Project Period	03/01/2010 - 06/30/2012
Award Amount	$144,538.70
Matching Contributions	$173,821.00
Project Location Description (from Proposal)	Sites will be located in western Cape Cod Bay and outer Buzzards Bay, Massachusetts. These two areas represent different lobster stocks and have varying environmental and fishery conditions.
Project Summary (from Proposal)	Assess mortality of lobsters and other marine species due to "ghost fishing". Project will also compare the rate of gear loss, trap degradation, and resource impacts north and south of Cape Cod, Massachusetts.
Summary of Accomplishments	In May 2010, we set and “abandoned” two baited six-pot trawls near Manomet Point, Cape Cod Bay and Penikese Island, Buzzards Bay, Massachusetts. Additional trawls were set at each location in November of 2010 and June of 2011. All trawls were set in approximately 10-m of water. SCUBA divers surveyed the gear twice a month during the months of April through November and once a month from December through March. Biological information from lobsters was collected as well as information on trap condition, species catch composition, and mortality of trapped animals. A total of 33 dive survey days were conducted in Cape Cod Bay from May 2010 through November 2011. In Buzzards Bay, 41 dive survey days were completed by the end of August 2012. Additional dive days were spent at each location to survey for suitable sites and to check the gear once it was deployed. A total of seventy-eight sea days were conducted for this project. Even though the grant period has ended, this gear is still being surveyed because it has not yet disabled and continues to catch and kill lobsters and bycatch. Additionally, we composed and distributed a confidential and anonymous self-administered mail questionnaire to the lobster fishing industry to gather information on the frequency and reasons for gear loss. In January 2011, the three-page survey was sent to all recently active Massachusetts commercial lobster permit holders with 2009 landings.
Lessons Learned	One of the primary lessons learned from this study is that ghost traps have the ability to continue to fish much longer than previously thought. Current regulations specify several methods for creating an opening to allow the escape of organisms within one year of a trap being lost. We have shown that the most commonly used method, the addition of release panels attached by biodegradable uncoated ferrous hog rings, results in traps capable of fishing for over two years if they are not hauled or exposed to storm activity. Traps set in deep water or sheltered environments may continue to catch lobster and bycatch species for an extended period of time due to a lack of oxidation of the metal while in the water and attachment of biofouling organisms over the panels.

Conservation Activities	Assessment of mortality rates of American lobster
Progress Measures	Other (Calculate estimate of mortality due to DFG)
Value at Grant Completion	75
Conservation Activities	Determine degradation rate of lost lobster traps

Progress Measures	Other (Calculate estimate of time for escape panels to release)
Value at Grant Completion	75
Conservation Activities	Determine rate and reasons for loss of lobster traps
Progress Measures	Calculated estimate of amount of total DFG in an area from a fishery
Value at Grant Completion	75

Conservation Outcome(s)	Assessment of mortality rates of American lobster and bycatch species
Conservation Indicator Metric(s)	Catch rate of derelict gear (ie. animals/gear type/year)
Baseline Metric Value	0
Metric Value at Grant Completion	75
Long-term Goal Metric Value	75
Year in which Long Term Metric Value is Anticipated	2011
Conservation Outcome(s)	Impact of ghost fishing on American lobster fishery
Conservation Indicator Metric(s)	Calculated mortality rate to target species (as caused by debris)
Baseline Metric Value	0
Metric Value at Grant Completion	75
Long-term Goal Metric Value	75
Year in which Long Term Metric Value is Anticipated	2011
Conservation Outcome(s)	Continued fishing of lost traps
Conservation Indicator Metric(s)	# of gear modifications adopted by fishermen
Baseline Metric Value	0
Metric Value at Grant Completion	75
Long-term Goal Metric Value	75
Year in which Long Term Metric Value is Anticipated	2013

Final Programmatic Report Narrative

Instructions: Save this document on your computer and complete the narrative in the format provided. The final narrative should not exceed ten (10) pages; do not delete the text provided below. Once complete, upload this document into the on-line final programmatic report task as instructed.

1. Summary of Accomplishments

In four to five sentences, provide a brief summary of the project's key accomplishments and outcomes that were observed or measured.

The results from our study indicate that the biodegradable ghost panels required on all lobster traps in the U.S. lobster fishery are not effective. After over two years in the water, 66% of the ghost pots deliberately set in Buzzards Bay are still fishing. We have demonstrated that ghost traps continue to catch and kill lobsters and bycatch species long after the gear has been lost. We have identified storms, ship traffic and conflict with other types of fishing gear as the primary mechanisms for gear loss, resulting in an estimated 1% to 5% annual rate of gear loss in the Massachusetts lobster fishery. Ghost fishing by derelict lobster traps represents a moderate threat to the management of the Massachusetts lobster fishery and resource.

