 8$, mean distance = 2.625 m) versus red and orange ropes, suggesting they were detecting the orange and red ropes from farther away. Although promising, this newly funded study is designed to develop both a biological understanding of right whale color vision and to field test color rope equivalents in the wild, in order to make these findings statistically robust. Field studies will take place in spring 2013 in Cape Cod Bay.

Improvements and Reduction in Bycatch Associated with This Project

If this work confirms the preliminary findings, and it is possible to adjust the color and/or visibility of commercially fished ropes to aid underwater detection, it may be possible to reduce the entanglement rates and mortalities of right whales in the U.S. waters of the western North Atlantic. If visual deterrence is effective, this will be a breakthrough in the 15-year search for ways to reduce the entanglements of large whales in fishing gear.

Project Title

Testing of a Modified Groundgear to Reduce Yellowtail Flounder and Juvenile Cod in the Large Mesh Groundfish Fishery on Georges Bank

BREP Funding Provided

\$184,674

Recipient

University of Massachusetts, Dartmouth

Resource Challenge

The multispecies groundfish fishery in the New England region transitioned to a catch share management system in 2010 with annual catch limits (ACLs) and catch allocations for regulated commercial groundfish. Managers determine annual catch limits for regulated species by stock unit, and these ACLs include the total catch of landed and discarded fish. For several regulated groundfish stocks, recent stock assessment results have led to management decisions resulting in low annual catch limits. The assessment of the Georges Bank (GB) stock of yellowtail flounder resulted in an annual catch limit of 218 metric tons for 2012, a reduction of 80 percent compared to the previous fishing year. The GB stock of Atlantic cod is also overfished, and overfishing is occurring. Catch limits for both stocks are expected to be substantially lower for 2013 and possibly beyond. The mixed species nature of the groundfish trawl fishery has directly impacted the ability of fishermen to effectively target certain stocks to fully harvest catch allocations while allowing stocks with low biomass to rebuild. Fishermen in the region have great interest in developing innovative gear solutions to address these issues.

Project Summary

The goal of this project is to test an experimental groundgear to reduce the catch of GB yellowtail flounder and juvenile GB Atlantic cod in the large mesh otter trawl fishery. The experimental groundgear is based on a commercial groundgear known as a Rubber Riser groundgear used by fishermen in the Northeast region. The experimental groundgear is modified from the commercial version to create “escape windows” between the rubber risers that allow yellowtail flounder and juvenile cod to escape early in the capture process (see Figure 4). The experimental groundgear takes advantage of the escape behavior of flatfish species, as well as length-dependent escape behavior of Atlantic cod that occurs at the groundgear.

This project builds upon previous projects funded by the Commercial Fisheries Research Foundation that were completed in 2011 and 2012. Results from the 2012 project showed a reduction in the catch of winter flounder, yellowtail flounder, and sub-legal cod, without a reduction of legal-size cod when compared with the control net. This project will build on the promising preliminary results to demonstrate its application in the GB trawl fishery, where fishermen target legal-size haddock and cod. The project will demonstrate whether this gear modification can reduce bycatch and optimize catch allocations.

Sea trials are expected to take place between February and August 2013 over the course of 14 days onboard the F/V *Hera* out of the port of New Bedford, Massachusetts. In preparation for sea trials, a Letter of Authorization has been obtained from the NMFS Northeast Regional

Office. This letter allows the fishing v
 project scientists have consulted with t
 fishing locations. The project scientist
 (Fairhaven, Massachusetts) regarding c



Figure 4. Photo of the experimental groundgear

Developments in Gear Technology Achieved

This project has just started, with sea trials in 2013. No specific gear technology developments have been achieved at this time.

Improvements and Reduction in Bycatch Associated with This Project

Because sea trials are not expected to take place until between February and August of 2013, no data regarding bycatch reduction are available at this time.

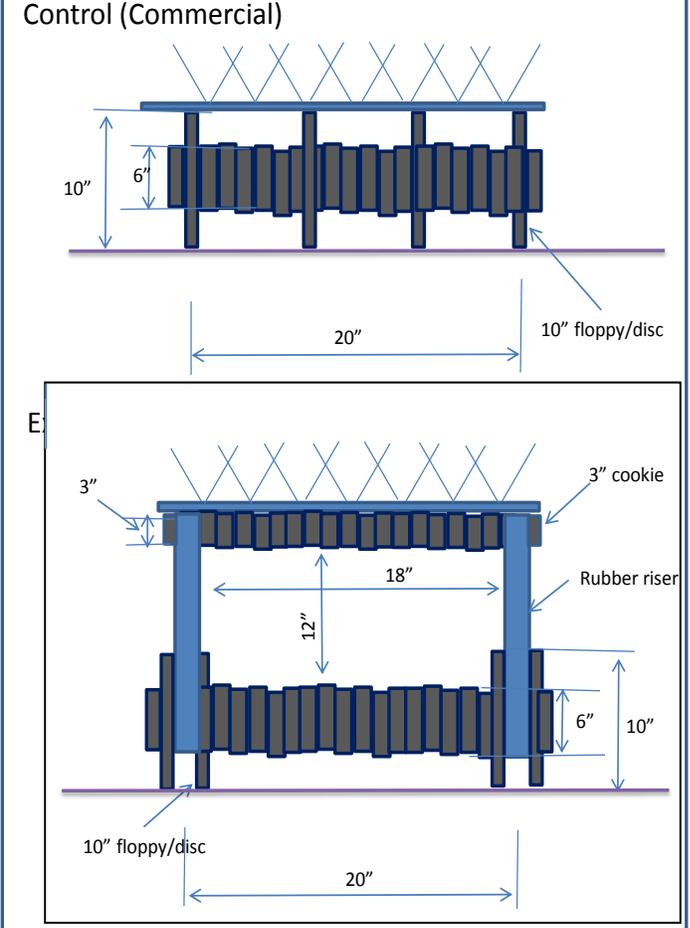


Figure 1. Schematic drawing of the regular groundgear (Control) and the modified Rubber Rise Sweep (Experimental).

Project Title

Maine Fishing Industry Monitoring Program

BREP Funding Provided

\$181,530

Recipient

Gulf of Maine Lobster Foundation

Resource Challenge

Right, humpback, and fin whales are currently the focus of mitigation measures to reduce the risk of their entanglement in fixed-gear fisheries. The baseline data used to drive these measures, in large part, aims to understand the fisheries involved and how they change both seasonally and in response to regulations. Fisheries characteristics can influence the effectiveness of regulatory measures put in place for the protection of these endangered whale species. It is important to work to increase detection and reporting of entanglement events and reduce the impacts of these events by decreasing the number of interactions that large whales have with fishing gear. Several data gaps hinder progress toward meaningful conversations about viable vertical line risk reduction measures. It also is important to expand the baseline knowledge about the density and seasonal movements of gear to determine the best management measures, monitor the fishery after regulations are put in place, and provide a mechanism to ground-truth the current baseline based on fishery-dependent datasets.

Project Summary

The Gulf of Maine Lobster Foundation will build on previous fishing gear density surveys by expanding the sampled region from state waters into federal waters from 3 to 12 miles offshore. This area is more likely to be the target of increased vertical line risk reduction measures through the Atlantic Large Whale Take Reduction Plan. This sampling will include securing vessels, finalizing survey transect lines, training field data collectors, and implementing the field portion of the project. Field protocols, data storage, and analysis systems will remain the same as previously conducted surveys. Collaborators at the Maine Department of Marine Resources will assist with geographic information system mapping of effort and gear locations, as well as spatially interpolating the density of gear by month. The resulting data layers of gear fields by month can be compared to current baseline data gathered by fishery-dependent voluntary surveys. Surveys will begin in April 2013 and continue through September 2013 in each of the seven Lobster Management Zones. A report at the end of the grant period will be provided to state and federal regulators and to the Atlantic Large Whale Take Reduction Team.

Developments in Gear Technology Achieved

At this time, no developments in gear technology have been achieved.

Improvements and Reduction in Bycatch Associated with This Project

At this time, the investigators have not yet started the field work, which will engage fishermen and scientists in assessing the possible risks of entanglement to large whales.

Project Title

Testing In-Trawl Image Collection and Analysis to Quantify and Record Bycatch in the Atlantic Herring/Mackerel Mid-Water Trawl Fishery

BREP Funding Provided

\$127,649

Recipient

Gulf of Maine Research Institute

Resource Challenge

The Atlantic herring/mackerel mid-water trawl fishery has low overall bycatch rates (1% from at-sea observer data), but these events tend to be sporadic. In addition, when a single haul can contain more than 100 tons of fish, the absolute amounts of bycatch may be quite large. Large catches also make it challenging to accurately quantify the amount of bycatch as the catch is pumped onboard. In addition, a portion of the catch is sometimes released from the net directly into the sea without being brought onboard if it is in excess of the vessel's capacity or if it is the wrong species. Further, mechanical or safety problems may arise with the pumping system, causing catch to be released before it is brought onboard. This "slipped catch" can, at best, be estimated based on visual observation from the deck, but it cannot be robustly quantified.

Project Summary

This project will test use of a camera system mounted inside a fishing trawl to continuously quantify the species composition as fish are being caught, rather than all at once as the catch is pumped onboard. Images (see Figure 5) will be stored for detailed analysis and streamed to the vessel's bridge in real time. This allows the captain to know precisely what species and sizes are being captured. Specifically, this project aims to evaluate the camera system's ability to:

1. Record all fish captured, even individuals that are released without being brought onboard.
2. Accurately quantify bycatch by species and numbers.
3. Provide a warning to the captain in real time if non-target species or sizes of fish are entering the trawl.
4. Document the temporal/spatial overlap between bycatch species and the targeted herring/mackerel.
5. Archive complete catch history at a haul level for fisheries monitoring purposes.



Figure 5. A 12-inch Atlantic herring imaged inside a trawl (not from this BREP project, but collected using identical camera equipment).

Developments in Gear Technology Achieved

Due to the schedule of the Atlantic herring fishery and historical timing of when bycatch events are most likely to occur—as well as needed hardware modifications and testing necessary to get the camera system configured for use inside a commercial fishing trawl and for live transfer of images from the trawl to the vessel—the field portion of this project will not begin until late summer 2013. Therefore, at this time, developments in gear technology have not yet been achieved.

Improvements and Reduction in Bycatch Associated with This Project

Fieldwork will begin in late summer 2013, with improvements and reduction in bycatch expected to follow successful completion of the project.

