2nd Program Report

Period covered by Report 6/30/2010 - 5/18/2012

River Herring bycatch Avoidance in Small Mesh Fisheries

Easygrants ID: 21368

Principle Investigators:	Dr. Kevin D. E. Stokesbury
	Dr. Daniel Georgianna
	Dr. Michael P. Armstrong
	Peter Moore
Primary Contact:	Dr. Kevin D. E. Stokesbury
Address:	School for Marine Science and Technology,
	University of Massachusetts Dartmouth,
	200 Mill Road Suite 325
	Fairhaven, MA, 02719
Phone:	(508) 910-6373
Fax:	(508) 910-6374
Email:	kstokesbury@umassd.edu

Project Summary

This project is a collaboration between the Sustainable Fisheries Coalition (SFC), the Massachusetts Division of Marine Fisheries (MA DMF) and the University of Massachusetts Dartmouth School of Marine Science and Technology (SMAST) to develop river herring and American shad (alosine) bycatch avoidance methods. Sustainable Fisheries Coalition members account for the majority of US landings of Atlantic herring and mackerel. River herring species are also encountered in these directed fisheries. Minimizing unintended bycatch has been a goal of SFC members since fisheries managers alerted the industry in 2006 that the river herring species complex was depressed. The specific goals of the project are to develop (1) a real-time bycatch avoidance intra-fleet communication system, (2) a predictive model of where alosines are likely to occur in space and time, and (3) additional support for port sampling to inform the initiative. Work completed to achieve each goal and comparison of to-date results grant evaluation metrics is described in detail in the body of the report. In summary, three river herring bycatch avoidance systems, focusing on the times and locations with the most alosine bycatch, have been conducted. High levels of cooperation by industry members and the appearance of distinct spatial and temporal bycatch patterns within the avoidance areas suggests these systems may have resulted in reduced alosine bycatch. Several ranges of environmental variables with significantly different probabilities of catch for species of interests have been identified within the National Marine Fisheries Service bottom trawl survey database. The MA DMF has sampled 13 of the 14 vessels that have landed in Massachusetts ports, and approximately 161 out of 299 trips (as of 3/15/12). This work is being incorporated into a PhD dissertation titled "Understanding and avoiding River herring and American shad bycatch in the Atlantic herring and mackerel mid-water trawl fisheries". The student has completed all course requirements, passed his comprehensive exams, and is preparing to defend his proposal on May, 30 2012. However, committee members have recommended that another year of fisheries dependent work would add significant strength to the dissertation.

Project Objective: Real-time fleet communication system

Since January 2011, 13 mid-water trawl vessels have participated in three alosine bycatch avoidance systems. These voluntary bycatch avoidance systems operated under the hypothesis that alosines do not continuously school with Atlantic herring and mackerel while at sea. Therefore, with enough information and clear, quick communication, areas for vessels to fish that contain adequate amounts of target species but not large amounts of alosines could be identified. The following steps were taken to implement an initial voluntary bycatch avoidance program for mid-water trawl vessels landing in Massachusetts during the 2011 winter fishery (January-March);

Determine Catch Information Source: One requirement of a near-real time information system is a reliable data source that systematically calculates bycatch rates and discloses fishing locations (Gauvin et al., 1996). Two programs, the Northeast Fisheries Observer Program (NEFOP) and the MA DMF portside sampling program, provided these data. The MA DMF portside sampling program samples approximately 50% of all Massachusetts landings and prior to 2010 about 85% of all mid-water trawl landings occur in Massachusetts (MA DMF, unpublished data). Edited trip level catch composition is available about 48 hours after a vessel lands. Tow locations were available through MA DMF trip logs voluntarily completed by vessel captains. From 2009-2010 the NEFOP sampled about 40% of Atlantic herring mid-water trips, though about two-thirds of these samples were from July to December (NEFMC, 2012). Uncorrected tow level data were available about 5 days after a vessel landed (Beagley personal comm.). Due to coverage rates and timeliness, the MA DMF portside sampling program was the primary information source for this study while NEFOP data provided tow level catch information for trips with multiple tows and high alosine bycatch.

Reduce spatial scale: The Atlantic herring and mackerel fisheries range from coastal waters to a maximum of 66°E. During the winter, fishing effort occurs south of Cape Cod, MA to Virginia. A program over this entire range could make communications cumbersome and contains numerous alosine hotspots. An alternative approach was to conduct the program in one specific high bycatch area (Gauvin et al 1996, O'Keefe et al. 2010). Based on historic MA DMF port sampling, NEFOP data and Cournane and Correia (2010) an approximately 60x70 nm area off the coast of New Jersey was identified as the target bycatch hotspot (Figure 1).

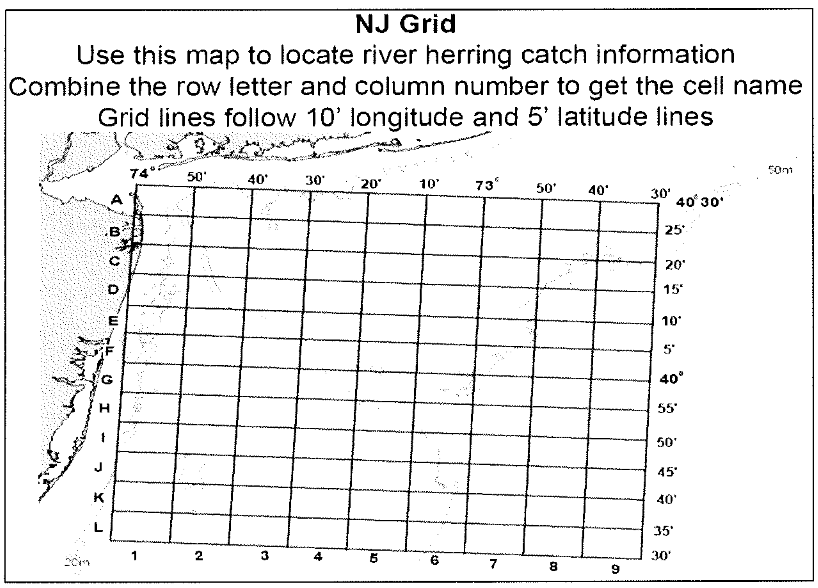

Figure 1. Area of focus for winter 2011 bycatch avoidance system. This handout was distributed to captains and used to communicate bycatch information.

