Manipulative Trapping Experiments
In The Monhegan Island Lobster Conservation Area

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Abstract

Two manipulative trapping experiments were conducted within the Monhegan Island Lobster Conservation Area (MILCA) during September through October 2005 and August through September 2007. In addition the MILCA fishery was evaluated with respect to annual catch, trap hauls, maximum trap limits and season length through daily harvester logbooks. The objectives of the trapping studies were to test the impact of trap density on catch rates and the cumulative catch, and to determine the relationship between soak time and catch rates. In 2005, catch rates for medium (167 km^{-2}) and low (50 km^{-2}) trap density areas always exceeded those of high (500 km^{-2}) trap density areas. Catch rates for all areas paralleled an increase in lobster abundance, determined by independent video monitoring, over the course of the study. The cumulative catch found in high trap density areas was 16 and 68% higher than medium and low density areas respectively. However, soak times in medium trap density areas could have been decreased to compensate for losses in total catch. Migration within the MILCA, as measured by recapture rates in trapping areas, suggest that in excess of 90% of lobsters moved out of the areas within eight days after initial capture. In 2007, the impact of soak time on catch was non-linear and indicates that a maximum catch for traps with reduced competition from other traps is 4.2 times higher than is observed in the surrounding Maine lobster fishery. The extension of the MILCA season by two months and reduction of the maximum trap limit from 600 to 300 traps following the 2006/2007 season resulted in a median 72 and 67% increase in landings for MILCA participants in the two seasons following the change. These studies suggest the current Maine lobster fishery could reduce traps with little impact on total catch, but the level and spatial extent of any reduction would need to be matched to the annual movements of the lobster resource and fishery.

Introduction

All three American lobster stocks in the United States are acknowledged to be heavily exploited. Yet, the assessment of the US lobster resource provides a mixed picture relative to stock status. The Southern New England stock is considered to be depleted with fishing mortality estimates above and abundance below the 1982 to 2003 median). The Gulf of Maine (GOM) and Georges Bank (GBK) stocks continue to benefit from favorable recruitment with resulting fishing mortality levels below and the abundance levels above median 1982 to 2003 levels (ASMFC 2009). This contrasting stock status serves as an opportunity to understand the mechanisms driving the trajectory of stock abundance and potential measures to improve unfavorable conditions.

While managers and fishermen have little influence on environmental conditions that may contribute to stock increases or decreases, steps have been taken manage aspects of the fishery in their control. Within the last ten years, the Atlantic States Marine Fisheries Commission (ASMFC) working with Lobster

Conservation Management Teams (LCMTs) as directed to develop plans designed to control or reduce fishing mortality. Each management area has taken steps to reduce traps in the fishery by implementing trap limits or establishing historical participation levels. Over 10,000 fishermen have been affected by these reductions directly or indirectly in the expectation of increased biological benefit. Unfortunately, the relationship between the number of traps and the associated fishing mortality rate is poorly understood, raising questions about the effectiveness of limiting traps to control fishing mortality.

Understanding how traps influence fishing effort is fundamental to our understanding of the assessment and management of the lobster resource in the Northwest Atlantic. The performance and selectivity of traps can be influenced by the availability of lobsters, inter and intra-specific interactions, bait efficiency and gear selectivity (Miller 1990, Krouse 1989). To date attempts to model the interaction of traps, fishing effort and fishing mortality have been limited and have offered little guidance to managers (Russell 1994). By conducting controlled fishing experiments, the effects of many of the above mentioned variables can be separately identified, possibly resulting in clearer understanding of how traps influence fishing effort, exploitation and finally fishing mortality.

Many studies have looked at the complexity of interactions with baited traps in the lobster fishery. In reviews by Krouse (1989) and Miller (1990) several factors were identified as contributing to the potential efficiency of traps, such as the quantity of bait used, bottom sea water temperatures, physical and biological characteristics of the bottom, inter and intra trap saturation effects, trap entrance and exit selectivity, and variable fishing strategies. All these factors make defining fishing effort in the lobster fishery difficult.

All lobster stocks in the Northwest Atlantic show signs of stress from fishing effort. Measures of the effect of fishing effort on the population and fishery include a reduced mean size, biased sex ratios, reduced reproductive potential and loss of revenue to the fleet (ASMFC 2009, Skud 1974, Krouse 1989, Rothschild 1972).