Southeast Grant Project Summaries

Project Title

Performance of a Long-Lasting Shark Repellent Bait for Bycatch Reduction during Commercial Pelagic Longline Fishing

BREP Funding Provided

\$234,311

Recipient

Florida Keys Community College

Resource Challenge

Shark catch is a major problem in any fishery that uses baited hooks and is not targeting sharks. A fishing hook is not selective enough to exclude sharks in favor of a target species such as tuna or swordfish. Commercial pelagic longline (PLL) fishing is a substantial contributor to shark bycatch mortality, and shark bycatch often results in serious safety concerns and adverse economic effects for commercial fishermen, including the following:

- *Reduced catch of marketable species.* Hooks occupied by shark bycatch are unavailable to catch target fish species, which results in substantial economic loss to fishermen.
- *Reduced fishing efficiency.* The capture of bycatch reduces fishing efficiency by requiring fishermen to deploy more hooks and fish more hours.
- *Risk of injury.* It is dangerous for the crew to handle captured sharks, and there is a serious risk of injury when branch lines snap from shark bite-offs.
- *Increased effort and expenditure of time.* A majority of fishermen consider the time required to remove sharks from gear, retrieve terminal tackle, and repair and replace gear as a central concern resulting from shark interactions.
- *Damage and loss of gear.* Typical PLL hooks are expensive (55–62¢ per hook), and substantial economic losses occur when sharks bite off terminal tackle (e.g., baited hook, leader, weighted swivel, and line); stretch and chafe branch lines; break the main line; and/or become entangled in the gear. PLL fishermen will often cut off hooks rather than try to extract hooks from live sharks.

Based on these issues, it is important to develop a shark repellent bait that will be accepted by commercial fishermen, especially in the Southeast U.S. commercial longline fishery, where species of concern—including the dusky (*Carcharhinus obscurus*), silky (*Carcharhinus falciformis*), and scalloped hammerhead shark (*Sphyrna lewini*)—are highly susceptible to bycatch. Effective shark repellent bait will need to selectively repel sharks without decreasing target catch.

Project Summary

Previous NOAA-funded research demonstrated substantial reductions in shark bycatch during commercial PLL fishing in the Straits of Florida using a bait infused with a time-released chemical shark repellent (SuperPolyShark™ (SPS), SharkDefense Technologies, LLC), which is derived from the rotting carcasses of dead sharks (Figure 6).

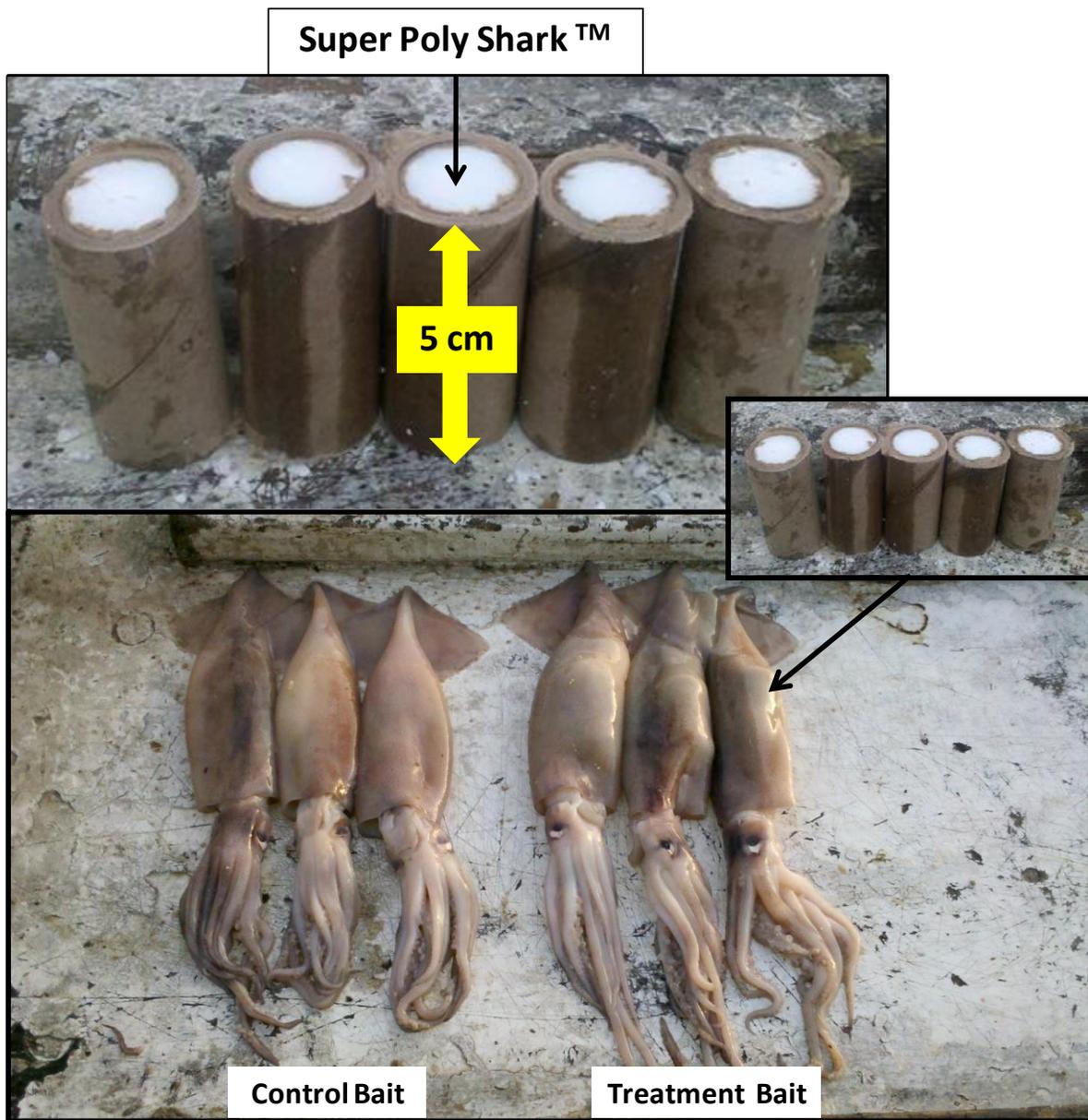


Figure 6. (Top) SuperPolyShark™ repellent combined with a water-soluble time-release gel capable of being inserted into fishing bait (bottom), creating a long-lasting shark repellent bait.

This previous research demonstrated that SPS repellent-treated bait deterred elasmobranchs from commercial PLL fishing gear by as much as 37 percent after up to 18 hours soak time, while having little effect on target species catch (Figure 7).

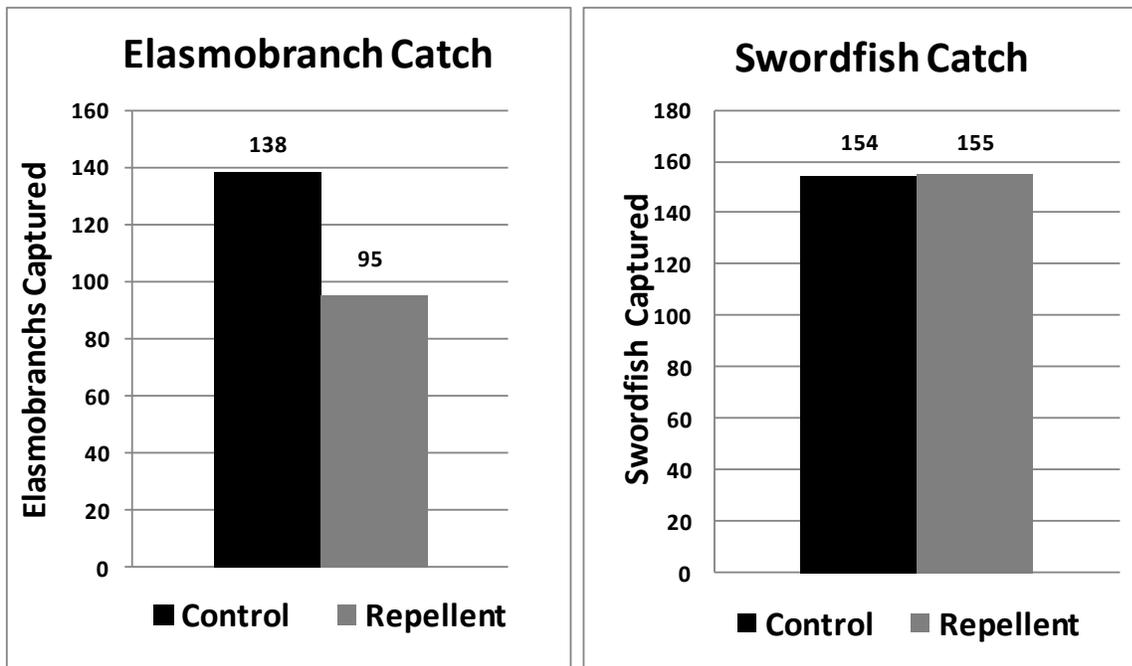


Figure 7. Elasmobranch (Subclass: Elasmobranchii) and swordfish (*Xiphias gladius*) captured by non-treated (control) and SuperPolyShark™ treated (repellent) hooks during experimental commercial pelagic longline fishing in the Straits of Florida.

However, preliminary hook-strike timer data analysis suggests that many of the elasmobranchs captured on SPS-treated hooks occurred after gear had soaked for more than 8 hours. This indicates that the efficacy of the SPS-treated bait decreases after approximately 8 hours of gear soak time. Pelagic longline gear deployment times vary considerably, and gear may regularly soak as long as 18 hours. Therefore, increasing the bait protection capabilities by SPS is important.

This project will result in (1) further research and development to increase the time-release capabilities and effectiveness of the SPS bait, and (2) quantification of the bait’s effectiveness during commercial fishing operations. This study also will measure the effect, if any, of environmental variables (e.g., water temperature, salinity, pH, turbidity) on chemical deterrent effectiveness. This study is a collaborative effort between Florida Keys Community College (FKCC), researchers at Seton Hall University, and PLL commercial fishermen of the Southeast Atlantic waters.

Specifically, this project should:

1. Increase the time-release capabilities for the SPS repellent for longer bait protection. Repellent performance will be measured using hook-strike timers.
2. Reduce logistical complications associated with SPS commercial fishery applications by developing simple, pre-prepared shark repellent bait. Performance of this objective will be based on feedback from commercial fishermen.
3. Recruit FKCC Marine Science and Technology students for internships and research assistantships. Project investigators will evaluate intern performance through technical reporting.
4. Conduct 20 at-sea experimental PLL trails.