2. Project Activities & Outcomes

Activities

- Describe and quantify (using the approved metrics referenced in your grant agreement) the primary activities conducted during this grant.

In May 2010, we set and "abandoned" two baited six-pot trawls near Manomet Point, Cape Cod Bay and Penikese Island, Buzzards Bay, Massachusetts. Additional trawls were set at each location in November of 2010 and June of 2011. All trawls were set in approximately 10-m of water. SCUBA divers surveyed the gear twice a month during the months of April through November and once a month from December through March. Biological information from lobsters was collected as well as information on trap condition, species catch composition, and mortality of trapped animals. A total of 33 dive survey days were conducted in Cape Cod Bay from May 2010 through November 2011. In Buzzards Bay, 41 dive survey days were completed by the end of August 2012. Additional dive days were spent at each location to survey for suitable sites and to check the gear once it was deployed. A total of seventy-eight sea days were conducted for this project. Even though the grant period has ended, this gear is still being surveyed because it has not yet disabled and continues to catch and kill lobsters and bycatch.

Additionally, we composed and distributed a confidential and anonymous self-administered mail questionnaire to the lobster fishing industry to gather information on the frequency and reasons for gear loss. In January 2011, the three-page survey (Figure 1) was sent to all recently active Massachusetts commercial lobster permit holders with 2009 landings. A total of 884 surveys were sent to those who had fished in Lobster Management Area 1 (LMA 1) (Gulf of Maine), LMA OC (Outer Cape Cod), LMA 2 (Southern New England), or LMA 3 (Offshore) (Figure 2). Two reminder postcards (Figure 1) were sent in the weeks following the survey mailing to encourage participation. Responses for each question were summarized by LMA and for some topics additionally summarized by smaller region (Cape Cod Bay and Buzzards Bay) to reflect the dive survey areas.

- Briefly explain discrepancies between the activities conducted during the grant and the activities agreed upon in your grant agreement.

For the mail survey component of the project, there were no deviations from the grant agreement plans. Response by the industry to the derelict/ghost lobster gear mail survey was favorable with a particularly high response rate, thus we did not need to supplement data collection through alternative methods.

In the grant agreement we planned to survey four 5-pot trawls over the course of two years at each of the two locations. We instead set four 6-pot trawls so that we could alternate two different escape vent shapes, rectangular and circular. Both vent shapes are legally fished in Massachusetts waters, and are known to have different retention rates for bycatch such as crabs and finfish. The longer trawl with three alternating vents of each shape made for more representative comparisons. Originally, we also agreed to survey the gear until December 2011. Since the Buzzards Bay gear was still actively fishing as of December 2011, we requested and received a no-cost extension for additional data collection through June 2012. Even after this date, the gear in Buzzards Bay continued to fish and we are currently continuing to monitor the gear.

In the event that the gear fished longer than the duration of the study, we agreed to fish "seasoned traps of a known age" to assess how long they would fish. This plan was aborted due to the numerous unknown variables that could have been introduced by using "seasoned traps". Instead, we have continued to monitor the original gear that was deployed for this study well past the granting period.

Outcomes

- Describe and quantify progress towards achieving the project outcomes described in your grant agreement. (Quantify using the approved metrics referenced in your grant agreement or by using more relevant metrics not included in the application.)

Current Massachusetts regulations (322 MA CMR 6.02) require that every lobster (*Homarus americanus)* pot has at least one biodegradable ghost panel that is designed to release within one year. We tested the two most common methods of constructing a ghost panel; 1) attaching the escape vent on the side of the trap using biodegradable hog rings, and 2) cutting a hole of at least 3 ¾ inches by 3 ¾ inches in the mesh of the door and re-attaching it with biodegradable hog rings. Although other methods of fastening ghost panels are allowed, biodegradable, uncoated, ferrous metal hog rings are the standard. There are no requirements as to how many biodegradable hog rings may be used. We used the conventional application used by Massachusetts commercial lobstermen, which is a biodegradable ring to secure each of the lower escape vent ghost panel corners and three biodegradable rings to secure three sides of the lid ghost panel. Non-biodegradable metal clips, plastic clips, or stainless non-biodegradable hog rings are used to attach one side of each type of ghost panel, which allow the ghost panel to swing open once the biodegradable rings sufficiently degrade.