Determine Thresholds to Classify Catches: Large catches of alosine in the mid-water trawl fishery are uncommon but account for the vast majority of alosine bycatch. From January 2000 through September 2010 the top 10% of tows with alosine bycatch (all tows with greater than 2,000kg of alosines) accounted for over 80% of NEFOP observed alosine mid-water trawl bycatch by weight (Figure 2). Thresholds were set to identify trips with these large tows (Table 1). Ratio thresholds were used instead of hard numbers to avoid biases created by small tow or trip sizes. A ratio of 1:81kg (Alosine: Target species) identified a trip in the top 10% of alosine bycatch events while a ratio of 1:425 suggested a lower bycatch event (Table 1). These ratios were used to classify trips as having high (1:80, greater than 1.25% alosines), low (1:425, less than 0.2% alosines), or moderate (between 1:80 and 1:425) amounts of bycatch.

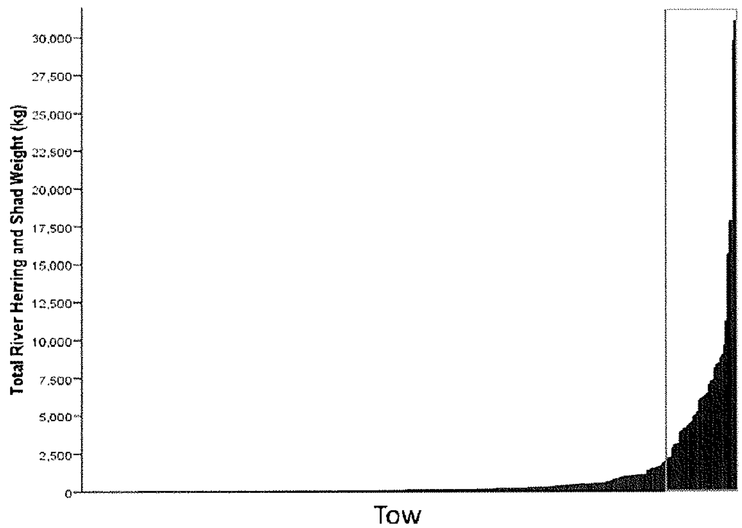

Figure 2. Northeast Fisheries Observer Program observed mid-water trawl tows from January 2000-Septermer 2010 ranked lowest to highest by amount of bycatch. Of the 343 tows shown in the figure the 35 tows with the most bycatch (grey box, top 10%) account for about 80% of observed bycatch.

Table 1. Of 72 trips sampled by Massachusetts Division of Marine Fisheries portside sampling from May 2008-July 2010, 55 had greater than 1kg of alosine bycatch. The six trips with the most bycatch (top 10%) all had greater than or equal to 2,000kg and a ratio less than 1kg of alosines:81kg of target species. Trips with a ratio greater than 1:425 all had less than 900kg of bycatch. Based on this, ratios of 1:80 (1.25%) and 1:425 (0.2%) were used to indicate high and low bycatch trips, respectively. Ratios between the two represented a buffer and identified a moderate trip.

Trip rank (total alosine bycatch)	Alosine:Target ratio (kg)
1	1:49
2	1:26
3	1:63
4	1:81
5	1:72
6	1:64
14-55	>1:425

Develop Communication System: Vessels notified the MA DMF and SMAST through their shipboard e-mail system of their departure and landing times, hail weights, landing ports and other information. These emails allowed MA DMF portside samplers to meet vessels at ports and sample entire offloads. Edited and expanded catch data were relayed by MA DMF staff to SMAST less than 48 hours after vessels completed their offloads. This information as well as tow locations (from MA DMF trip logs) and any available NEFOP information was then accumulated and transformed into a weekly or bi-weekly bycatch advisory that was emailed to vessels. Bycatch information was accessed and shared with captains using a coded, grid system of small cells approximately 5x8 nm that was distributed to them (Figure 1). Based on the pace of the fishery weekly or bi-weekly advisories via email were appropriate. Advisories classify areas as either having low, moderate, or high bycatch and contained other information such as weekly bycatch rates or catches of river herring outside of the areas of focus. Information was not reported for cells without tows, and advisories only included information less than two weeks old. Cumulative bycatch information is available through the SMAST website (http://www.smast.umassd.edu/Bycatch_Avoidance/index.php).

Using the methods described above (currently being reviewed for publication in Fisheries Research see Bethoney et al Submission), two additional avoidance systems were implemented in the fall of 2011 and winter of 2012. The fall 2011 system targeted an area in the Gulf of Maine identified as a high river herring bycatch area. Due to a limited amount of Atlantic herring Total Allowable Catch when the Atlantic herring spawning area closure was opened to mid-water trawl vessels, fishing activity occurred for approximately two weeks. Information indicating alosine bycatch was unlikely to occur at depths greater than 73m was circulated prior to the launching of the bycatch information system. In the winter of 2012, the scope of the avoidance system was expanded to include an area off Rhode Island that is heavily utilized by the mid-water fleet.