5. Determine the efficacy of improved SPS as a commercial shark bycatch technology. Project investigators will analyze and report performance through annual reporting requirements as well as manuscript submission, symposia presentations, and web-based reporting.

Developments in Gear Technology Achieved

This project has not yet achieved any developments in gear technology.

Improvements and Reduction in Bycatch Associated with This Project

This project has not yet achieved any reductions in bycatch.

Project Title

Geospatial Preference Modeling and Real-Time Catch Reporting in Support of an Atlantic Bluefin Tuna Avoidance System

BREP Funding Provided

\$227,636

Recipient

GeoEye Imagery Collection Systems, Inc.

Resource Challenge

Atlantic bluefin tuna (ABFT) is regarded by many as one of the most highly stressed fish populations in the ocean. Stringent management measures have been put in place at the international level to ensure the survival of this species, but incidental bycatch of ABFT in non-ABFT-targeting fisheries still occurs. In the United States, this most frequently occurs in the Pelagic Longline Fisheries of the North Atlantic and Gulf of Mexico, which target swordfish.

Fisheries managers face difficult decisions on how to reduce bycatch of ABFT while minimizing, to the extent practicable, adverse social and economic impacts of management measures. Options presently under consideration by managers include revised ABFT quota allocations, modification of ABFT quota rules, individual fishing quotas (catch shares), modification of existing time/area closures, and implementation of new closures. Managers also are considering enhanced ABFT reporting methods and a process for communicating real-time hotspot maps of ABFT activity to the fishing industry.

Project Summary

The combination of enhanced reporting methods and delivery of real-time hotspot maps to fishing vessels is known among the fisheries management community as an “Atlantic Bluefin Tuna Avoidance System.” The overall objective of this project is to provide a proof of concept for this technology. Doing so will require persistent analysis over a number of years, so this effort is broken up into phases.

In phase 1, a team of scientists comprised of individuals from GeoEye Inc. and the University of Massachusetts Large Pelagics Research Center will attempt to construct a Geospatial Preference Model that predicts the movements of ABFT. The first stage of this project will involve analysis of historical catch and environmental data. The initial area of interest under consideration is known as the Florida East Coast (FEC) region. By building an environmental model using oceanographic and other factor datasets and then training the model with fish catch, or event data, project investigators expect that a pattern or “geospatial signature” of ABFT preferences and movements will emerge.

During this initial phase of addressing the historical data, real-time catch data also will be collected on vessels fishing within the FEC. These catch data will record catches of all species, so that a distinction can be made between preferences of ABFT and those of the target swordfish. By the end of this phase, the investigators hope to achieve semi-automation of the fish catch

analysis process in the environmental model and deliver hotspot maps to a vessel fishing in the FEC. From there, the process will continue to run while results are examined.

Initial geospatial analysis work has been started. A preliminary geospatial analysis project has been set up that defines the analysis area of interest, oceanographic factors to apply, the model training event set, and choices of models to perform analysis.

The area of interest is larger than the area surrounding the FEC. This large area of interest is necessary to incorporate sufficient influences of the oceanographic factors (see Figure 8).

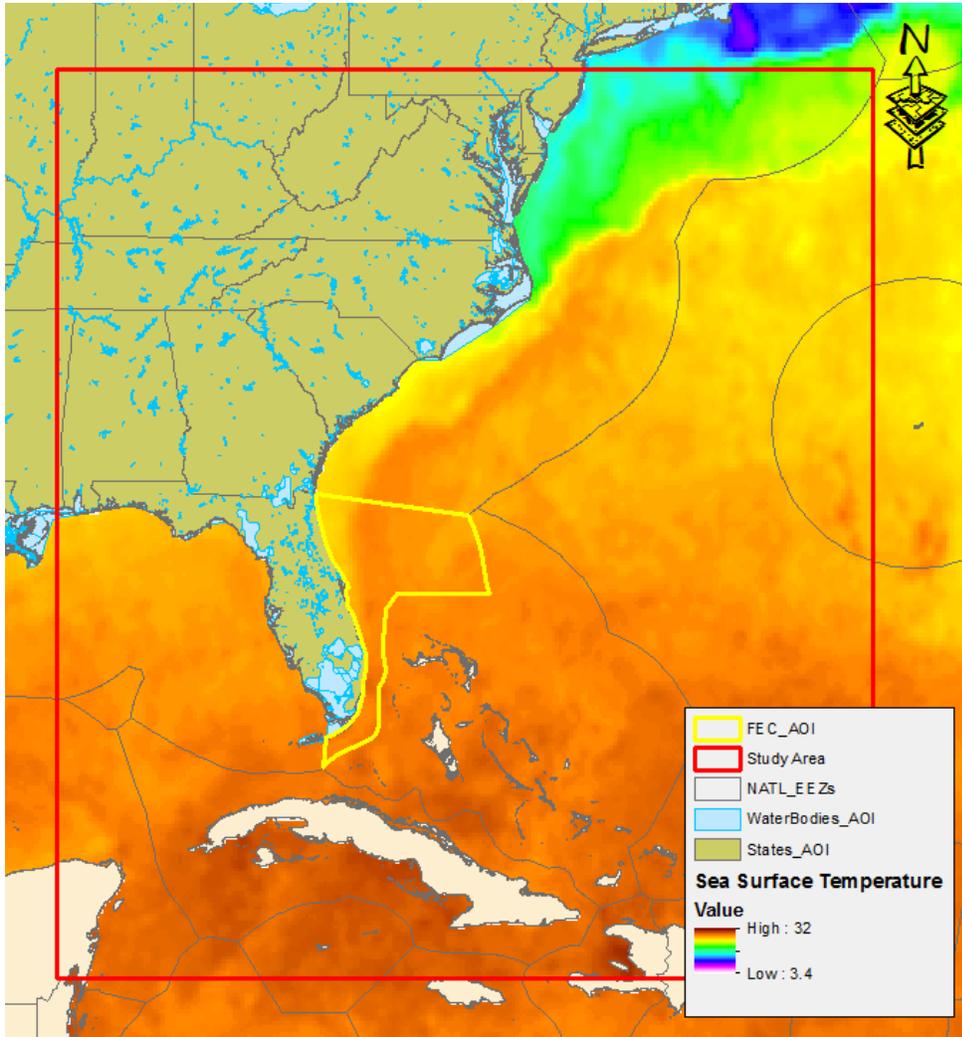


Figure 8. Study area that includes the Florida East Coast (FEC) fishing region.

Project investigators have identified an initial set of oceanographic factors, including several experimental factors, to be applied in the model (Table 2). The factor data have spatial and temporal characteristics that will allow investigators to update the spatial model characteristics over time, adapting to changes in the species behavior.

Table 2: Candidate oceanographic factors.

Base	Experimental
Surface current speed and direction	Upwelling areas
Chlorophyll concentration	Other species critical habitat
Sea surface height anomaly	Commercial shipping lane density
Maximum temperature gradient	Sea floor geometry
Temperature front location	Magnetic anomaly
Sea surface temperature	Wind direction/cloud data
Thermocline depth	Subsurface temperature
River locations	Salinity front location
Bathymetry	

Project investigators have not yet defined the model training event set, but the set will be made from historical catch data. The training set database will increase as new catch data are received.

Project investigators have identified three model candidates: (1) feature space preference (FSP), logistic regression, and Naïve Bayes. Given a small set of event spatial locations, the FSP model is probably the best option. Project investigators may also apply a combination of models (also known as an ensemble model), which effectively find the spatial locations where the models agree the most.

Project investigators have begun initial discussions to address the following three modeling aspects:

1. *Normalization of catch data.* Project investigators are preparing to define the standard effort and the catch per unit effort to address variations in how the catch data represent the relative abundance of the species.
2. *Dynamic behavior of the species' habitats.* Project investigators will derive different geospatial signatures that cover the dynamic behavior of the species' habitats. This will include classifying the oceanographic data and event data into time windows and applying potentially different models to each window's spatial data. The resulting model will be a set of geospatial signatures representing the different habitat behaviors spread over time.
3. *Discrepancy or contrast catch model.* The two fish species, ABFT and swordfish, will be modeled individually and contrasted. Project investigators are discussing how to incorporate the discrepancy between the two individual models.

Developments in Gear Technology Achieved

This project is not designed to develop fishing gear technology.

Improvements and Reduction in Bycatch Associated with This Project

Scientists have used environmental avoidance to decrease the bycatch of sea turtles in the Hawaii-based swordfish fishery based only on sea surface temperature and surface currents. NMFS implemented this methodology as part of its TurtleWatch program (www.pifsc.noaa.gov/eod/turtlewatch.php). Atlantic bluefin tuna habitat and oceanography in the Atlantic is much more heterogeneous than the habitat off Hawaii, creating a need for a multi-factor geospatial analysis and modeling to better understand relationships. Derivation of a

suitable signature of ABFT movements could have potential for dramatic reductions in incidental bycatch.

The success of avoidance systems in other fisheries suggests that this project's anticipated results can be an effective countermeasure against bycatch, provided the individual stakeholders willingly participate. Such participation is likely because successful implementation of this system will be mutually beneficial to fishermen and resource managers.

Project Title

Enhancing Proof of Concept Procedures of Potential Bycatch Reduction Devices in the Southeastern Shrimp Fishery

BREP Funding Provided

\$83,571

Recipient

Texas A&M University

Resource Challenge

Finfish bycatch is a significant challenge for the Southeastern shrimp fishery. Vessels fishing in federal waters are required to use bycatch reduction devices (BRDs), which are federally certified to reduce overall finfish catch by at least 30 percent. Although several devices are available to the industry, fishermen often lose shrimp or experience related problems when using this type of gear. Further, the most popular certified BRDs barely achieve the mandate for minimum finfish exclusion. It is imperative that more effective and efficient BRDs for shrimp trawls are developed by fishermen and scientists.

Project Summary

The goal of this project is to improve BRD technology in the shrimp fishery. The project is designed to acquire ideas and concepts for BRDs from fishermen, NMFS researchers, and international sources. Project investigators will tow suitable gears on fishing grounds in an attempt to establish “proof of concept.” Gear experts will participate in an extensive offshore trip aboard a commercial trawler to evaluate a number of different finfish excluder devices. Project investigators will compare trawls equipped with experimental BRDs to simultaneously towed nets without finfish excluder devices. Project investigators will document a number of parameters regarding effectiveness of finfish exclusion devices, including success of overall finfish reduction, specific species reduction, and shrimp retention. Project investigators will recommend gears that show promise for more in-depth certification trials, which require extensive time offshore and financial commitment. This project will make selection of potentially effective BRDs a more efficient and effective process and will enhance certification of new excluder devices.