In Cape Cod Bay, only two traps out of eighteen (10.5%) that were set in 2010 lasted longer than 365 days. On average, the gear was last observed fishing 269 (s.e. =26.7) days after set (DAS), with a range of 76 to 487 days. Half of the traps were originally disabled for reasons other than the release of the biodegradable hog rings on the ghost panel. Storm events in Cape Cod Bay subjected the gear to heavy wave action, causing the gear to move and to be battered against rocks. This caused the bungees that hold the door closed to snap on some traps. The majority of (14 of the 18, or 77.8%) escape vent ghost panels from the Cape Cod Bay gear released during the course of this study. Of the escape vent panels that did release, they ranged from 203 to 487 DAS. Only five of the 18 (27.8%) lid ghost panels released during the survey, they also ranged from 203 to 487 DAS. Ghost panels of both types were in the water for as many as 537 DAS and never released. Of the traps that became disabled, most of them stopped fishing after major storm events. None of the traps that were set in June 2011 were disabled as of 16 November 2011, when the gear was hauled out of the water at 175 DAS. None of the traps set in Cape Cod Bay during the spring of 2011 were included in the panel release analysis due to the short duration the gear was in the water, but the trap content data were included in the catch and mortality estimates.

The Buzzards Bay gear was not subjected to heavy storm activity, and as such, fished longer than the gear in Cape Cod Bay. Only 6 of the 18 (33%) traps in Buzzards Bay disabled, and this occurred between 505 and 824 DAS. All of the traps that disabled were due to release of a ghost panel. Of the 36 ghost panels on the 18 traps set in 2010, only six had disabled (16.7%) after as many as 824 DAS. Five of the six ghost panels were escape vents rigged with biodegradable hog rings and only one was a lid vent. The trap with the "disabled" lid vent continued to kill Jonah crabs even after the biodegradable hog rings had released, as the panel's non-biodegradable clips were crimped too tightly and the vent did not fully open as designed. We encountered a few traps with lids that became slightly bent open over the parlor section of the trap. This left an approximate 3" gap between the lid and the trap, decreasing efficiency of the trap. There were also a few occasions when some of the traps were found upside down, even though there were no storm events that could explain the movement. The cause of the bent lids is unknown. There is a population of gray seals *Halichoerus grypus* in the area and they were frequently seen during the survey. We speculate that the seals were attempting to gain access to fish captured in the trap, rolled the traps and bent the lids. The fourth trawl, added in June of 2011 was not included in gear analysis, although it has been disabled. Sometime after 377 DAS, the gear was disabled by someone who opened the lid and diver doors and cut the trawl line. A gaff was also found hooked into one of the traps, which means the gear was likely hauled to the surface. All four trawls were used to calculate catch and mortality rates.

A total of 267 individual lobsters were observed in Cape Cod Bay. This equates to a nominal catch rate of 0.052 lobsters $trap^{-1}day^{-1}$ (s.e. = 0.007), or 18.994 lobsters $trap^{-1}year^{-1}$ (s.e. = 2.482). Individual lobsters were tagged, allowing us to determine which lobsters were new to the trap on each observation. Other species of commercial interest found in the traps included Atlantic cod *Gadus morhua*, Jonah crab *Cancer borealis*, Atlantic rock crab *Cancer irroratus*, winter flounder *Pseudopleuronectes americanus*,and tautog *Tautoga onitis*. All traps showed an initial decrease in lobster catch shortly after all the bait was gone, but all trawls later showed an increase in catch weeks and months after the bait had been exhausted. Catch rates in the three trawls that were set in the spring (two in the spring of 2010 and one in the spring of 2011) increased during the summer months to the point where they caught just as many lobsters as they had in the spring with bait (Figure 3**)**. When trawl-four was hauled out of the water, even though the bait had long been exhausted, its catch rate was greater than when it was originally set and bait was present. The catch trends of the ghost traps followed normal seasonal catch trends of the commercial fishery (Dean 2010). Fall and early winter storms caused most of the traps to stop fishing; therefore the amount of new lobsters fell dramatically.

A total of 68 lobsters were observed dead in the Cape Cod Bay ghost traps (Table 1**)**. The mortality rate of lobsters was 0.013 $trap^{-1}day^{-1}$ (s.e. = 0.002), or 4.754 $trap^{-1}year^{-1}$ (s.e. = 0.830). Both sublegal and legal sized lobsters were killed in the traps (Figure 4**)**. Most mortalities were of lobsters close to minimum legal size (83 mm), but ranged from 63 mm to 113 mm. Thirty-five percent of the mortalities were below minimum legal size. Lobsters were the second most commonly found dead animal, following Jonah crabs. Jonah crabs had a mortality rate of 0.028 $trap^{-1}day^{-1}$ (s.e. = 0.008), or 10.322 $trap^{-1}year^{-1}$ (s.e. = 3.102).