Progress towards Value at Grant Completion: Reduced bycatch

Year to year bycatch reduction should not be used as the primary metric to evaluate the success of this system to reduce bycatch because of potential changes in alosine populations levels, inter-annual variability in alosine catchability, and the nature of bycatch in the fishery (Figure 2). Alosine biomass fluctuations could increase or decrease bycatch amounts independent of avoidance measures. Overlap between mid-water trawl effort and alosine distribution varies inter-annually due to environmental factors and fleet behavior (Kritzer and Black 2009). A single trip within an avoidance area could contain a larger amount of alosines than observed during the entire previous year. If the location of this catch was shared with the fleet, the area was avoided and an area with low bycatch was identified, the system should not be classified as a failure. Based on these reasons evaluation methods should focus on intra-annual metrics of industry participation, consistent, low bycatch in identified areas, and reduced intra-annual bycatch rates (Abbot and Wilen 2010).

Winter 2011: High levels of cooperation by industry members, fishing patterns within the avoidance area, and the appearance of distinct spatial and temporal bycatch patterns within the avoidance areas suggests near-real time communications may have resulted in reduced alosine bycatch. Nine of the 12 active mid-water trawl vessels fishing for Atlantic herring and mackerel participated in the near-real time information system (two of the active mid-water trawl vessels were not recruited to participate because they were landing in New Jersey and primarily targeting squid but these vessels have participated in subsequent avoidance programs). Approximately 150 emails (indicating departing and landing location, dates and times as well as catch size) were received from these vessels and processing plant managers. A high percent of MA DMF trip logs (containing spatial, temporal and qualitative tow information) were completed by captains of participating vessels. Initial effort was focused in the northwest portion of the avoidance grid. Cells fished in this area were identified as having low or moderate bycatch until an advisory on February 17th identified cell E3 as having high bycatch (Figure 3). This area remained a high bycatch area throughout the fishery as E3 was reentered resulting in another high bycatch event and an additional advisory. After February 17th until the end of the fishery, the mean vector of observed effort was 115 degrees ± 35 degrees (r=0.75, n=8) and significantly different from the direction of the high bycatch area (270 to 360 degrees, Figure 4). The directions are in relation to a center point, placed at the lower right corner of cell E3 (Figure 4). This region, depicted in Figure 4, was chosen as the high bycatch region because it contained multiple moderate cells and a high cell that were identified early enough to expect a quantifiable reaction. The direction of mean effort after February 17th pointed towards the southeast region of the avoidance grid. This region of the avoidance grid was identified as a low bycatch area through an advisory issued on February 25th (Figure 3).

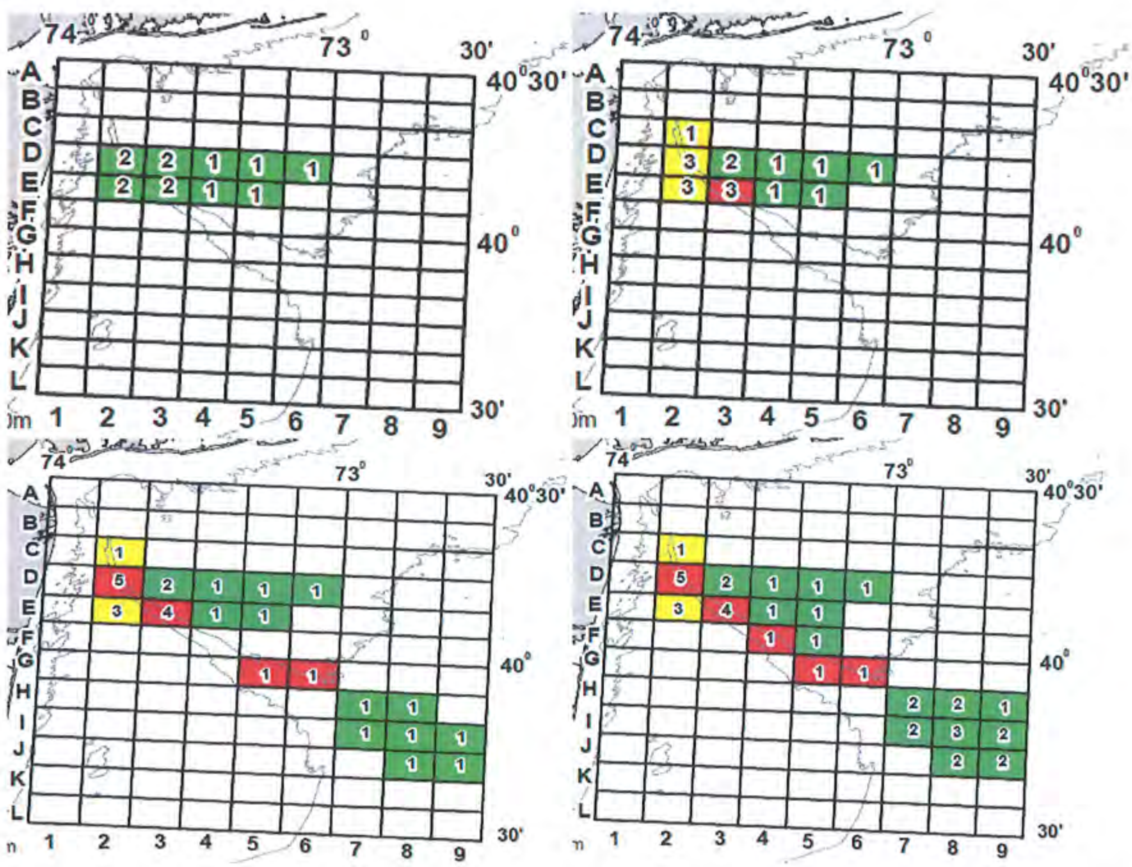

Figure 3. Cumulative bycatch information from 4 different time periods during the winter of 2011, from top left: 2/1, 2/17, 3/2, 4/1. Numbers inside cells indicate the number of tows

within each cell. Red indicates cells with high alosine bycatch while yellow and green indicate moderate and low respectively.