Although still early in the project timeline, through collaborations with several progressive captains and NMFS gear specialists along the Gulf coast, five prototype BRDs have been identified for testing:

1. The Billy Burbank Turtle Excluder Device (TED) BRD Combo.
2. The NMFS TED BRD Combo with Hummer Fish Deflector (see Figure 9).
3. The Witch’s Hat, an Australian design.
4. The Triple Fish Eye Array with Water Deflectors.
5. The Hum Line placed in the mouth of the trawl (see Figure 10).



Figure 9. Port-side and bottom view of the NMFS TED BRD combo, showing fish excluder panels under the TED grid above.



Figure 10. A hum line device.

Developments in Gear Technology Achieved

This project has just gotten underway and has not yet achieved any developments in gear technology.

Improvements and Reduction in Bycatch Associated with This Project

This project has just gotten underway and has not yet achieved any reductions in bycatch.

Southwest Grant Project Summaries

Project Title

Testing Modified Deep-Set Buoy Gear to Minimize Bycatch and Increase Swordfish Selectivity

BREP Funding Provided

\$150,272

Recipient

Pfleger Institute of Environmental Research

Resource Challenge

California-based swordfish fisheries have been subject to several time/area closures over the past 30 years due primarily to fishery interactions with protected species (i.e., marine mammals and sea turtles). These restrictions have negatively impacted West Coast fishermen and supporting shore-side businesses, resulting in significant decreases in domestic swordfish landings and revenues. Today, the California-based swordfish fleet has dwindled to fewer than 50 vessels despite the presence of a healthy swordfish stock and consistent local demand. Much of that demand, however, is being met by imports from foreign fishing fleets that operate with considerably less regulatory oversight and enforcement. This project focuses on designing an alternative swordfish gear type that selectively targets swordfish (see Figure 11) at depth during the day while avoiding bycatch species of concern.



Figure 11. Basking swordfish are used to determine set locations.

Project Summary

The modified gear types used for this project include a hybrid deep-set buoy gear design that uses fewer buoys and increases the number of hooks per set of gear. The gear is specifically designed to target swordfish during the day and avoid bycatch species of concern that primarily inhabit the surface waters. Similar to previous deep-set buoy gear trials off the West Coast, this project will use recent depth distribution data from swordfish and bycatch species to strategically position hooks in the water column. This project also includes a strong outreach component

whereby industry representatives will be brought together to discuss and comment on the proposed gear design. Upon determining a final design, the gear will be tested during the 2013 swordfish season off the California coast. Catch and bycatch rates will be quantified, and results will be presented at Regional Fishery Management Council meetings.

Developments in Gear Technology Achieved

This study is based on designing and testing an alternative swordfish gear type that couples information from recent NOAA-sponsored deep-set buoy gear studies and integrates the knowledge of cooperative fishermen from other disciplines. The resulting configuration modifies traditional West Coast deep-set buoy gear by enhancing hook presentation and decreasing vertical tangling, which also should reduce the risk of lost gear. These issues have been raised by cooperative swordfish fishermen who have been working with the project investigators over the past 3 years.

Improvements and Reduction in Bycatch Associated with This Project

In 2012, the Pflieger Institute of Environmental Research leveraged this project's funds with additional funds from other sources to support extended gear trials in 2013. To date, this study has made progress on the initial gear design phase (see Figure 12), with final designs pending additional discussions with industry. Field trials will be conducted pending swordfish availability and will run through the 2013 swordfish season. Trials will be used to identify whether the alternative configuration results in increased catch rates while maintaining low levels of bycatch. If the configuration performs well, this work may be used to develop alternative gear technologies or gear changes that could be applied to West Coast swordfish fisheries.



Figure 12. Pflieger Institute researchers testing alternative configurations aboard the R/V *Malolo*.

Northwest Grant Project Summaries

Project Title

Reducing the Bycatch of Overfished and Rebuilding Rockfish Species in the U.S. Pacific Hake Fishery

BREP Funding Provided

\$144,598

Recipient

Pacific States Marine Fisheries Commission

Resource Challenge

The Pacific hake (*Merluccius productus*) fishery is the largest groundfish fishery by volume off the U.S. West Coast, with landings exceeding 267,000 metric tons in some years. In 2011, the U.S. West Coast groundfish trawl fishery was managed under a catch shares program. This new program establishes annual catch limits and individual fishing quotas (IFQs) along with individual bycatch quotas (IBQs). For many Pacific hake fishermen who participate in this program, rockfish bycatch is a concern. Individual fishermen could reach a rockfish species IBQ before reaching their Pacific hake IFQ, thereby ending their fishing season. Developing techniques that reduce rockfish bycatch while retaining a high proportion of the targeted species in this fishery is increasingly important.

Project Summary

In May 2012, NMFS's Northwest Fisheries Science Center-Habitat and Conservation Engineering group and the Pacific States Marine Fisheries Commission (PSMFC) conducted a collaborative workshop to develop a rockfish excluder for testing in the 2012 Pacific hake fishery. After an exchange of information and considerable discussion, the group came to a consensus that a flexible sorting grid excluder showed promise for reducing rockfish bycatch. Following the workshop, NMFS developed such an excluder. The design uses two vertical sorting grids and an exit ramp that sort fish by size as they move back toward the codend (Figure 13). Fish that are smaller than the sorting grid openings (i.e., Pacific hake) will pass through and be retained, whereas larger fish (i.e., rockfishes) will be excluded.

Gear testing will occur over 16 charter days aboard a chartered commercial fishing vessel during the 2013 Pacific hake fishery. Fish retention and escapement rates will be quantified using a recapture net. Underwater video camera systems will gather information on fish behavior in relation to the excluder and confirm that the gear and recapture net are performing as expected. The majority of trawl effort, however, will occur without the use of video cameras to examine the gear's effectiveness under "normal" fishing conditions. This study is a collaborative project between the PSMFC, Pacific hake fishermen, regional net manufacturers, and the NMFS Habitat and Conservation Engineering group.

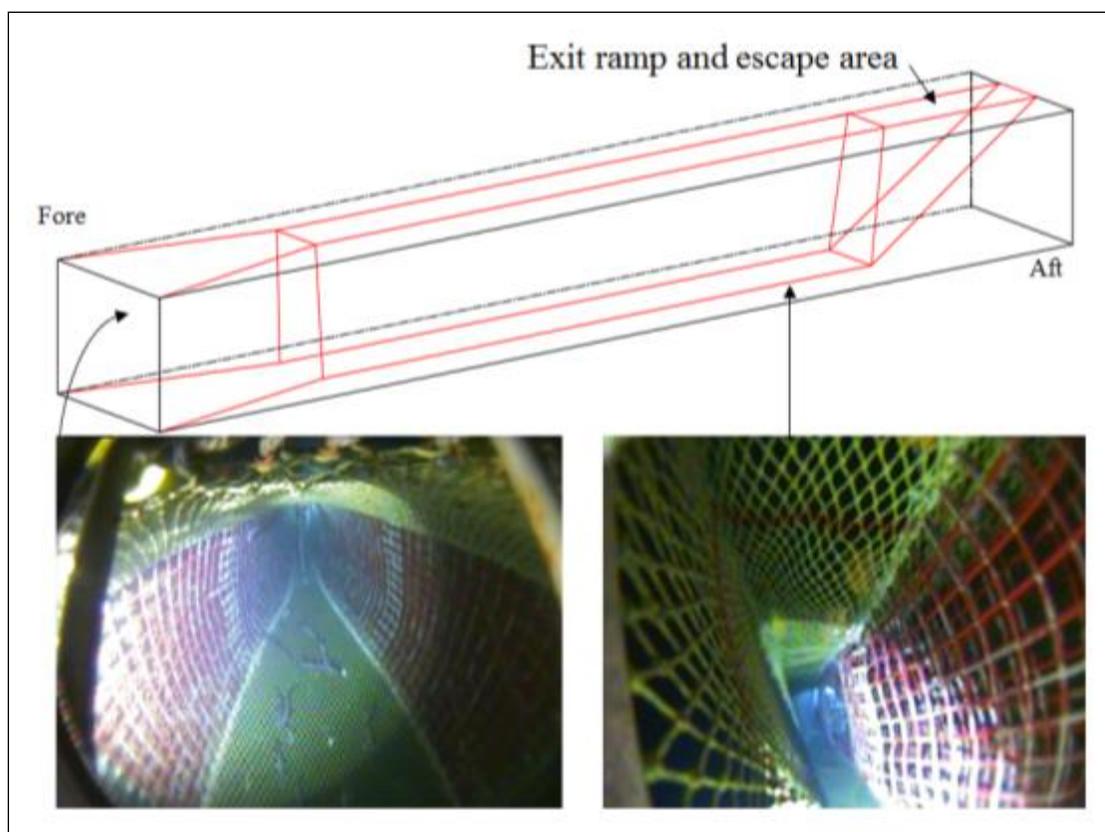


Figure 13. Schematic diagram and images of a flexible sorting grid excluder used in a midwater trawl fishery; Aft view of the forward portion of the excluder where fish first enter and interact with the gear (bottom left); fore view of the space where fish would enter after passing through the port vertical panel grid (bottom right) and move aft toward the codend. This design is similar to the excluder to be tested in this study.

Developments in Gear Technology Achieved

The excluder to be tested was designed based on a successful collaborative workshop that included gear researchers and Pacific hake fishing industry participants. The excluder will be manufactured in April 2013, with gear testing starting as early as May 2013 when the Pacific hake fishery begins.

Improvements and Reduction in Bycatch Associated with This Project

Results from this research may lead to the development and use of flexible sorting grid rockfish excluders in the Pacific hake fishery. Reducing this bycatch would provide fishermen more opportunities to harvest their catch share quota.