A one-way ANOVA comparing mortality rates showed that circular vents killed significantly more Jonah crabs ($p < 0.001$), rock crabs ($p < 0.05$), and winter flounder ($p < 0.05$) than rectangular vents. Cape Cod Bay Jonah crabs averaged 0.054 mortalities $trap^{-1}day^{-1}$ in circular vented traps compared to only 0.002 crabs $trap^{-1}day^{-1}$ in rectangular vents. Rock crabs and winter flounder both average 0.004 mortalities $trap^{-1}day^{-1}$ in circular vented traps and less than 0.001 $trap^{-1}day^{-1}$ in rectangular vents. There was a no significant difference in mortality rates of lobster between the two trap vent shapes in Cape Cod Bay, which averaged 0.015 $trap^{-1}day^{-1}$ in circular vented traps and 0.011 $trap^{-1}day^{-1}$ in rectangular vented traps.

Two-hundred and four individual lobsters were observed in the Buzzards Bay ghost traps through the end of 2011, which equates to a nominal catch rate of 0.023 lobsters $trap^{-1}day^{-1}$ (s.e. = 0.003), or 8.456 lobsters $trap^{-1}year^{-1}$ (s.e. = 1.254). The number of new lobsters found in traps set in the spring showed similar trends, all three traps had their highest catch rates approximately one month after they were set (Figure 5). The catch picked up slightly in the summer, but generally stayed low. The trawl that was set in the fall had its highest catch rate immediately after it was baited and set, and then dropped off precipitously. Tautog were frequently observed in the Buzzards Bay traps. All of the trawls began to catch large numbers of tautog in the spring and retained high numbers until late summer (Figure 6). The trawl set in the fall of 2010 had over 60 tautog during one observation. Some circular vented traps had over 20 tautog during one observation.

Buzzards Bay ghost traps are still fishing and continue to kill lobsters and other species. By the end of the 2011 field season, the Buzzards Bay traps had killed 108 lobsters, which was more than any other species (Table 2). Seventy-three percent of lobster mortalities were sub-legal sized animals (< 86 mm). Mortalities ranged from 60 mm to 94 mm (Figure 7). The lobster mortality rate was 0.010 $trap^{-1}day^{-1}$ (s.e. = 0.0015), or 3.56 $trap^{-1}year^{-1}$ (s.e. = 0.53). Other species commonly observed dead in the traps included Jonah crab and tautog which totaled 73 and 31 mortalities, respectively. Jonah crabs had a mortality rate of 0.008 $trap^{-1}day^{-1}$ (s.e. =0.003), or 3.042 $trap^{-1}year^{-1}$ (s.e. =1.221), while tautog had a mortality rate of 0.003 $trap^{-1}day^{-1}$ (s.e. =0.0008), or 1.06 $trap^{-1}year^{-1}$ (s.e. =0.279).

A one-way ANOVA comparing the mortality rates of the two vent shapes showed that there were significantly more mortalities associated with circular vents than for rectangular vents for Jonah crabs ($p < 0.001$), and tautog ($p < 0.001$) in Buzzards Bay. There was no significant difference in mortality rates of lobster between the two trap vent shapes in Buzzards Bay, which averaged 0.009 lobster mortalities $trap^{-1}day^{-1}$ in circular vented traps and 0.010 $trap^{-1}day^{-1}$ in rectangular vented traps. Circular vented traps killed 0.016 Jonah crabs $trap^{-1}day^{-1}$ and 0.005 tautog $trap^{-1}day^{-1}$, whereas rectangular vents killed 0.001 Jonah crabs and tautog $trap^{-1}day^{-1}$.

The confidential self-administered mail survey was an effective tool for gathering information on rates and reasons for gear loss in the Massachusetts lobster fishery. Survey response was high, with a majority of surveys received within the first month (Figure 8) indicating that the presence of derelict gear is a topic of interest among Massachusetts lobster fishers. Of the 884 surveys mailed, 520 surveys were returned for an overall 59% response rate. The response rate varied between 53% and 61% by LMA (Figure 9) indicating good representation from all four regions of the Massachusetts lobster fishery (Gulf of Maine, outer Cape Cod, southern New England, and offshore), and making it possible to calculate reliable estimates of traps loss by LMA.