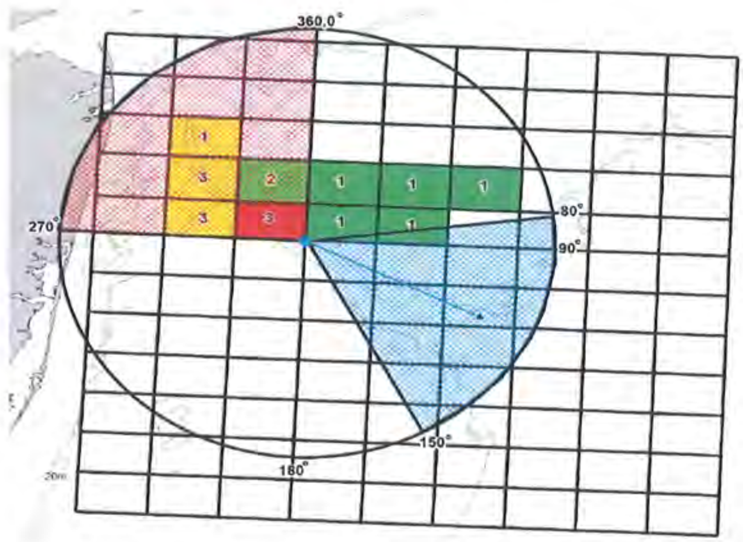

Figure 4. Cumulative alosine bycatch information through February 17th as well as mean direction vector of tow locations (blue arrow) and 95% confidence interval (blue cross-hatch) after February 17th. The vector direction relates to a center point (blue circle) placed at corner of the high bycatch area (red cross-hatch). Numbers inside cells indicate the number of tows within each cell. Red indicates cells with high bycatch while yellow and green indicate moderate and low, respectively.

The overall behavior of the vessels within the avoidance area provides evidence of cooperation (Figure 4). Though the significant shift in tow locations away from the high bycatch area to the southeast could be due to the availability target species, the timing of this shift coincides with bycatch advisories and avoidance of a known high bycatch area. Reentry into the high bycatch cell shows that target species were present in both the northwest and southeast portions of the avoidance grid simultaneously (Figure 3). In total 5 cells were classified as having high bycatch with only one possibly reentered

The appearance of distinct spatial and temporal bycatch patterns within the avoidance area suggests vessels can avoid large catches of alosines within the spatial scale used for this study. The percentages of effort, target catch, and alosine catch, based on MA DMF trip logs and port-sampling, in the northwest region (above row H, Figure 3) and southeast low bycatch region (row H and below, Figure 3) are displayed in Table 2. Based on the occurrence of high and moderate catches of alosines, it appears that alosines initially were absent from the northwestern part of the avoidance grid in large quantities but moved into this area as the winter progressed (Figure 4, Table 2). As effort shifted further offshore to the southeast later in the season, no high or moderate catches of alosines occurred, suggesting a high abundance of target fishes but not alosines. In addition, the only re-entry into a high bycatch cell, after about 8 days, resulted in another high bycatch event. This displays a degree of temporal stability in the bycatch pattern, which is essential to an effective avoidance system (Abbot and Whilen, 2010; Gauvin et al., 1996). Though the timing of migrations, exact routes and distribution undoubtedly varies from year to year, the catch pattern observed suggests mid-water trawl vessels can be moved to areas with low alosine bycatch and adequate levels of target species using the scale of this study (Table 2).

Table 2. Percentage of trips, target catch, and alosine catch in two separate regions of a voluntary bycatch avoidance area. For trips comprised of tows in both areas, estimated tow weights (by vessel captains) were used for the amount of target catch, while portside sampling amounts of alosines were assigned to a single tow identified by the Northeast Fisheries Observer Program.

Northwest Area			**Southeast Area**		
Trips	Target Catch	Alosine Catch	Trips	Target Catch	Alosine Catch
75%	75%	97%	25%	25%	3%

Intra-annual bycatch reduction was tested by comparing bycatch rates calculated from NEFOP data of participating vessels to a control group. The three active mid-water trawl vessels not in communication or completing MA DMF trip logs during the winter of 2011 were identified as the control group. Bycatch rates (alosine kg/ target mt) are a better measurement of bycatch reduction than total alosine catch, because rates are comparable across different catch and vessel sizes, reflect productivity, and match the definition of bycatch classifications given to SFC members. Though the avoidance systems only alters vessel behavior within areas of focus, the system assumes the majority of bycatch occurs within these areas. Incorporating bycatch rates from all areas could reveal if this assumption is correct and increase sample size. Intra-annual past seasonal (December-April) bycatch rates (2008-2010) of the control and participating vessels for each avoidance system was compared to test if bycatch rates were different before the avoidance system. No significant difference was found between the bycatch rates of control in participating vessels in any year (Figure 5, Mann-Whitney U Test's, all p-values >0.2). However, in 2011 the difference between the mean bycatch rate of participating and control vessels was greatest and the lack of significance is likely due to variance (sample size of control vessels was only 6 tows) and not similarity.