Project Title

Use of Artificial Light to Enhance the Escapement of Chinook Salmon when Used in Conjunction with a Bycatch Reduction Device in a Pacific Hake Midwater Trawl Net

BREP Funding Provided

\$130,043

Recipient

Pacific States Marine Fisheries Commission

Resource Challenge

The Pacific hake (*Merluccius productus*) fishery is the largest groundfish fishery by volume off the U.S. West Coast, with landings exceeding 267,000 metric tons in some years. Although landed catches consist of mostly Pacific hake, bycatch of Chinook salmon (*Oncorhynchus tshawytscha*), a prohibited take species, affects the fishery. Although the catch ratio of Chinook salmon caught in the fishery is typically <0.04 fish per metric ton of Pacific hake, there are concerns about bycatch because of the high volume of the fishery and the incidental capture of ESA-listed Chinook salmon that sometimes occurs. Since 2009, the Pacific States Marine Fisheries Commission (PSMFC), Pacific hake fishermen, Foulweather Trawl (Newport, Oregon), and NMFS' Northwest Fisheries Science Center Habitat and Conservation Engineering group have worked on developing an open escape window bycatch reduction device (BRD) designed to reduce Chinook salmon bycatch. The design of this BRD consists of two square-mesh ramps that are inserted inside a tube of netting. The ramps are used to guide actively swimming fish toward large escape windows cut out of each side of the netting tube on the upper portions of the port and starboard side panels of the net. Although a promising design has been developed (Figure 14), recent data suggest that the use of artificial lights may further enhance the escapement of Chinook salmon by attracting them toward the open escape window areas of the BRD.

Project Summary

To examine the influence of artificial light on Chinook salmon escapement, project investigators will use a randomized block design approach to determine the sequence in which the port and starboard side escape windows will be illuminated. Project investigators will place one light at each escape window selected from the randomized block design. Project investigators will measure light levels at each escape window using a Wildlife Computers TDR-MK9 archival tag. Categorical data (i.e., whether the fish exit out the escape window that was illuminated) will be collected and analyzed using a one-proportion test to determine whether artificial light significantly influences which escape window Chinook salmon use when exiting the BRD. Project investigators also will collect data on individual and mean Chinook salmon escape times. This information is important when examining the effectiveness of BRDs because stress, injuries, and fatigue associated with the capture and capture-escape process can cause unaccounted mortality after release. Project investigators will collect data on fish escapement and escape times using video camera systems. This research will occur over 14 charter days aboard a chartered commercial fishing vessel during the 2013 Pacific hake fishery. This project is a collaborative study between the PSMFC, Pacific hake fishermen, Foulweather Trawl, and NMFS' Northwest Fisheries Science Center Habitat and Conservation Engineering group.

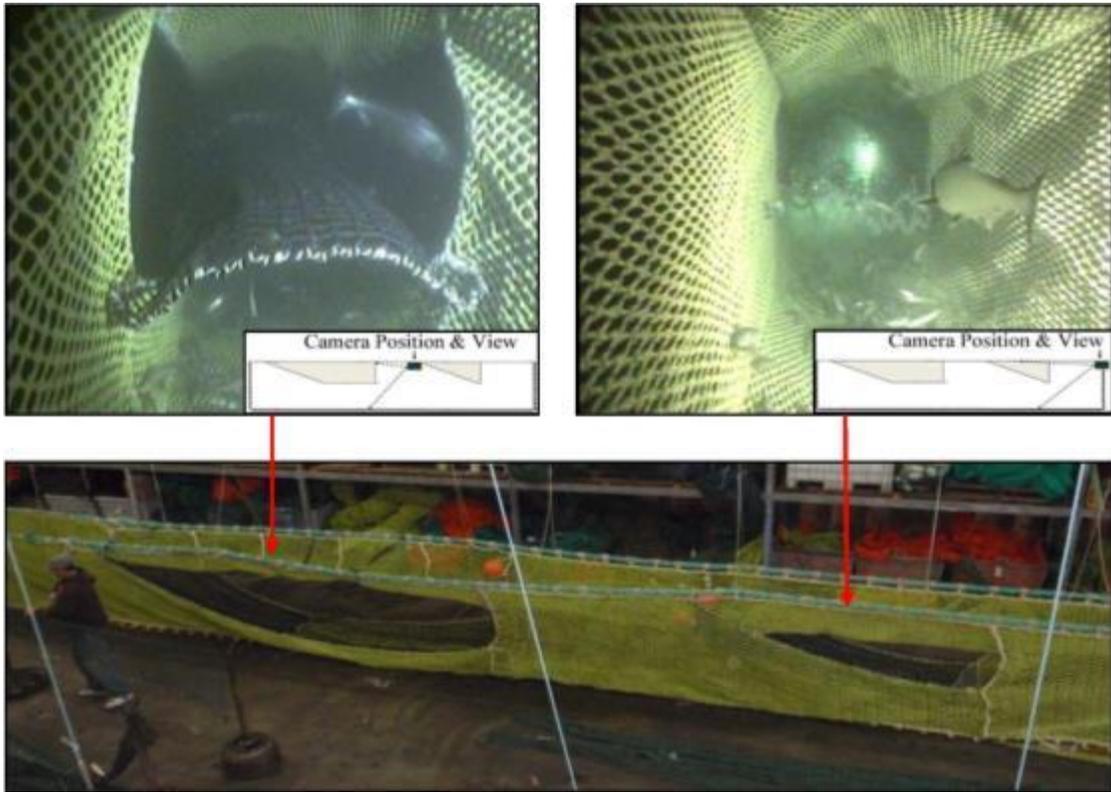


Figure 14. An open escape window BRD tested from 2009 to 2011 with BREP funds. The upper left image depicts a Chinook salmon escaping through the starboard-forward open escape window. The upper-right image depicts a Chinook salmon just prior to escaping through the starboard-aft open escape window. The bottom image depicts a port-side view of the forward and aft open escape windows. This BRD will be used in this study.

Developments in Gear Technology Achieved

The BRD to be used in this study was developed in 2009 with BREP funds. This project is scheduled to begin as early as May 2013 when the Pacific hake fishery begins.

Improvements and Reduction in Bycatch Associated with This Project

Results from this research may lead to the development and use of artificial lights on BRDs. Findings from this work may also help reduce salmon bycatch in the Alaska walleye pollock (*Theragra chalcogramma*) trawl fishery, which faces similar challenges.

Project Title

Field Validation of the RAMP Approach for Determining Crab Bycatch Mortality

BREP Funding Provided

\$68,289

Recipient

Oregon State University

Resource Challenge

Tools are needed to effectively, rapidly, and inexpensively determine bycatch mortality rates for fisheries and to assess how changes to a fishery (e.g., gear modification) affect these rates. The Reflex Action Mortality Predictor (RAMP) approach is increasingly being applied in fishing gear experiments and in estimating bycatch mortality rates. This methodology, however, has not been cross-validated against an alternative assessment method to evaluate the efficacy of this approach.

In addition, to ensure the sustainability of the Oregon Dungeness crab (*Metacarcinus magister*) recreational and commercial fisheries (see Figures 15 and 16), it is important that mortality rates be known for crab that are discarded (only male crab over a set size may be retained).



Figure 15. Fishermen on a commercial ocean crabbing trip sort through their catch, discarding all female crabs and all male crabs below the minimum size.



Figure 16. Recreational fisherman measuring and sorting catch.

Project Summary

This study proposes to use mark-recapture methods to determine bycatch mortality rates for Dungeness crab in Oregon's crab fisheries and to cross-validate the standard RAMP methodology. In addition to evaluating consistency in results across methods, the mark-recapture study will assess whether the RAMP approach's exclusion of the long-term effects of being bycaught results in underestimated mortality rates, and whether traditional laboratory holding influences probability of survival given the non-natural environment.

Dungeness crab intended to be discarded in Oregon's commercial ocean and recreational bay crab fisheries will be RAMP-assessed, tagged, and subsequently released at location of capture during ride-along trips aboard fishing vessels. Crab will be tagged and released each month over a 1-year period from October 2012 to September 2013. Fishermen will be encouraged to report recaptured crab through extensive outreach efforts. Data collection for this project will be complete in February 2014, which is the deadline for returning tags. The data also will be analyzed in March 2014.

Bycatch mortality rates generated from the mark-recapture study will be compared to rates estimated using the traditional RAMP approach. This comparative study, which began in January 2012, is being supported by the Oregon Dungeness Crab Commission (ODCC). This work includes the development of RAMP methods to estimate Dungeness crab discard mortality rates. For this component of the study, 5,500 crabs have been assessed using RAMP over the course of 32 sampling trips. This research will continue during the mark-recapture study for parallel comparisons.

To date, 122 crab have been tagged and released in Yaquina Bay, Oregon, during recreational crabbing trips. Additional crabs will be tagged each month until completion of the study. Beginning in December 2012, the start of the commercial ocean crabbing season, crabs are also being tagged and released each month during commercial crabbing trips.

Developments in Gear Technology Achieved

This project will not directly achieve any developments in gear technology. Instead, this project will validate or identify limitations to a methodology that greatly facilitates the development and testing of gear technology to reduce bycatch. Independent validation of RAMP mortality estimation will support the ability of such gear technology projects to evaluate mortality of released fish.

Improvements and Reduction in Bycatch Associated with This Project

This study has the potential to strengthen the RAMP approach as a tool for determining and evaluating bycatch mortality, and to identify ways to improve the RAMP approach to make it a more useful management tool. Moreover, the ODCC has been tasked with determining discard mortality of Dungeness crab as part of the process for maintaining Marine Stewardship Council (MSC) certification. Therefore, this work will contribute to the fishing community's efforts to be part of the MSC label and will provide insight into ways that fishing practices may be altered to reduce mortality rates of discarded crab. In addition, the collaborative method used in this project will help facilitate exchange of information between the fishing and scientific communities in Oregon.

Project investigators will share results from this study with members of the fishing industry, collaborating state and federal fisheries scientists, and the general public via a mailed flyer, posts on fishing websites and the project website, and a workshop that will be held at the completion of the study. Project investigators also will submit results for publication in peer-reviewed journals and in papers at relevant conferences.

Alaska Grant Project Summaries

Project Title

Using Combined Video/Acoustic Recordings of Marine Mammal/Fishing Gear Interactions to Evaluate Utility of Passive Acoustic Monitoring

BREP Funding Provided

\$202,476

Recipient

Scripps Institution of Oceanography, University of California, San Diego

Resource Challenge

Minimizing (or, preferably, eliminating) marine mammal interactions with longline gear is a prominent bycatch issue, particularly for species that remove the catch or bait off gear, a behavior known as depredation. Depredation is the active intentional removal of prey, in contrast to a whale inadvertently stumbling into a net or line. Sperm whales (*Physeter macrocephalus*), killer whales (*Orcinus orca*), and false killer whales (*Pseudorca crassidens*) are among the cetacean species that actively engage in depredation. These whales risk entanglement and fishermen take longer to catch their quota or experience economic losses due to lost hooks and damaged fishing gear. Exploring ways to reduce depredation is hampered by lack of knowledge about the basic behavior itself, and the lack of an inexpensive way of quantifying depredation activity on fishing trips where human observers are impractical and expensive. Passive acoustic monitoring may be a useful, cost-effective tool for detecting the presence of certain species around fishing gear and thereby gaining insight into gear depredation rates and behavior as a function of time and location.