By utilizing the reported average number of traps lost per fishermen in each LMA, we were able to determine the total number of traps lost by active permit holders. The total number of traps lost by Massachusetts lobstermen in 2010 was between 6,997 and 16,992 based on survey response rates. This represents a loss of 1.8% to 4.5% of lobster traps fished annually in Massachusetts, and is comparable to the loss range of 1 to 5% that fishermen from all four LMAs cited most commonly (Figures 10 - 13). Comparison of the average number of traps lost by LMA in 2010 revealed that the most individual traps lost per fisherman occurred in LMA 3 (19 to 46), followed by LMA OC (14 to 34), then LMA 1 (10 to 23), and LMA 2 (8 to 21) (Table 3). This trend is consistent with the total cost of gear loss in 2010, which averaged a staggering $3,860 to $7,140 per LMA 3 fisherman, followed by $1,410 to $2,950 per LMA OC fisherman, $640 to $1,570 per LMA 1 fisherman, and $570 to $1,500 per LMA 2 fisherman (Table 4). In all areas, the majority of respondents reported that the amount of gear lost in 2010 was "typical" (Table 5), thus confirming that these trends are representative of recent fishing years. When scaled up to the entire Massachusetts lobster fishery, the total cost of gear loss ranged between $676,000 and $1,587,000 annually. This figure does not incorporate the value of lost landings of lobsters, crabs, and finfish retained within the unfished derelict traps.

A comparison of trap loss rates by trawl configuration, irrespective of LMA, revealed that maximum trap loss rates for those fishing singles and pairs was higher on average (roughly 20% loss) than for those fishing three or more traps per trawl (8.7%) (Table 6). Additionally, when total trap loss was partitioned by LMA, LMA 1 represented 78% of the trap loss while having 80% of the active fishers; LMA OC had 12% of the trap loss with 8% of the active fishers; LMA 2 represented 7% of the trap loss with 10% of the active fishers, and; LMA 3 represented 2% of the trap loss with 2% of the active fishers in the state. From these analyses, it appears that trap configuration can influence the likelihood of trap loss, and configuration was one of the most striking differences among the LMAs. Seventy-one percent of LMA OC fishers fished singles, compared to 18% of fishers in LMA 1, 18% of fishers in LMA 2, and 0% of fishers in LMA 3 (Figure 14). Singles may be more prone to loss, particularly in areas where major storms are a primary source of gear loss, as was reported for LMA 1 and LMA OC (Figures 15 & 16).

Primary reasons for gear loss varied among LMAs, where major storm events and vessel traffic were major factors in LMA 1 and LMA OC (Figrues 14 & 15). Vessel traffic and hang-ups on bottom were pertinent in LMA 2 (Figure 17), while conflict with draggers, wear of line over time, and major storm events were primary sources of loss in LMA 3 (Figure 18). These results inform us that development of strategies to reduce and prevent gear loss may need to incorporate regional factors, as no single source of loss was common to all areas even within Massachusetts alone. Major storm events were frequently cited however, it is typical for storm events to occur in the winter months when fishing activity is less likely at least in LMAs 1, OC, and 2 according to survey responses (Figures 19 - 22).

Also of interest was whether Massachusetts lobstermen regarded derelict gear as a problem for the lobster fishery and whether they supported removal efforts. Overall, less than half of all respondents (range 37-49% across LMAs) believed that lost lobster gear has a negative impact on the lobster resource in Massachusetts. Interestingly, a majority of respondents (range 55-71% across LMAs) reported that efforts should be made to remove derelict lobster gear from the water, and that these efforts should involve commercial fishermen (range 67-86% across LMAs). The season most often selected of when gear removal efforts should take place was January to March for all LMAs.

We collected data on the perception of how long lost traps continue to fish and catch lobsters, as well as how long traps take to self-disable. Information on this subject as it relates to lobster traps is principally anecdotal as it had not been reliably tested in New England until the dive component of this study. Thus, we found significant variation in response on how long fishermen believe traps continue to fish. In LMAs 1 and 2, the majority of responses were partitioned among four categories ranging anywhere from several days to one year (Table 7). In LMA OC responses were less varied with most selecting from two categories ranging from several months to one year. In LMA 3 fishermen were divided with most answering either several weeks or several months to one year (Table 7). Clearly, individuals have varying opinions on how long traps continue to fish after being lost, which may be related to fluctuations in fishing time based on biotic (e.g. presence of bycatch and the "rebaiting effect") and abiotic (e.g. temperature, depth, bottom type) factors.

Specific to the dive survey areas, we found that reported trap loss rates ranged from 3.6 to 7.9% in Buzzards Bay and 2.5 to 6.6% in Cape Cod Bay (Figure 23), slightly higher than the average rate for all areas combined. In both Buzzards Bay and Cape Cod Bay, vessel traffic (82% and 79% of respondents, respectively) and major storms (47% and 65% of respondents, respectively) were attributed as primary reasons for gear loss. Months when gear loss was reported to most likely to occur was July through September in Buzzards Bay, and later in Cape Cod Bay, August through November. The average cost of gear loss per lobsterman ranged from $527 to $1,447 in Buzzards Bay and $756 to $1,799 in Cape Cod Bay.