Fishing mortality and exploitation rates can be measured from fishery dependent and independent sources. Assessment techniques include tag recapture experiments (Ricker, 1975), Length cohort analysis and catch-effort methods (Estrella and Cadrin 1996) and survey based estimates (ASMFC 2000). In recent years change-in-ratio (CIR) methods have been successfully used in the Tasmanian rock lobster fishery (Frusher et al. 1997), similar approaches have been introduced for the Gulf of St. Lawrence (Comeau and Mallet 2001) and Nova Scotia (Claytor and Allard 2003).

Ultimately the number of traps do relate to fishing mortality. However, because the lobster fishery has the ability to compensate for reductions in traps by

increasing efficiency, the relationship between trap number and effective fishing effort is likely to be highly nonlinear (Russell 1994). Reductions in effort (traps) to decrease fishing mortality have been questioned by industry and have not been successful in practice.

Project Objectives and Scientific Hypothesis

Objectives

- Identify eight suitable 0.9 km^2 areas of equivalent depth and bottom characteristics within the Monhegan Island Lobster Conservation Area (MILCA).
- Deploy traps in areas covering three experimental trap densities that are representative of the variation along the coast of Maine.
- Conduct trapping experiments over a two-month period standardizing for soak time, bait and gear.
- Record catch composition (legal, sublegal, V-notch and egg bearing) for each trap hauled using electronic logbooks and on-board observers.
- Tag each lobster with batch tags unique to each trapping day.
- Record the location, incidence, size and biological status of recaptured lobsters over the study period.
- Determine habitat specific lobster density before, during and after the study period using remote video cameras.
- Monitoring the MILCA fishing season
- Record daily catch statistics during the MILCA fishing season (traps hauled, average depth fished, average location, bait used, soak time)
- Investigate the impact on catch with variable soak (2005, 2007)

Hypothesis

- Catch rates of lobsters are influenced by trap density
- Cumulative impacts on local population structure (fishing “mortality”, density, size composition, sex ratio) vary by trap density and trapping duration.
- Catch rates are not influenced by soak time.
- Using the continuous change in ratio (CIR) method advanced by Claytor and Allard (2003) determine the trajectory of daily exploitation of MILCA fishing season relative to changes in catch and catch rates over the course of the season.

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Methods

The waters surrounding Monhegan Island have been a seasonal winter fishery since 1907; in 1998 the Maine legislature officially recognized this area as the Monhegan Island Lobster Conservation Area (MILCA). Participation in the MILCA is limited to 17 lobstermen in approximately 95 km^2 immediately surrounding Monhegan Island (Figure 1). The MILCA is the only area in New England that is closed during summer and fall months when the rest of New England's lobster fishery is at its peak. The MILCA represents a rare opportunity to conduct experiments in a trap free setting in one of the most productive lobster regions of the coast. An explicit aim of the Maine legislature, when establishing MILCA, was to promote scientific studies, a goal that complements the Northeast Consortium goal of evaluating closed areas and improving fishing practices.

Multibeam Survey of MILCA Waters

In April 2005, a week long Multi-Beam survey was conducted to survey the Monhegan Island Lobster Conservation Area. The survey was conducted by mounting the multi-beam transducer to the off-side of the F/V Seldom Seen. The survey was sub-contracted through the Pennsylvania State University, under the leadership of Dr. Tom Weber (now with UNH). The resulting survey produced a map with a horizontal resolution of 5-meters and a 1-meter depth. Backscatter data was recorded and will be used as a proxy for habitat, but was not available at the time of site selection. Subsequent video drops were conducted in July, 2005 to validate backscatter data.