A fundamental assumption behind using passive acoustic monitoring is that animals are acoustically active when interacting with the gear. However, this assumption may not be true during daylight conditions, because many toothed whales have good visual acuity. The one published study on false killer whale acoustics around longline gear found no correlation between depredation activity and passive acoustic detections of false killer whales. A preliminary analysis of killer whale interactions with vessels in the Bering Sea found uncertain correlations between acoustic and depredation activities. Essentially, relatively few (9) click trains or buzzes were detected on a longline with 100 percent depredation (2,600 hooks) deployed during daylight hours, and therefore killer whales may use vision, along with echolocation, to interact with gear.

For example, in 2006 the project investigators deployed an autonomous video camera with an external hydrophone on a demersal longline haul as part of an effort called the Southeast Alaska Sperm Whale Avoidance Project (SEASWAP). The camera could only record for 40 minutes and was depth-limited to 100 meters. Despite these limitations, out of 12 deployments, two sperm whale interactions were documented (see Figure 17). Both encounters revealed that, when interacting with the longline, sperm whales generated a variation of the so-called “creak” sound that has been well-documented in previous bioacoustics literature. The animals were

acoustically active even under good visual conditions, thus validating the heavy use of passive acoustic technology currently employed by SEASWAP.



Figure 17. Sperm whales captured on an underwater video camera depredate a demersal longline at 100 m depth off Southeast Alaska.

Project Summary

The key to reducing depredation with viable and realistic solutions is to fully understand how the whales are removing the bait or catch (and knowing whether whales are removing catch or bait, which currently is uncertain for false killer whales). Previous audio/video work by SEASWAP found that sperm whales use echolocation to acquire black cod from longlines, even under good visual conditions. This project will expand this work to address whether two other species, killer and false killer whales, consistently use sound to interact with longlines, and whether these sounds can be distinguished from natural acoustic behaviors. Two existing autonomous acoustic recorders previously developed with NOAA and fishing industry support are being expanded to incorporate a camera module. The module will capture up to three frames per second using a trigger signal generated by the autonomous recorder. The modified system will first be deployed to study killer whale and sperm whale interactions in Alaskan waters, where encounters with marine mammals are predictable and highly probable. Then it will be incorporated with other acoustic field efforts studying endangered false killer whales in Hawaiian waters. This project includes logistical support for Alaska fishermen to attend a depredation summit in Hawaii. The summit will provide a forum for exchanging ideas regarding attaching and camouflaging the camera system with minimum inconvenience to fishermen.

This project's overriding objective is to simultaneously deploy cameras and acoustic recorders from fishing gear to determine whether visually documented interactions of killer whales and false killer whales are accompanied by distinctive acoustic cues, such as echolocation sounds, by the species of interest.

Specific sub-objectives include the following:

1. Expanding two existing autonomous acoustic recorders to incorporate a long-endurance natural-lighting camera capability (between 24 hours to 7 day coverage, depending on picture frame acquisition rate).
2. Testing the system on sperm whales and killer whales in Alaska and false killer whales in Hawaii.
3. Using visually documented encounters to determine the probability that killer whales and false killer whales generate sounds during fishing gear interaction during daylight hours, as a function of gear depth.
4. Exploiting opportunistic visual records of other bycatch events to determine whether acoustic cues are generated by entanglement with the fishing gear.

Developments in Gear Technology Achieved

The pressure case for the camera system is being designed, and the final selection of the camera system was made at the end of November 2012. Tentative arrangements are being made to test the system off Alaska in March–April 2013.

Improvements and Reduction in Bycatch Associated with This Project

This BREP study has only been funded for a couple of months and is just getting under way. The project investigators are in the early stages of planning and implementing their course of action. Therefore, this project has not yet achieved any improvements and reductions in bycatch.

Pacific Islands Grant Project Summaries

Project Title

Estimating Post-Release Mortality in Istiophorid Billfish

BREP Funding Provided

\$226,039

Recipient

Queen's University, Ontario, Canada

Resource Challenge

Commercial and recreational fishing activities have the potential to adversely affect the populations of large pelagic species, whether they are target, incidental, or bycatch species. Uncertainty about post-release survival is a management challenge in many fisheries for large pelagic species. Although there is considerable disagreement about the current state of large pelagic fish populations, the species at greatest risk are the large apex predators, particularly billfish. Because commercial and recreational fishing activities generally remove the largest animals, substantial reductions in parental biomass of these long-lived, late-maturing predators could cause prolonged population, genetic, and ecosystem effects.

The greatest pressure on Pacific billfish populations arises from the commercial longline fishery. Greater than 90 percent of mortality in marlin is caused by commercial longline fishing practices targeting yellowfin and bigeye tunas. Although the billfish bycatch is released, survival rates are unknown. Determining the fishing practices that best promote long-term survival of released fish can help promote healthy billfish populations.

Project Summary

This project has two components that will proceed independently but then be compiled synergistically to provide predictive power about the likelihood of post-release survival. The project investigators pioneered the approach of combining modern tagging approaches (i.e., pop-up satellite archival tags, or PSATs) with comprehensive pathophysiological analyses. This combination of approaches allows the project investigators to define the typical physiological profile of fish that would survive release and those likely to die upon release.

The first component of this project uses PSATs to estimate the post-release survival of large Pacific blue marlin (*Makaira nigricans*) and striped marlin (*Kajikia audax*) released from pelagic longline gear. These data will provide important information about post-release survival of marlin bycatch in the tuna longline fishery.

The second component of this study will establish biochemical predictors of morbidity and mortality from tissue plugs and blood. This approach conducts comprehensive pathophysiological analyses of large numbers of fish (including tagged fish) to diagnose primary factors that account for the fish condition, as well as secondary factors that might change dramatically but have little impact on survivability. Integration of PSATs and pathophysiological analyses generates predictive power. The project investigators can then use

the PSAT-calibrated indicators to assess the impact of fishery-dependent factors such as soak time and hook type.

Developments in Gear Technology Achieved

Any recommendations in relation to gear technology will come after complete analyses of the data. The approach used in this project should be readily transferable between species and fisheries (e.g., commercial versus sport fishing) and permit a more cost-effective way of assessing the impact of changes and differences in fishery methods.

Improvements and Reduction in Bycatch Associated with This Project

For effective management measures to be implemented, it is beneficial to have accurate estimates of both at-vessel and post-release mortality rates. These data are necessary for estimating total fishery-induced mortality and for improving stock assessments. Mitigation strategies could then be given special consideration for species with high rates of post-release mortality. However, without robust estimates of post-release survival, it would be impossible to evaluate possible bycatch mitigation measures.

The primary benefit expected from this grant is to generate robust estimates of post-release survival of striped and blue marlin released from longline fishing gear that targets tuna. For example, the PSAT analyses will be able to conclude that a given number of marlin released from longline gear survived upon release. The second benefit of this project is that the investigators will be able to develop a pathophysiological profile of fish condition at the time of capture and, in combination with PSAT analyses, develop predictors of survival.

Updates from FY 2011 NMFS Projects

This report also provides updates concerning BREP projects funded in 2011 for which results were not available in time for the 2011 Report to Congress.

Project Title

Monitoring Seabird Bycatch in Northeast Commercial Fisheries

FY 2011 BREP Funding Provided

\$40,000

Recipient

NMFS Northeast Fisheries Science Center

Resource Challenge

Incidental mortality of seabirds during commercial fishing operations is of growing concern in the Northeast and Mid-Atlantic United States. For many seabird species, the total number of birds taken each year by various fisheries (e.g., gillnet, mid-water trawl) is unknown. This is mostly due to the rarity of seabird bycatch events and the difficulty estimating subsequent bycatch rates. Increased observer coverage by the Northeast Fishery Observer Program (NEFOP) and the At-Sea Monitoring (ASM) program has identified interactions between commercial fisheries and seabirds within the Northwest Atlantic. To date, greater shearwaters (*Puffinus gravis*) make up the predominate seabird species bycaught in the Northwest Atlantic, with over 1,275 recorded takes in 2011 by commercial gillnetters. NMFS' Northeast Fisheries Science Center (NEFSC) staff developed analytical methods that will be applied to observed incidental takes of seabirds. These methods will provide estimates of overall seabird bycatch by fishery and species where there are sufficient data.

Project Summary

During 2012, data from several sources (NEFOP and ASM observer datasets, and Vessel Trip Report and Commercial Landings effort datasets) were collated and synthesized to provide a cohesive dataset that can be used to estimate seabird bycatch. Researchers are developing a Bayesian two-part models approach to estimate a seabird bycatch rate from the observer data, which have a disproportionately high percentage of zero-bycatch observations. These models will describe the bycatch rate as it relates to important covariates—for example, time, area, water, and fishing gear characteristics. The observer data will be used to determine which covariates are important. Bayesian models are useful because they can easily produce future bycatch estimates by using newly collected data to update the models that were developed using past data. To ensure development of accurate and precise estimates, sensitivity of estimated bycatch rates to variable selection methods is being investigated.

Developments in Gear Technology Achieved

This project has not directly achieved any developments in gear technology at this time. However, in the process of developing bycatch estimates, factors associated with high bycatch rates will be identified. This could possibly provide scientific advice on future potential mitigation measures for gear modifications to reduce seabird bycatch.

Improvements and Reduction in Bycatch Associated with This Project

Estimates of seabird bycatch are expected to be available by mid-2013 for certain seabirds, with high-priority species taking precedence (e.g., the U.S. Fish and Wildlife Service's Birds of Conservation Concern).

Project Title

Assessing the Potential of the Tow Time Data Logger

FY 2011 BREP Funding Provided

\$21,800

Recipient

NMFS Northeast Fisheries Science Center

Resource Challenge

In the early 2000s, NMFS recognized the need to address sea turtle bycatch in a more comprehensive manner. As a result, NMFS developed the Strategy for Sea Turtle Conservation and Recovery in Relation to Atlantic Ocean and Gulf of Mexico Fisheries (Strategy). The Strategy addressed sea turtle bycatch by gear type rather than by target fishery and identified trawl gear as the first gear type to be addressed. Trawling—a method of fishing that involves actively pushing or towing a net through the water—might incidentally capture sea turtles and other species.