Expanding the estimates of trap loss and lobster mortality up to the scale of the Massachusetts lobster fishery would provide context on the magnitude of the ghost fishing problem. Rates of gear loss varied substantially by LMA and rates of trap degradation and mortality varied among our two study areas. As such it is not possible to provide precise statewide expanded estimates of annual loss to the fishery and to the lobster population. However, we can provide robust estimates of loss for the two regions in which we conducted the dive survey.

In 2010, the Cape Cod Bay portion of the Massachusetts lobster fishery landed a total of 1.5 million pounds of lobsters using 105,000 traps. The annual rates of gear loss in Cape Cod Bay from our mail-in survey ranged from 2.5% to 6.6%. This would equate to a loss of traps ranging from 2,633 to 6,951 in 2010 in this region. An "average" commercial lobster trap is worth approximately $75. When multiplied by the annual rate of trap loss we estimate an economic loss of $197,000 to $521,000 per year. The annual mortality rate of lobsters for derelict traps in Cape Cod Bay was 4.754 $trap^{-1}year^{-1}$, which when multiplied by the annual estimates of trap loss, provides an estimated range of 12,518 to 33,067 of dead lobsters. From this we estimate an additional loss of revenue from $55,000 to $145,000 (assuming the average weight of a lobster is 1.25 lbs and the average price is $3.50) in lobster yield to the fishery per year. If combined, the annual value of lost traps and the reduced yield in lobsters represents a $252,000 to $665,000 loss in revenue to the fishery in this relatively small embayment alone.

The Buzzards Bay lobster stock is in a depleted condition and as a result the fishery is in a severely depressed state. In 2010 a total of 69,263 lbs. of lobster were landed in Buzzards Bay using 10,137 traps. The annual rates of gear loss in Buzzards Bay from our mail-in survey ranged from 3.6% to 7.9%. This expands to an estimate of 365 to 801 lost traps valued at $13,000 to $60,000. The annual mortality rate of lobsters for derelict traps in Buzzards Bay was 3.56 $trap^{-1}year^{-1}$, which when multiplied by the annual estimates of trap loss, provides an estimated range of 1,299 to 2,851 of dead lobsters. From this we estimate an additional loss of revenue from $6,000 to $13,000 (assuming the average weight of a lobster is 1.33 lbs and the average price is $3.50) in lobster yield to the fishery per year. The total ex-vessel value of the Buzzards Bay lobster fishery in 2010 was $242,000, meaning annual losses in revenue from lost gear and ghost fishing are between 7% ($19,000) and 30% ($73,000) of the total value of the fishery.

To provide context to the potential magnitude of the loss in lobsters and revenue from ghost fishing it is necessary to consider the scale of both the Massachusetts and U.S. lobster fishery. In 2010, the Massachusetts lobster fishery deployed more than 375,000 traps, and more than 4,000,000 were deployed in the entire U.S. lobster fishery. The revelation from this study that derelict traps are capable of fishing for multiple years, having a compounding effect, elevates concern for this problem. If you make the fairly safe assumption that rates of gear loss and lobster mortality are of a similar magnitude to what we observed in our study, the potential economic loss from ghost fishing in Massachusetts, and especially coastwide is staggering.

- Briefly explain discrepancies between what actually happened compared to what was anticipated to happen.

We anticipated being able to document all mortalities that occurred in the traps, of both lobsters and bycatch. However, we believe that some mortality was missed due to our bi-weekly sampling interval and environmental conditions at certain times of the year allowing for rapid decomposition. In the early stages of this study, we noticed fish that were near death or had recently died. Upon our next observation two weeks later, there was often no sign of the dead fish from the previous trip. Our estimates of mortality represent minimums, as we were able to show through an ad hoc test that decay of at least one bycatch species, tautog, occurred more rapidly than our sampling regime would capture. For this test, we set a trap in Buzzards Bay with four freshly-dead tautog and checked the contents daily. After only seven days, the only sign of the fish were scattered bones, some of which had fallen through the trap mesh. Thus, we believe we could have missed up to half of the fish mortality due to our sampling interval being roughly twice as long as decay.