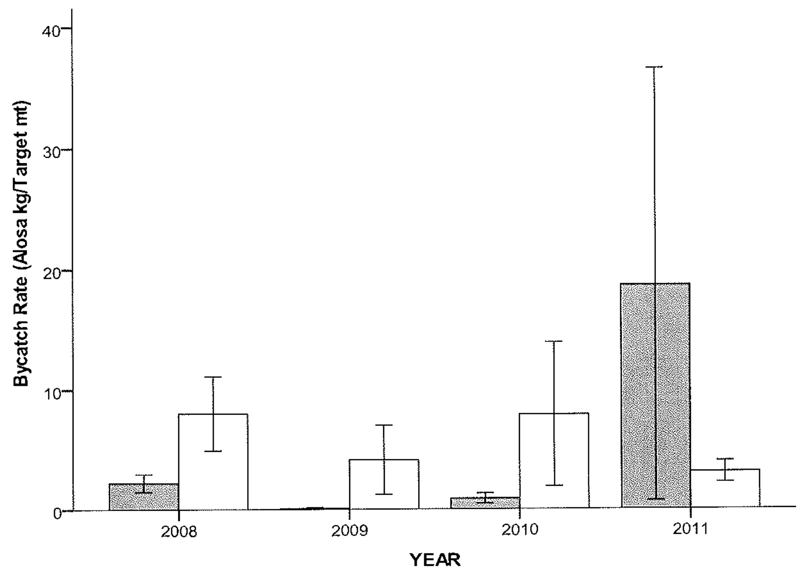

Figure 5. Bycatch rates, calculated from Northeast Fisheries Observer Program documentation of vessels that participated in the winter 2011 avoidance system (white) and those that did not (grey). Past bycatch rates during previous winter seasons (December-April) are also shown. Error bars are ± 1 standard error.

Fall of 2011: Similar to the winter of 2011, industry cooperation and the separation of alosines and target species suggests this system may have resulted in decreased alosine catch. Captains and on-shore managers continued to notify the project of landing and departure times as well as completing MA DMF trip logs. In addition, 10 of the 11 active mid-water trawl vessels participated in the avoidance. Initial effort occurred in the northeast part of the grid with low bycatch (Figure 6). This information was shared with the fleet and effort continued there for the remainder of the two-week fishery with little alosine bycatch. Fifteen of the seventeen Massachusetts landings during the avoidance system were sampled by the MA DMF. These trips landed approximately 3,000 mt of Atlantic herring and less than 3 mt of alosines (MA DMF, Unpublished data). The mean tow depth of participating vessels was significantly deeper than 73m (97m,1-tailed t-test P=.02) and greater than in previous years (ANOVA, Tukey Post Hoc Ps<.01, except 2009 P=.43). NEFOP data from this time period has been requested but not yet received so the bycatch rates of participating and non-participating vessels cannot be compared. In addition, this comparison may not be appropriate because only one active vessel did not participate.

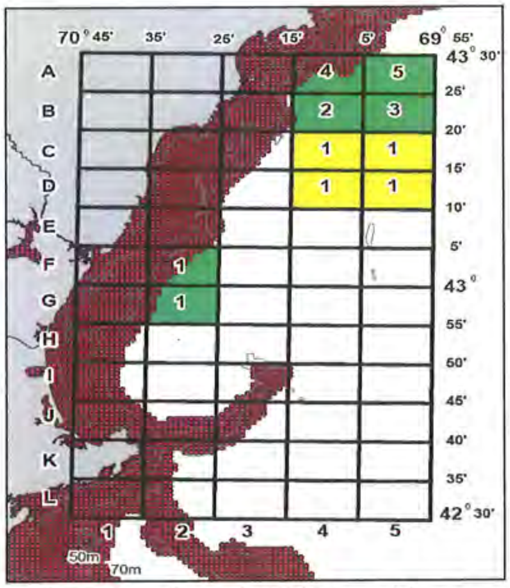

Figure 6. Cumulative bycatch information from fall 2011 avoidance system in the western Gulf of Maine. Numbers inside cells indicate the number of tows within each cell. Yellow and green indicate moderate and low bycatch events. Prior to the opening of the fishery, industry members were informed alosine bycatch was most likely to occur at depths less than 40 fathoms (73m, red dots).

Winter 2012: An avoidance system, covering an additional area off of Rhode Island, was run from mid-December until the Atlantic herring Management Area 2 was closed in mid-February (Figure 7). The results of this avoidance system have not been fully analyzed. Eight advisories were issued during this time period. Fleet participation was high (10 of 11 active vessels). After an advisory on February 4th identified high bycatch in the Rhode Island area, most participating vessels shifted their effort to the New Jersey area to pursue Atlantic mackerel and avoid river herring (D.Conneely personal comm.). One pair of vessels wanted to re-enter a cell classified as having high bycatch. This reentry was discussed and the captain felt, if he used a different technique, he could avoid catching river herring in this area. In his subsequent trip he returned to the high bycatch area and was able to reduce his bycatch percentage from 3.0% to 0.3% (MA DMF, Unpublished data).