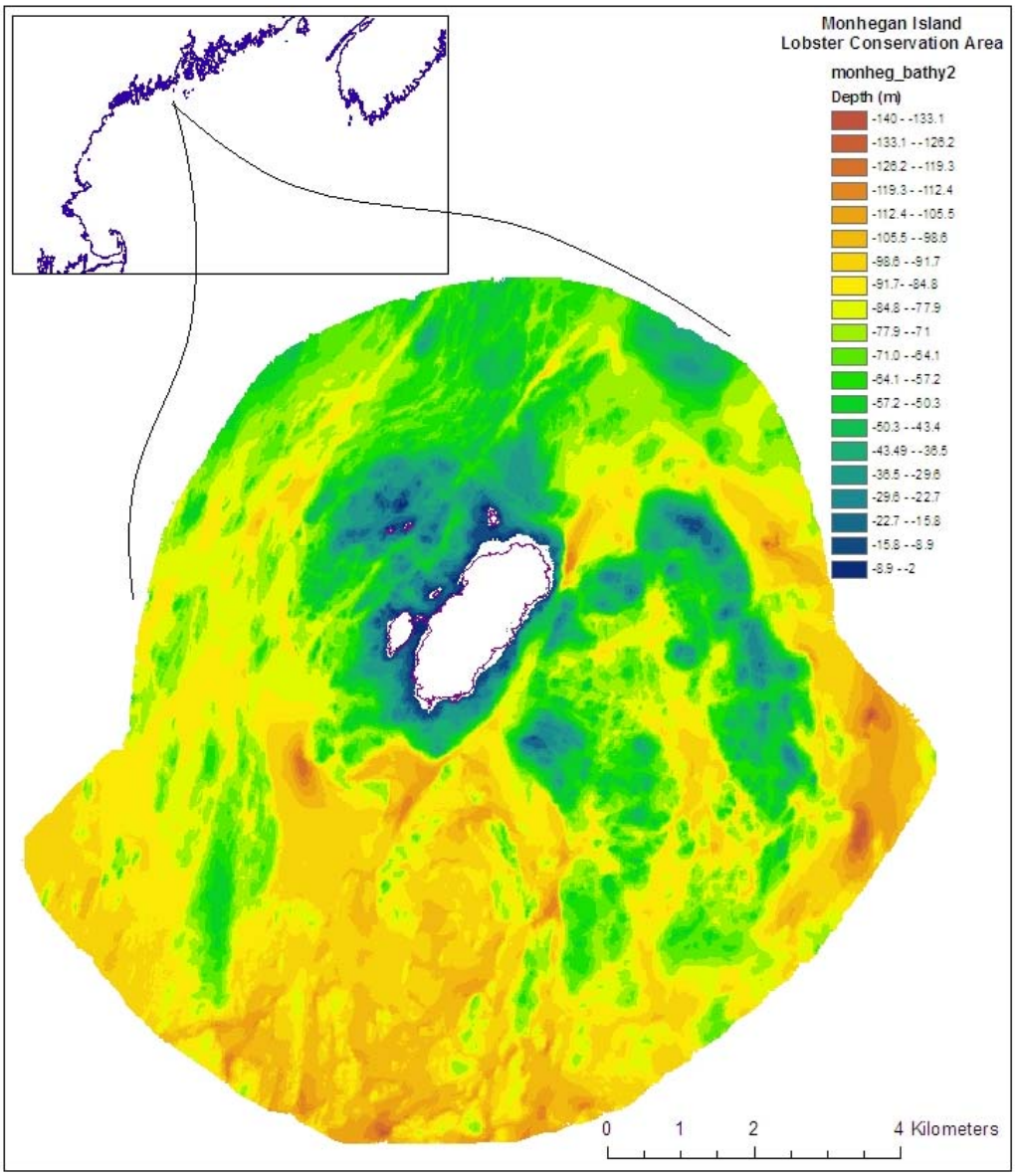

Figure 1. Bathymetry of the Monhegan Island Lobster Conservation Area (MILCA). The MILCA is located in the Mid-coast region of Maine, and is the only area seasonally closed to the lobster fishery in the US. Soundings were taken during a weeklong multi-beam survey on the F/V Seldom Seen.

The impact of trap density on catch (September and October, 2005)

Eight 0.9 km^2 experimental trapping areas were selected based on their bathymetric characteristics, six areas were randomly selected for the trap density experiment (Figure 2). Three levels of trap densities (50, 167 and 500 traps km^{-2}) were assigned to these areas, with soak time standardized at 4-nights (96 hours). Fishermen were randomly assigned areas and the number of traps to be

placed in each area. The remaining two experimental areas were assigned a density of 167 km^{-2} to test the impact on catch with variable soak times described below (Table 1 and Figure 2).