Lobster mortality likely represents a minimum estimate as well, as it is possible some individuals decomposed or were consumed without observation, particularly if they were soft or new-shelled. Many organisms within the trap were likely consumed before they could be observed during the dive survey. Some lobsters were trapped in the same pot for over eight months. Lobsters and other organisms that were trapped for extended periods were limited in their ability to forage for food and may have consumed any evidence of trap mortalities. It was possible to find lobster tags and pieces of exoskeleton within and beneath the traps, however some tags from dead lobsters could have been lost by being washed away by surge or strong tides. Claws were the most likely body part to persist in the traps, as such, detached claws of dead lobsters were marked, to avoid double counting of mortalities.

- Provide any further information (such as unexpected outcomes) important for understanding project activities and outcome results.

There are a number of variables that could be explored relating to how long ghost gear fishes. For this study, we affixed the traps with two ghost panels, which increased the likelihood of trap disablement. But the ghost panels were also secured with brand new hog rings. This represents a "worst-case scenario" similar to if a fishermen were to lose traps after setting them for the first time or just after replacing the hog rings on a seasoned trap. The amount of time hog rings are exposed to air before being lost likely has an effect on how quickly they will release. We were not able to test differences in the strength of hog rings of various haul ages, however we do know that lobstermen replace the rings frequently as to prevent their release while being actively fished. Thus, it is likely our results are representative of a large portion of fished traps bearing new or relatively new hog rings.

The number of sublegal lobster mortalities was surprising. Published literature has shown that sublegal lobsters pass easily through escape vents of lobster traps (Jury 2001), yet 35% and 73% of the mortalities in Cape Cod Bay and Buzzards Bay respectively, were sublegal. An 81 mm lobster, approximately 5 mm below minimum legal size in Buzzards Bay, was observed on twelve occasions over more than eight months before it was eventually found dead in the trap.

Biofouling on escape vents decreased the size of the vent opening on some traps, which may have led to an increase in the number of sublegal lobsters retained in the traps, though sublegal mortalities were also found in vents with no or limited growth. Biofouling was expected on traps after spending extended period of time undisturbed on the sea floor. We expected to see encrusting animals such as barnacles and mussels, but with the exception of a limited amount of barnacle spat in the early spring, we did not see much evidence of either species. The most common biofouling organism was *Didemnum vexillum*, an invasive tunicate that covered many of the vents in Buzzards Bay restricting the size of the vent opening and delaying or preventing the release of the biodegradable hog rings (see uploaded picture number 7). Traps that contained numerous crabs were often devoid of any fouling (see uploaded figure 8) in the parlor section, while heavily fouled on the kitchen section. This is likely due to the crab's food supply being limited, forcing them to forage for what limited food was available in and on the trap.

3. Lessons Learned

- Describe the key lessons learned from this project, such as the least and most effective conservation practices or notable aspects of the project's methods, monitoring, or results. How could other conservation organizations adapt their projects to build upon some of these key lessons about what worked best and what did not?

One of the primary lessons learned from this study is that ghost traps have the ability to continue to fish much longer than previously thought. Current regulations specify several methods for creating an opening to allow the escape of organisms within one year of a trap being lost. We have shown that the most commonly used method, the addition of release panels attached by biodegradable, uncoated ferrous hog rings, results in traps capable of fishing for over two years if they are not hauled or exposed to storm activity. Traps set in deep water or sheltered environments may continue to catch lobster and bycatch species for an extended period of time due to a lack of oxidation of the metal while in the water and attachment of biofouling organisms over the panels.

Our survey traps continued to catch animals for longer than anticipated. However, the mortality rate for lobster was not particularly high when compared to similar studies conducted for other pot fisheries. Antonelis et al. (2011) showed that the Dungeness crab *Cancer magister* fishery in Washington State had a mortality rate of 0.70 crabs $trap^{-1}day^{-1}$, which is approximately seven times higher than the mortality rate of lobster in our study. Ghost blue crab traps in Louisiana had a mortality rate of 25.8 $trap^{-1}year^{-1}$ (Guillory 1993), which is more than five and six times our rate for Cape Cod Bay and Buzzards Bay annual lobster mortality, respectively. [1]. The Buzzards Bay lobster population is currently in a depleted condition and the population density of lobsters in Cape Cod Bay is substantially lower than lobster populations in the northern and eastern portions of the Gulf of Maine. Areas of greater lobster abundance would likely have higher mortality rates. While mortality rates may be low, with over 4 million traps fished annually in the U.S. American lobster fishery alone, even a marginal mortality rate could have a staggering negative impact.