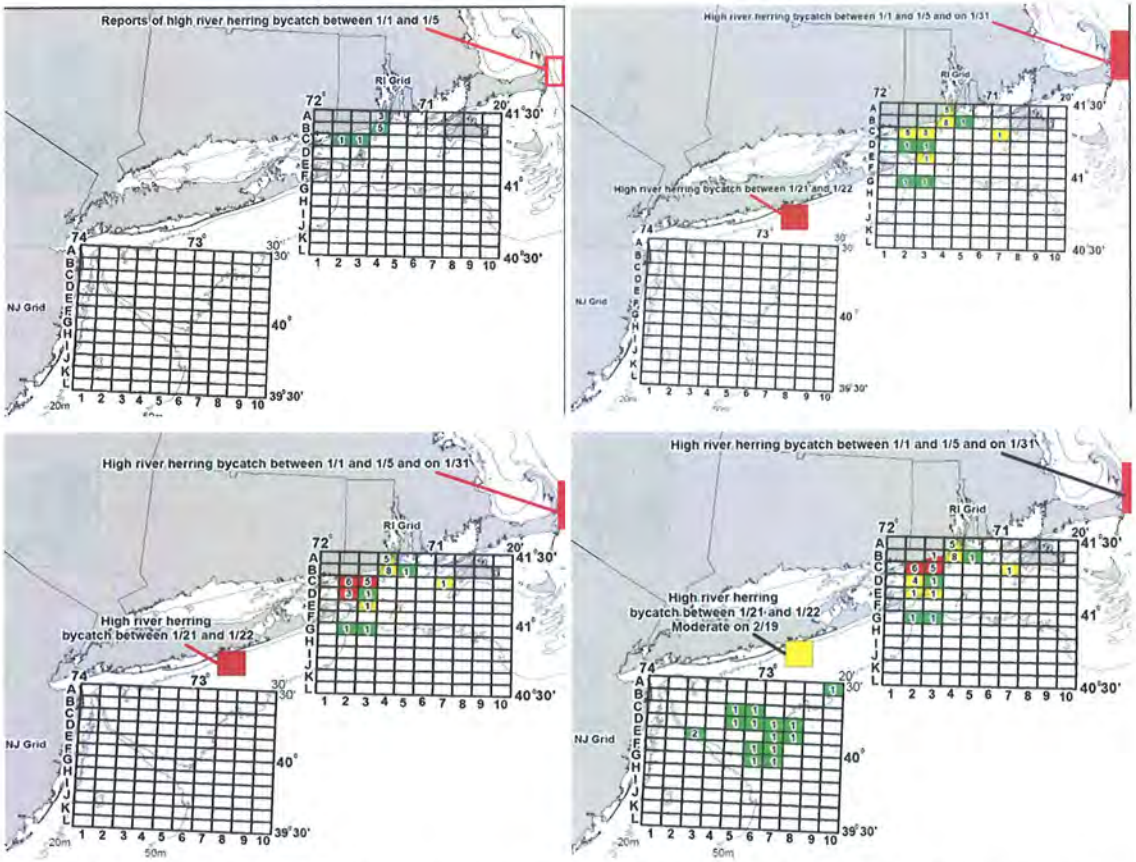

Figure 7. Cumulative bycatch information from 4 different time periods during the winter of 2012, from top left: 1/20, 2/1, 2/4,2/20. Numbers inside cells indicate the number of tows within each cell. Red indicates areas with high alosine bycatch while yellow and green indicate moderate and low respectively.

Overall, the amount and location of effort in the winter of 2012 was substantially different from the winter of 2011 (Figure 3, Figure 7). This difference was likely due to the availability of large schools of Atlantic herring in inshore waters that allowed the Area 2 quota to be taken by February 20th. In past years the vessels continued fishing for the target species in Area 2 until late March or early April and returned in December without reaching the area quota before the new fishing year. In addition, there was more effort off of Cape Cod and Long Island. No avoidance grid was placed near the backside of Cape Cod and disagreement about the spatial scale of information may have resulted in a high bycatch event. The moderate and high catches of alosines off of Long Island represent a bycatch pattern not previously document by any at sea monitoring program. In contrast, only low bycatch events were documented within the New Jersey avoidance area despite effort in similar areas at similar times (specifically cell E3, see Figures 3, 7). These points emphasize the importance of repeating this monitoring and avoidance effort for a third year as there is little past information to compare the amount, locations, and timing of alosine bycatch found in the previous two years. Further, the ability to conduct another avoidance system during the fall will reveal if previous results and bycatch patterns observed in 2011 are repeated 2012. Due to continued high participation by mid-water vessels, there is a lack of a "control" group (one vessel not participating). If bycatch rates cannot be compared between vessels receiving bycatch information and those that are not, a new method to directly test the effect of these systems on bycatch may be needed. If a direct measure cannot be established, it will be critical to build as much descriptive evidence for bycatch reduction as possible.

Progress towards Value at Grant Completion: Replicable bycatch reduction program (program usable for small mesh fisheries)

In the winter of 2012, with funding from The Nature Conservancy, we replicated our near-real time bycatch information system in the Rhode Island small mesh bottom trawl fishery. Please see attached Nature Conservancy final repot draft for detailed information.

Outreach

Scientific Presentations

6/27/2011: "Developing an alternative scale to address river herring bycatch in U.S. Northwest Atlantic mid-water trawl fisheries". Poster presentation at Reconciling Spatial Scales and Stock Structure for Fisheries Science and Management, Portsmouth, NH

9/3/2011: "An information system to avoid river herring (*Alosa pseudoharengus*, *Alosa aestivalis*) bycatch in the Northwest-Atlantic". Oral presentation at the American Fisheries Society annual meeting, Seattle, WA

9/3/2011: "River Herring and American Shad Bycatch Avoidance in Atlantic Herring and Mackerel Mid-Water Trawl Fisheries". Oral presentation at the American Fisheries Society annual meeting, Seattle, WA

10/27/2011: "River Herring and American Shad Bycatch Avoidance in Atlantic Herring and Mackerel Mid-Water Trawl Fisheries". Oral presentation at the Northeast Regional Collaborative Research Conference, Portsmouth, NH

9/27/2012: "Quantifying and reducing river herring bycatch in the U.S. northwest pelagic trawl fisheries" Abstract submitted to ICES Annual Science Conference, Bergen, Norway

Scientific Publications

"Developing a fine scale system to address river herring (*Alosa pseudoharengus*, *A. aestivalis*) and American shad (*A. sapidissima*) bycatch in the U.S. Northwest Atlantic mid-water trawl fishery" Under review by Fisheries Research

Management/Public Presentations

12/20/2011: Oral presentation to the NEFMC Herring Oversight Committee and Advisory Panel

6/30/2011: Poster presentation to NEFMC Plan Development Team

10/11/2011: Oral presentation to MAFMC

2/7/2012: Oral presentation to ASMFC Shad and River herring Management Board

Management/Public Publications

Avoidance system listed as possible river herring bycatch reduction alternative in the NEFMC Amendment 5 to the Atlantic herring Fishery Management Plan

Information from project included in NEFMC Amendment 5 Environmental Impact Statement

Avoidance system listed as possible river herring bycatch reduction alternative in the MAFMC Amendment 14 to the squid, mackerel, butterfish Fishery Management Plan

4/2/2012: "Experts team up to reduce bycatch", New Bedford Standard Times.