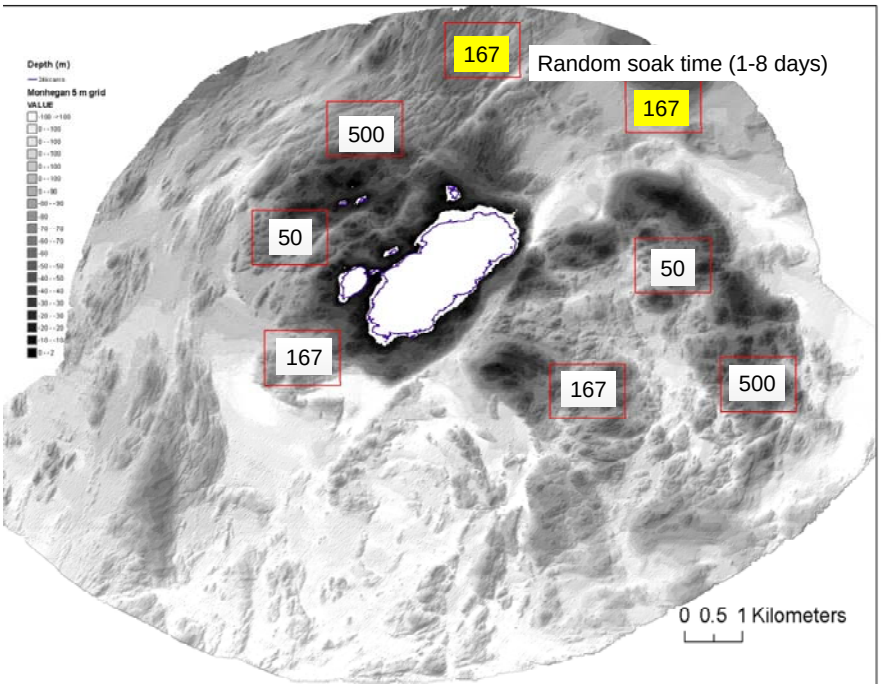

Figure 2. Defined areas indicate the location and trap density tested for the 2005 trapping experiment.

Table 1. The distribution of traps by industry participant for the 2005 manipulative trapping project.

Area	Fisherman MW	RB	SS	DM	LC	DB	MT	Density	Traps
1	44	90	40	90	96	90		500	450
2*							150	167	150
3*							150	167	150
4	16				30			50	46
5	30		10	6				50	46
6	40		30	30	50			167	150
7	66	96	104	60	20	104		500	450
8	20	30	30	30	20	20		167	150

*** Random Soak**

Trapping experiments were conducted from August 30 (traps set) through November 1, 2005 (traps removed). Traps in the six areas with a fixed 4-night soak time were hauled 12 times.

All traps were set as pairs. Each trap was a standard 4-foot, double parlor, wire trap with a minimum of one escape vent for juvenile lobster. All traps were hauled and rebaited on predetermined dates. If traps were missed (entangled, lost buoy, gear loss) these were noted and replacement traps were added to the area on the next hauling date.

The contents of each trap were counted for composition of the lobster catch (legal, sublegal, V-notch, egg bearing and oversize). Crab counts were collected after October 1, 2005 through the completion of the experiment. All lobster and crab counts were immediately entered in to a Thistle Marine Electronic Logbook, which subsequently attached a latitude longitude location and time stamp to each entry. Legal lobsters were removed, banded and placed in on-board recirculating tanks. At the end of the day all legal lobsters were released at a common drop point within the MILCA (N 43°46.2" W 69°20.0"). At-sea observers were placed on 20% of all trips (20 of 99) to record detailed biological information on lobsters encountered.

Investigation of soak on catch (2005 and 2007)

Two experiments were conducted, in 2005 and 2007, to test the impact of soak time on catch. In 2005, two 0.9 km^2 areas were assigned a 167 trap km^{-2} density. In this case one fisherman (M. Thomson, F/V Pats Girl) was the only industry participant (Table 1 and Figure 1). Soak time varied from one to eight days and were randomly assigned throughout the experiment. The two areas with random soak times were scheduled to be hauled 15 times. In this experiment, legal lobsters were immediately returned to the water.

A second soak time experiment was conducted between August 15 and September 15, 2007. For this experiment the entire MILCA was used as a test area (Figure 1). In total, 360 traps were set as pairs. Half of the traps were assigned random locations that remained fixed over the course of the experiment, The second half of the traps were moved at the discretion of the industry participants. The 90 fixed sites were evenly distributed between three depth strata (0-30, 31-60, 60-90 m). These fixed sites were evenly distributed between industry participants (Chioffi, Weber and Stanley). All traps were hauled ten times on random dates, with soak times varying from one to six days. On rare occasions some traps were hauled on as little as five hours soak. Each industry participant had an independent hauling schedule to ensure soak times were evenly assigned throughout the experiment and minimize the effect of changing lobster availability.