Turtle excluder devices (TEDs) have been proven an effective method to minimize adverse effects related to sea turtle bycatch in several trawl fisheries around the world. However, TEDs may not be feasible for some trawl fisheries given the size of the target catch or the gear configuration. In the event that TEDs are not feasible, other mitigation measures (e.g., tow time restrictions, time/area closures) may need to be considered.

Project Summary

The goal of this work is to determine and document the effectiveness of a tow time data logger in a commercial bottom trawl fishery. At this time, the feasibility of using a data logger to monitor compliance and enforce tow time restrictions within a fishery is unknown. The NMFS Northeast Fisheries Science Center (NEFSC) worked with Onset Computers (Bourne, Massachusetts) to develop a tow time data logger, an electronic device that automatically measures the tow duration of fishing trawls (see Figure 18). The NEFSC installed prototype loggers on commercial vessels, and preliminary testing was completed in 2010. These loggers were then refined to address issues identified during the preliminary testing. Further testing in 2011–2012 showed that the loggers are adequately rugged to withstand the rigors of commercial fishing activities and prolonged exposure to a marine environment. Currently, Onset Computers is providing software updates and improvements to the loggers. Following these updates, NMFS will finalize a structured and comprehensive plan to test the data loggers in an experimental fishery. This ongoing research may result in another tool that could be used to address sea turtle bycatch in trawl fisheries.

Developments in Gear Technology Achieved

During 2012 the modified data logger was deployed aboard:

- One near-shore summer flounder trawl vessel – Woods Hole, Massachusetts
- One offshore squid vessel – Point Judith, Rhode Island
- One scallop trawl vessel – Barnegat Light, New Jersey
- Two horseshoe crab trawl vessels – Ocean City, Maryland

- One horseshoe crab/croaker flynet trawl vessel – Ocean City, Maryland
- Two groundfish vessels – New Bedford, Massachusetts

As of late 2012, the loggers were being retrieved and the readouts compared to a haul log that was completed by the vessel captains. Retrieval of all loggers and analysis of the results are anticipated to be complete by mid-summer 2013.

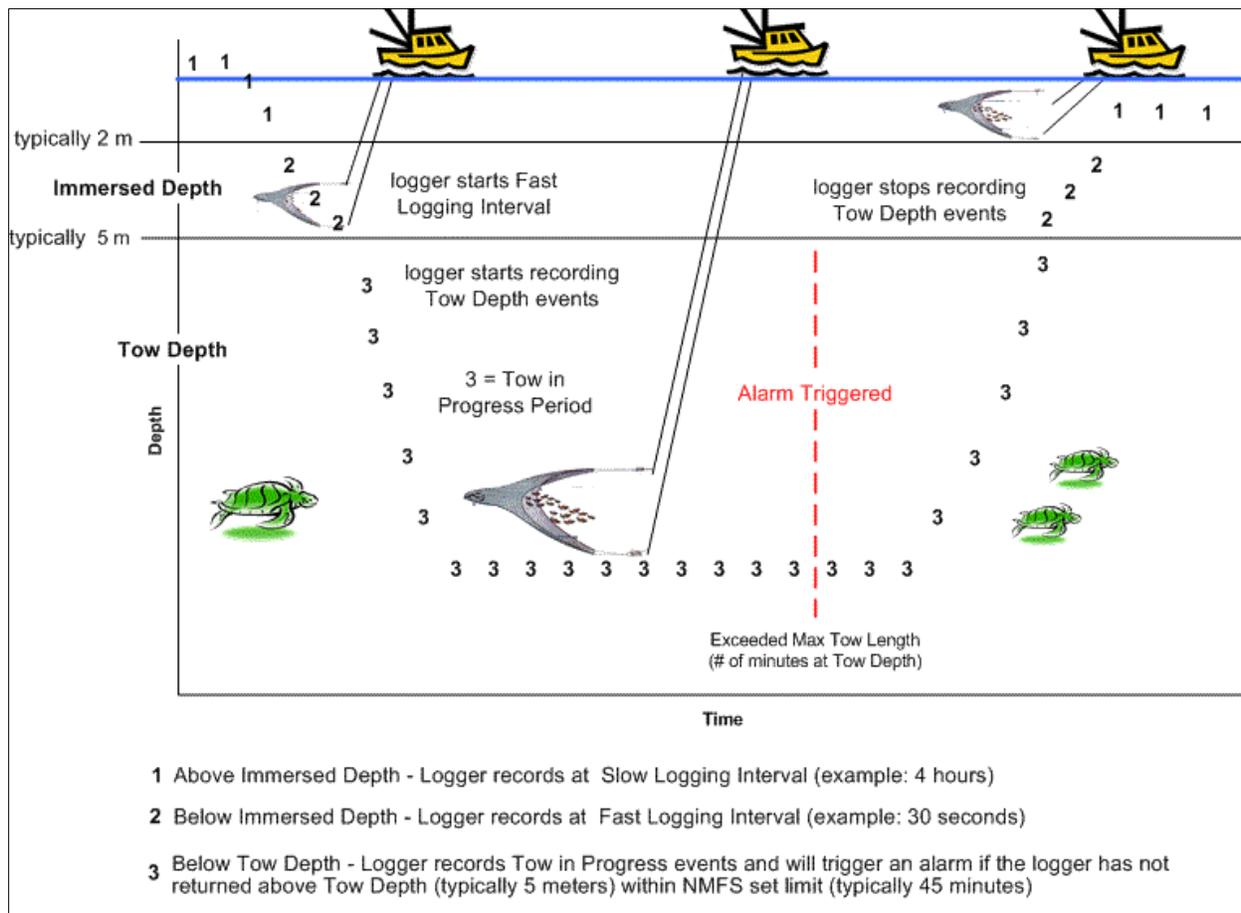


Figure 18. A schematic describing the operation of a tow time data logger.

Improvements and Reduction in Bycatch Associated with This Project

The NEFSC is in the process of demonstrating the logger as a viable management tool that could monitor tow times if tow time restrictions were used to reduce sea turtle mortalities.

Project Title

Ability of Southern California Deepwater Rockfish to Survive Barotrauma Following in-situ Recompression

FY 2011 BREP Funding Provided

\$104,290

Recipient

NMFS Southwest Fisheries Science Center

Resource Challenges

Currently the Pacific Fishery Management Council lists seven species of Pacific rockfish as “depleted,” and several other populations are in decline. Rockfishes experience high rates of post-release mortality from a condition called barotrauma, which is caused by the change in pressure associated with being captured at depth and brought rapidly to the surface. Barotrauma results in a number of injuries, as well as excessive buoyancy, which makes it difficult for many rockfish species to swim back to depth under their own power. Discarded (released) rockfish (which include depleted species that are required to be released) are thus often left floating on the surface, where they typically succumb to their injuries, thermal shock, suffocation, and/or predation. Recent research has shown that rockfish can be recompressed and successfully released using commercially available descending devices that send fish back toward their depth of capture. Although recent research has shown that recompressing excessively buoyant rockfish caught at shallow depths can result in high short-term survival rates, little was known about the ability of deep-water rockfish species to survive (five out of the seven depleted species commonly occur at depths between 100 and 150 m or more) and whether short-term survival is indicative of long-term survival.

Project Summary

This study examined the long-term survival rate of deep-water rockfish species captured from depths between 80 and 180 m (mean = 135 m) and subsequently recompressed and released using a weighted cage (Figures 19B, 19C) or other commercially available recompression device. Scientists monitored rockfish survival and behavior for up to 4 months following release using newly developed accelerometer and pressure sensitive acoustic transmitters that were attached to each fish upon capture (Figure 19A). These tags reported fish movement data to strategically located underwater receivers. Fifty tags were deployed on five different species, and of the fish that remained within detection range, 92.9 percent survived in the short-term (up to 2 days), with 76.7 percent surviving long-term. The two deep-dwelling depleted species tagged in this project, bocaccio (*Sebastes paucispinis*) and cowcod (*S. levis*), both showed high long-term survival following recompression and release (90.0% and 100% respectively). In addition to tagging studies, scientists collected tissue samples from various fish to determine the extent of internal injuries (e.g., emboli). As hypothesized, differences in rockfish morphology and physiology resulted in species-specific rates of internal injury and associated mortality.



Figure 19. Images of a 47.5 cm bocaccio rockfish following capture (from 147 m below the surface) and during release. **(A)** Bocaccio at the surface immediately following capture showing signs of extreme barotrauma: bloated body, everted esophagus and stomach, bulging eyes, and ocular emphysema (air bubbles in the eyes). Note tag attached near the dorsal fin. **(B)** Positively buoyant bocaccio just below the surface during release using a weighted cage. **(C)** At 40 m depth the fish has been recompressed and is ready for release as it actively attempts to swim back down to the sea floor. Tag data from this fish revealed that it survived the duration of the 4-month study.

Developments in Gear Technology Achieved

Several types of commercially available “recompression” or “descending” devices can be used by recreational and commercial fishermen to release rockfish bycatch. The goal of this study was to use examples of such devices to determine whether they can successfully release rockfishes caught from deep depths and suffering from extreme barotrauma (i.e., do released fish survive long-term?). A long-term survival rate of over 75 percent suggests that these devices should be considered in future management decisions as options to reduce bycatch mortality. Further studies are now needed to test the relative feasibility of the use and the success of different device types in the various fisheries that encounter rockfishes as bycatch. Instructions for the successful use of descending devices will help ensure high survival rates. This study showed that rockfish caught deeper than 125 m should be recompressed to a minimum depth of 40 to 45 m. Such details (e.g., determination of minimum depths to achieve successful releases) are crucial in developing the future technology and protocols needed to properly implement recompression practices on a large scale.

Improvements and Reduction in Bycatch Associated with This Project

The results of this work were recently incorporated into an assessment produced by the Groundfish Management Team of the Pacific Fishery Management Council (PFMC) to adjust estimates of rockfish post-release survival based on the use of recompression devices. The team presented this assessment at the PFMC’s November 2012 meeting. The Council’s Scientific and Statistical Committee discussed the prospect of reducing estimated mortality rates of certain heavily impacted rockfish species while maintaining fishery access by incorporating the use of descending devices into recreational management. A discussion of the results and impacts of this study were also published in the early November issue of *Science* in an article titled “Putting Rockfish Back Where They Belong.” Additional details can also be viewed at the Southwest Fisheries Science Center barotrauma page: <http://swfsc.noaa.gov/barotrauma/>

Project Title

Developing, Testing, and Demonstrating Bycatch Reduction Devices in West Coast Trawl Fisheries

FY 2011 BREP Funding Provided

\$93,670

Recipient

NMFS Northwest Fisheries Science Center

Resource Challenge

The Pacific hake (*Merluccius productus*) fishery is the largest groundfish fishery by volume off the U.S. West Coast, with landings exceeding 267,000 metric tons in some years. Pacific hake are caught using midwater trawls, by catcher boats delivering to shore-based processing plants and at-sea mothership processors, and by large catcher-processor vessels. Since 2011, the West Coast groundfish trawl fishery has been managed under a catch shares program. This new program established annual catch limits and individual fishing quotas (IFQs) along with individual bycatch quotas (IBQs). For many Pacific hake fishermen who participate in this program, rockfish bycatch is a concern. Individual fishermen could reach an IBQ for a given rockfish species before reaching their Pacific hake IFQ, thereby ending their fishing season.