5/2012: "Avoidance program IDs river herring hot spots", Commercial Fisheries News

Literature Cited

Abbott JK and Wilen JE. 2010. Voluntary cooperation in the commons? evaluating the sea state program with reduced form and structural models. Land Econ 1(86):131-54.

Gauvin JR, Haflinger K, Nerini M. 1996. Solving bycatch: Considerations for today and tomorrow - implementation of a voluntary bycatch avoidance program in the flatfish fisheries of the eastern Bering sea. Fairbanks, AK: Alaska University. Report nr 96-03. 79 p.

Kritzer J. and Black P. 2009. The oceanic distribution of alewives: An examination of seasonal and interannual patterns, and bycatch rise. Challenges for diadromous fishes in a dynamic global environment; 6/18/07; Halifax. Bathesda,MD: American Fisheries Society. 936 p.

NEFMC (New England Fisheries Management Council). 2012. Draft amendment 5 to the Atlantic herring FMP.

O'Keefe C. E., DeCelles G., Georgianna D., Stokesbury K. D. E. and Cadrin S. X. 2010. Confronting the bycatch issue: An incentive-led approach to maximizing yield in the US sea scallop fishery. ICES CM; September 20-24; Nantes,France. . 4 p.

Project Objective: Refine "hot spot" data and develop predictive model

Through discussions with Drs. Eric Palkovacs and Andre Boustany at the Duke University Marine Laboratory (who are working on a National Fish and Wild Foundation project with a similar objective), it was agreed that they would focus on predicting river herring distributions throughout all seasons, while our project would focus on predicting distributions during the winter and applying these findings to bycatch reduction. To achieve this object, we are testing if oceanographic features can be used to indicate areas with a high probability of large catches of alosines, Atlantic herring and Atlantic mackerel. The National Marine Fishery Service (NMFS) bottom trawl and NEFOP mid-water trawl data sets contain catch at sea data useful for achieving this goal. Restricting our analysis to the winter allows us to focus on the region (south of Cape Cod, Massachusetts) and time where the NMFS bottom trawl survey and the mid-water trawl fishery overlap, where the most alosine bycatch occurs, and reduces seasonal and regional factors. Based upon the environmental measurements taken at sea by the NMFS bottom survey and past studies, the variables sea surface temperature, bottom temperature, the difference between sea surface and bottom temperature, bottom salinity, surface salinity and depth were examined for a relationship to catch at sea.

If correlations are found between environmental factors and catch at sea, results could be used to identify specific pathways or areas associated with each species. The utility of this information to reduce bycatch could then be tested using the NEFOP mid-water trawl dataset and the Finite-Volume Community Ocean Model (FVCOM). FVCOM is a verified prognostic coastal ocean circulation model that incorporates realistic time-dependent temperature projections and can be used to identify oceanographic conditions on a daily basis from 2000-2009 (Chen et al. 2003, Chen et al. 2006, Cowles 2008). FVCOM environmental data was joined to NEFOP catch at sea data through at stepwise process in ArcGIS 10. Hindcast environmental conditions were mapped using natural neighbor interpolation to create a continuous surface of temperature, salinity and depth values from the FVCOM data points. Natural neighbor interpolation uses continuous, area-based weighted averages to create a structured surface of points based on existing data points and does not interpret trends (therefore all values are within the range of real data). The result is a smoothed distribution, making it appropriate for variables that are influenced by adjacent areas (Tsai et al. 2005). NEFOP catch-at-sea data was then be plotted with an area of uncertainty for catch location. Catch locations were assigned a catch radius equal to the average straight line tow distance because most mid-water trawl vessels turn during a tow; eliminating the usefulness of the tow end location. The NEFOP catch locations were then joined to the environmental conditions they overlapped with in time and space. This created a new dataset that could be used to compare much bycatch and target catch was within predicted alosine "hot spots".

Progress towards Value at Grant Completion: Predictive maps

For all five species the NMFS data set is dominated by samples without catch but that may contain relevant environmental information. Based upon this and graphs of abundance and presence/absence of each species against environmental variables, we attempted to use logistic regressions to find correlations between environmental variables and catch at sea. Logistic regression models can provide equivalent qualitative results as more complex statistical approaches (Fletcher et al. 2005, Lewin et al. 2010). Logistic regressions relate binary response variables to predictor variables by identifying a probability of occurrence as a function of the predictor variables (Hosmer and Lemeshow 2000). Catch at sea of alewife, blueback herring, American shad, Atlantic herring, and Atlantic mackerel was transformed into a binary variable by classifying the fishes as present or absent in a tow or by using a threshold amount. However, catch at sea patterns within the NMFS bottom trawl dataset fitted logistic regression models poorly. When environmental variables were transformed, through squaring or square rooting, results did not make sense from a biological perspective despite indications of a good fit to the logistic regression model. Therefore, we have changed our approach and are now using a likelihood ratio test (G test). The G-test can be used to test if the probability of catch at sea is uniform across an environmental variable range. Further, if the initial test yields significant results, the G-test statistic is additive allowing for the results of several G-tests to be summed. This allows for ranges of equal probability of catch to be identified (Sokal and Rohlf 1995). Using this method we have identified several ranges of environmental variables with significantly different probabilities of alewife catch within the NMFS bottom trawl survey (Table 3). In addition, the probability of Atlantic herring catch differs with ranges of sea surface and bottom temperature (Table 3). We plan to continue using the G-test method to test the remaining environmental variables and species of interests. These result could then be analyzed and combined to create predictive maps of where alosines are most likely occur during the winter. The utility of this information to reduce bycatch could then be evaluated by comparing the environmental ranges associated with alosines to Atlantic herring or mackerel and catch within the NEFOP/FVCOM database .