Ghost fishing is having a substantial negative impact on some by-catch species commonly observed in the lobster trap fishery. Mortality rates of tautog in Buzzards Bay range from 0.0006 to 0.0058 $trap^{-1}day^{-1}$, for lobster traps with rectangular and circular vents respectively. Over the course of one year, these traps would kill 0.21 to 1.9 tautog $trap^{-1}year^{-1}$. Based on MA DMF data, approximately 10,000 lobster traps were fished in Buzzards Bay, in 2010. According to responses to the mail survey, more than half of Southern New England fishermen reported losing between 1 and 5% of their traps annually, which represents 100 and 500 traps lost within Buzzards Bay annually. In 2012, the tautog quota in Massachusetts was set at 61,180 lbs. From our bycatch mortality rates we calculate a minimum loss of 21 to 950 tautog per year in lost lobster traps. If we assume that each of these fish is an average size tautog caught by the commercial tautog trap fishery (4 lbs) (MA DMF unpublished data), then these traps kill between 84 and 3,800 pounds, or 0.1 to 6.2% of the annual state quota in Buzzards Bay alone. With the knowledge that traps can continue to fish for more than two years, the annual estimate of lost traps could be doubled, effectively doubling annual tautog mortality. These estimates do not take into account that we likely underestimated tautog mortality rates based on our ad hoc experiment that showed we may have missed half of the total tautog mortality based on the length of our sampling interval. These estimated figures also do not include mortality of fish in lost fish traps. Similar to lobster traps, fish traps are required to have escape vents and ghost panels. Of the nearly 4,000 fish traps reported fished in Buzzards Bay in 2010, most are believed to be affixed with circular vents, as they are better at retaining fish. No information exists on the loss rate of fish traps in this area, but it is reasonable to assume that these rates are similar among these fisheries. Gear loss and ghost fishing cause a substantial economic loss to the Massachusetts lobster and finfish fisheries. In the future management programs should focus on strategies to reduce or prevent gear loss, as well as strategies to increase the rate of degradation of derelict lobster traps. Each of these strategies could have the potential to mitigate for losses to the lobster resource and to the lobster fishery and are not as costly or inefficient as gear retrieval.

4. Dissemination

Briefly identify any dissemination of lessons learned or other project results to external audiences, such as the public or other conservation organizations.

Oral presentations

The American Lobster in a Changing Ecosystem: A U.S.-Canada Science Symposium, November 2012, Portland, ME; American Institute of Fisheries Research Biologists, June, 2012, New Bedford, MA; Derelict Gear Workshop, February 2012; Massachusetts Lobstermen's Association Annual Trade Show, January 2011, Hyannis, MA; Southern New England Chapter of the American Fisheries Society, Woods Hole, MA, January 2011.

Posters

Boston Sea Rovers, March 2012, Danvers, MA; Massachusetts Lobstermen's Association Annual Trade Show, January 2012, Hyannis, MA; New Bedford Working Waterfront Festival, September 2011, New Bedford, MA; Massachusetts Lobstermen's Association Annual Trade Show, January 2011, Hyannis, MA.

Publications

Boston Magazine, March 2012. http://www.bostonmagazine.com/articles/2012/03/lost-fishing-gear-massachusetts/

Massachusetts Division of Marine Fisheries 2010 Annual Report.

Email correspondence
Erin Pelletier, Gulf of Maine Lobster Foundation, June 2012; Casey Lyons, Boston Magazine, January 2012;

5. Project Documents
Include in your final programmatic report, via the Uploads section of this task, the following:

- 2-10 representative photos from the project. Photos need to have a minimum resolution of 300 dpi and must be accompanied with a legend or caption describing the file name and content of the photos;
- report publications, GIS data, brochures, videos, outreach tools, press releases, media coverage;
- any project deliverables per the terms of your grant agreement.

POSTING OF FINAL REPORT: *This report and attached project documents may be shared by the Foundation and any Funding Source for the Project via their respective websites. In the event that the Recipient intends to claim that its final report or project documents contains material that does not have to be posted on such websites because it is protected from disclosure by statutory or regulatory provisions, the Recipient shall clearly mark all such potentially protected materials as "PROTECTED" and provide an explanation and complete citation to the statutory or regulatory source for such protection.*

Antonelis, K., D. Huppert, D. Velasquez, J. June. 2011. Dungeness crab mortality due to lost traps and a cost-benefit analysis of trap removal in Washington State waters of the Salish Sea. North American Journal of Fisheries Management 31: 880-893.

Dean, M.J. Massachusetts lobster fishery statistics for 2006. Massachusetts Division of Marine Fisheries Technical Report TR-39.

Guillory, V. 1993. Ghost fishing by blue crab traps. North American Journal of Fisheries Management 13: 459-466

Jury, S.H., H. Howell, D.F. O'Grady, and W.H. Watson III. 2001, Lobster trap video: *in situ* video surveillance of the behavior of *Homarus americanus* in and around traps. Marine and Freshwater Research 52: 1125-1132