Project Summary

In May 2012, NMFS' Northwest Fisheries Science Center Habitat and Conservation Engineering group and the Pacific States Marine Fisheries Commission conducted a collaborative workshop to develop a rockfish excluder for testing in the 2012 Pacific hake fishery. Twenty-nine attendees—including vessel owners, captains and crewmen, seafood company operators, regional net manufacturers, and gear researchers—participated in the workshop. Following the workshop, NMFS used information from the workshop to develop a flexible sorting grid rockfish excluder. The design uses two vertical sorting grids and an exit ramp that sort fish by size as they move back toward the end of the net. The concept of this design is that fish smaller than the sorting grid openings (i.e., Pacific hake) will pass through and be retained, whereas larger fish (i.e., rockfishes) will be excluded.

This pilot study examined two versions of a flexible sorting grid excluder (design A and design B) aboard the chartered F/V *Perseverance*. The primary difference between the two designs is that design A has grid openings of 3.5 x 5.5" (H x L), whereas design B has grid openings of 3.0 x 3.5" (H x L). Fish retention and escapement rates were quantified using a recapture net. Both designs retained a relatively high proportion (>93%) of Pacific hake. However, the two designs did not perform equally, with design B being much more effective at reducing bycatch (Figure 20). Results showed rockfish bycatch was reduced by 70.2 percent under design B and only 15.4 percent under design A (Table 3). Unfortunately, both designs tested were only effective at sorting target and non-target fishes under slow to moderate fish volumes. Under heavy fish volumes, both designs tended to clog, resulting in the vessel having to haul back before filling its codend.



Figure 20. Photos illustrating results from excluder design B. Left image shows a portion of the trawl catch (mostly Pacific hake); whereas the right top image shows the entire recapture net catch (mixture of rockfishes and Pacific hake). The bottom right image shows baskets of rockfishes sorted from the recapture net catch.

Table 3. Percent escapement by weight of target and non-target species between excluder designs A and B.

Species	Design A (3.5 x 5.5" grid)		Design B (3.0 x 3.5" grid)	
	Weight - kg (trawl/recapture net)	% escapement	Weight - kg (trawl/recapture net)	% escapement
Pacific hake	175,096 / 5,933	3.3	137,768 / 8915	6.1
Yellowtail rockfish	2,836 / 379	11.8	1,478 / 3,340	69.3
Widow rockfish	45 / 5	9.9	22 / 104	82.2
Canary rockfish	493 / 220	30.9	0 / 3	100.0
Rougheye rockfish	2 / 0	0.0	5 / 101	95.3
Darkblotched rockfish	1 / 0	0.0	1 / 5	80.0
Bocaccio	0 / 13	100.0	0 / 0	-
Total – Rockfish	3377 / 617	15.4	1506 / 3553	70.2
<u>Prohibited take species</u>				
Chinook salmon*	2 / 3	60.0	1 / 0	0.0
Pacific halibut*	1 / 0	0.0	0 / 2	100.0

* = numbers of fish.

Developments in Gear Technology Achieved

During this pilot study a flexible sorting grid rockfish excluder was tested for application in the Pacific hake fishery. This gear design was developed from a successful workshop held between gear researchers and Pacific hake fishing industry participants. This study is the first project along the U.S. West Coast to test a flexible sorting grid rockfish excluder and evaluate its effectiveness in a midwater trawl fishery.

Improvements and Reduction in Bycatch Associated with This Project

Findings from this research suggest the potential for reducing rockfish bycatch in the Pacific hake fishery using a flexible sorting grid. This gear design also shows promise at reducing the incidental catch of Chinook salmon (*Oncorhynchus tshawytscha*) and Pacific halibut (*Hippoglossus stenolepis*), which are prohibited take species. During this project, genetic data on all Chinook salmon caught were provided to the Oregon State University-Hatfield Marine Science Center-Collaborative Research on Oregon Ocean Salmon (CROOS) program for DNA analysis. Recently, CROOS informed NMFS that two ESA-listed Chinook salmon were caught during this project (*Prob.* = 1 & 0.99). These ESA-listed fish were both caught in the recapture net. Following the conclusion of this project, the Pacific hake fishing industry has continued to use and experiment with design B to try to improve the gear's performance under heavy fish volumes. Insights and lessons learned during this project and from fishermen's use of the gear will be used to modify design B for further testing during the 2013 Pacific hake fishery.

Project Title

Acoustically Observing False Killer Whales in the Hawaii-Based Tuna Longline Fishery

FY 2011 BREP Funding Provided

\$87,770

Recipient

NMFS Pacific Islands Fisheries Science Center

Resource Challenge

Direct interactions between cetaceans and fishing gear pose a substantial threat to the viability of cetacean populations and can lead to significant financial losses for fishermen due to predation and gear damage. Cetaceans may approach fishing lines to procure bait or catch, which can lead to entanglement or hooking of the animal, resulting in serious injury or death. False killer whales have been found to interact with the Hawaii-based deep-set, tuna-target longline fishery, resulting in bycatch removal rates that exceed sustainable levels. This issue has prompted the development of new acoustic technology that will be used with the cooperation of fishermen from the Hawaii Longline Association to record the sounds associated with setting, soaking, and hauling gear, as well as sounds produced by false killer whales that may interact with fishing gear.

Project Summary

The goal of this research is to acoustically monitor the Hawaii-based longline fishery to gain a better understanding of false killer whale interactions with fishing gear. According to the project's design, acoustic recorders would be used to detect the occurrence of such interactions, based on sounds produced by the animals as well as sounds associated with setting, soaking, and hauling the gear. This project included the following objectives:

1. Develop a methodology for attaching and deploying autonomous acoustic recorders onto longline fishing gear.
2. Generally analyze acoustic data to obtain information on the presence of false killer whales in the vicinity of fishing vessels, and the frequency of interactions.
3. Conduct a specific analysis on changes in the acoustic behavior of a false killer whale during an interaction, and determine the presence of any possible acoustic cues produced by the vessel that may attract an animal and lead to an interaction.
4. Recommend modifications in the design of fishing gear and/or fishing techniques that may help reduce the frequency of interactions.

In conjunction with fishing operations, the nature of interactions between an animal and a vessel's gear can be determined through analysis of acoustic data. A better understanding of these interactions should be obtained through this project. This will provide insight into appropriate management measures that should be implemented for protection of the Hawaiian population of false killer whales and a reduction in depredation of catch from the longline fishery.

Developments in Gear Technology Achieved

BREP funds in 2011 were used to purchase three High-frequency Acoustic Recording Packages (HARPs) developed by engineers at the Scripps Institution of Oceanography. The HARPs are equipped with saltwater switches to facilitate easy deployment. In early 2012, two recorders were delivered for use in field trials. Project scientists first worked on developing the safest and most effective method for attaching recorders to the longlines (see Figure 21). This required working closely with fishermen in gear set-up and attachment techniques. Initial deployments provided guidance on the optimal location of recorders on the gear. A flexible deployment scheme was used in order to provide fishermen with the opportunity to determine the best design and method of attachment for their individual vessel. In order to obtain data throughout the entire fishing process, recorders were attached to the longlines, deployed during line setting, and retrieved at the end of the haul. This project's investigators attended approximately one fishing trip per month over a period of 3 months, from December 2011 to February 2012. Each trip consisted of 10 to 15 sets at up to 12 hours each.

The most common attachment scheme implemented by fishermen involved attaching the instrument to the mainline, which is the area of line between two floats, within a basket. The HARPs were attached with the same wire branchline used for fishing hooks and two locking branch clips to keep it from sliding along the mainline. This attachment was designed to enable the instrument to float above the mainline from the buoyancy of an attached syntactic float, and to remain between 50 and 100 m deep. Careful notes on the configuration of the gear, including arrangement in the water (strait line, U-shaped set, split sets, etc.), were recorded to facilitate more accurate assessment of the attachment design. This project's investigators noted the float and hook number where the instrument was attached and deployed time-depth recorders on each acoustic recorder to monitor vertical movement throughout the set and provide measurements of light and pressure levels. The instruments recorded at 200 kilohertz sample rate to provide uninterrupted, full-bandwidth data to capture any interactions between cetaceans and fishing gear, along with vessel and gear sounds.

Due to unforeseen sound pollution created by the saltwater switch on each recorder, the data collected during initial deployments were difficult to analyze. To resolve this issue, engineers at Scripps redesigned the switch and are retrofitting the two original instruments as well as the remaining, and as yet undelivered, instruments. The investigators anticipate delivery of all recorders with the new saltwater switch by early 2013, with opportunistic deployments within the fishery to continue at that time to better quantify acoustic cues for false killer whales.



Figure 21. HARP mooring outfitted for deployment from the longline vessel *Sea Hunt* in December 2011.

Improvements and Reduction in Bycatch Associated with This Project

Although this project has not yet produced definitive findings on acoustic cues for false killer whales, it has helped develop strong working relationships between NMFS scientists and various vessel captains from the Hawaii-based longline fleet. The NMFS scientists have received a great deal of interest, cooperation, and input from fishermen, which has created a solid foundation for the completion of this project. Fishermen contributions to this project's methods and designs have been crucial to understanding the fishing process and the best techniques for deploying recorders.

A general analysis of the acoustic data collected during field trials has shown consistent gear noises that animals may be cueing in on. NMFS scientists have identified specific vessel sounds during both setting and hauling of the gear, which is consistent with anecdotal evidence from fishermen suggesting that false killer whales are feeding from longlines at the ends of sets. More fishing trips need to be carried out in order to obtain data on the acoustic behavior of false killer whales during an interaction, as well as their position and movement along the lines. This information can be used in mitigation strategies aimed at preventing detrimental interactions between whales and the fishery.



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