Table 3. Preliminary results of G-test analysis to identify marine preferences for alewife, blueback herring, American shad, Atlantic herring and mackerel. The probability of catch within a given range is homogenous, while the probability of catch between groups is significantly different (Unplanned tests for homogeneity with Dunn-Šidák Correction). Blank spaces indicate a repeated cell value.

Feature	Species	Range	Proportion Present
Sea Surface Temp. (°C)	Atlantic herring	1-3,5-7	0.60
		4	0.52
		8-9	0.25
		10-11	0.05
	Alewife	1-6	0.51
		7	0.37
		8-9	0.20
		10-11	0.05
Bottom Temp. (°C)	Atlantic herring	6-7	0.70
		1-5	0.56
		8	0.42
		9	0.25
		10	0.12
		11-13	0.05
	Alewife	1-7	0.47
		8-9	0.25
		10-14	0.15
Sea Surface-Bottom Temp. (°C)		-8--4,-2-0	0.36
		1-2,-3	0.28
		3	0.05
Surface Salinity (PPT)		20-30,32-33	0.45
		31,34	0.25
		35	0.03
Bottom Salinity (PPT)		24-33	0.45
		34	0.34
		35	0.16
		36	0.09
Depth (m)		41-80	0.46
		0-30,101-110	0.33
		31-40,81-100,111-291	0.24

Outreach

Scientific Presentations

6/26/2012: "The utility of environmental predictors of catch to reduce bycatch in the northwest Atlantic mid-water trawl fishery" Abstract accepted to The Relative Importance of Fishing and the Environment in the Regulation of Fish Population Abundance, A Symposium of the American Institute of Fishery Research Biologists, New Bedford, MA

Literature Cited

Chen C, Beardsley R, Cowles G. 2006. An unstructured grid, finite-volume coastal ocean model (FVCOM) system special issue entitled "advances in computational oceanography". Oceanography 19(1):78-89.

Chen C, Liu H, Beardsley R. 2003. An unstructured grid, finite-volume, three-dimensional primitive equations ocean model: Application to coastal ocean and estuaries. J Atmos Ocean Tech 20(1):159-86.

Cowles G. 2008. Parallelization of the FVCOM coastal ocean model. Int J High Perform C 22:177-93.

Fletcher D, MacKenzi D, Villouta E. 2005. Modelling skewed data with many zeros: A simple approach combining ordinary and logistic regression. Environ Ecol Stat 12:45-54.

Hosmer DW and Lemeshow S. 2000. Applied logistic regression. 2nd ed. New York: Wiley-Interscience Publications.

Lewin WC, Freyhof J, Huckstorf V, Mehner T, Wolter C. 2010. When no catches matter: Coping with zeros in environmental assessments. Ecol Indic (10):572-83.

Sokal RR and Rohlf FJ. 1995. Analysis of frequencies. In: Biometry. 3rd ed. New York: W.H. Freeman and Company. 685 p.

Tsai FT, Sun N, Yeh WW. 2005. Geophysical parameterization and parameter structure identification using natural neighbors in groundwater inverse problems. J Hydrol 308:269-83.

Project Objective: Expand MA DMF Port-sampling Program

Collaboration with the SFC has been critical to the success of the portside sampling program. The 11 active SFC mid-water trawl vessels represent a significant portion of the Atlantic mackerel and herring mid-water trawl fleet. For example, 99% of NEFOP documented mid-water trawl Atlantic mackerel catch by weight in 2010 occurred on vessels that were part of the SFC (2 vessels observed in 2010 are no longer active). A fleet communication system was created in October 2010; vessels notify the MA DMF and SMAST through their shipboard e-mail system of their departure and landing times, hail weights and landing ports. Notification of landing times and other information allows portside samplers to easily meet vessels at ports and sample entire offloads. Additionally, captains voluntarily complete MA DMF trip logs that reveal tow locations, weights and other information.

The MA DMF port sampling program was a reliable and timely source of catch composition and, in general, the proximity of tows within a trip or the lack of bycatch made trip level catch information equivalent to tow by tow information. Coordination between the MA DMF and the NEFOP has maximized the number of trips observed and the speed of information exchange with the added ability to address uncertainties created by trip level catch information. Without the higher coverage rates of the portside sampling program the second highest catch of alosines observed during the winter 2011 avoidance system would have gone unnoticed. Without the tow by tow information of the NEFOP, a low bycatch area would have been misclassified as a high bycatch area.

The MA DMF completed a pilot comparison of NEFOP sea sampling estimates of river herring bycatch to portside sampling estimates. This study was presented to the Atlantic herring Plan Development Team (PDT) and, in contrast to a previous study, found good agreement between portside and at sea estimates (for detailed methods see attached Support Document B). However, this analysis only included 30 co-sampled mid-water trawl trips. Including co-sampled trips since the completion of the study and after June 30, 2012 would make the analysis more robust.

Progress towards Value at Grant Completion: 50% fleet coverage

Since the implementation of the project on October 1, 2010 MA DMF has sampled 13 of the 14 vessels that have landed in Massachusetts ports, and 164 out of 328 trips (as of 5/23/12).

Outreach

Management/Public Presentations

Information gathered by the MA DMF port-sampling program is used to inform MA DMF employees on Regional Councils, Plan Development Teams, and through other decision making avenues.