Table 2. The hauling schedule for three industry participants was determined by random draw of soak times from one to six days. Each participants hauled fixed location traps and industry selected locations each designated day. The experiment began August 15 and ended September 15, 2007.

Haul #	Chioffi	Stanley	Weber
	Soak time (Days)		
1	4	3	3
2	2	1	4
3	6	3	6
4	1	5	5
5	3	4	2
6	5	2	4
7	4	6	2
8	2	2	1
9	3	1	3
10	1	4	1

As each pair was hauled; location, depth and trap contents were recorded on a paper log. The number of legal, sublegal and illegal lobster in each pair was noted. Each lobster was "knuckle banded" and returned immediately to the water. Any recaptures were noted and rebanded.

To determine the relationship between catch rate and soak time, individual haul data was fit to the three parameter model described in Saila et. Al. (2002) where the catch at time (C_t) is described as

Equation 1.0 $$C_t = ab + a(t-b)e^{-ct}$$

Where C_t is the catch at time *t*, and *a*, *b* and *c* are parameters to be solved for. The time when a trap reaches maximal catch, T_{max}, can be resolved via the equation

Equation 2.0 $$T_{\max} = 1/c + b$$

And the maximal catch, C_{max}, via

Equation 3.0 $$C_{\max} = ab + ac^{-1}e^{-(1+cb)}$$

The product of the parameters *a* and *b* is the asymptotic catch and parameters *a* and *c* depend on local animal density and trap entry rates; however, *c* largely reflects the probability of escape (Saila et al. 2002).

The model parameters were estimated by least squares minimization using MS Excel Solver. In the case of the 2005 experiment, all traps (recorded as pairs but reported as catch per trap) were used from both areas as the catch rates between the two areas were not significantly different. For the 2007 experiment, fixed location traps were compared to industry selected traps regardless of depth.

Finally, the catch at time was compared to the state wide Lobster Port Sampling Program results from 2000-2007, an intercept survey that randomly selects 10

dealers each month and interviews harvesters that land their catch on the selected day. Each interviewed harvester is asked a series of catch and effort questions; including total pounds landed, traps hauled and average soak time. In this case, model parameters were estimated using trip level data reported on a per trap basis.

Tag and recapture experiment

All lobster encountered during the 2005 trap density experiment were batch tagged with a daily, uniquely colored, "knuckle band". In the six trapping areas with constant soak time, legal lobsters were removed, banded and placed in on-board recirculating tanks. At the end of the day all legal lobsters were released at a common drop point within the MILCA (N 43°46.2" W 69°20.0"). All sublegal and illegal (V-notch, Egg bearing, Oversize) lobsters were "knuckle banded" and immediately returned to the sea.

In the two trapping areas investigating the impact of variable soak times in 2005, all lobsters were "knuckle banded" and immediately released after counts were taken.

Recaptures were entered into the Thistle Marine Electronic Logbooks and recorded by on-board observers for both experiments in 2005. Specific information taken for each recaptured lobster included the original date of capture and additional recaptures (derived from band color and quantity), location, size, sex, and reproductive status.

For the 2007 experiment on soak time, all lobsters were "knuckle banded" immediately and released after counts were recorded. For this experiment, unique batch colors were not assigned as the hauling schedule varied randomly between the three industry participants (Table 2). Recaptures were recorded and an additional "knuckle band" was added. Recaptures were recorded as sublegal, legal or illegal and were counted independently of other lobsters.

Independent monitoring of MILCA during experimental trapping

In an attempt to quantify lobster density in experimental trapping areas throughout the 2005 experiment, video surveys were conducted on four dates, September 2 and 30 and October 19 and 21, 2005, to determine relative abundance of lobster and crab. Surveys were conducted by drifting with prevailing winds and currents. Four transects were conducted in each area on each day, with a planned minimum transect length of 100 m or approximately 15 minutes of video. The video camera was suspended off the sea floor bottom, with an average viewing area of 1.0 m^2. Four 150 watt halogen lights were located at the base of the camera frame and were adjusted for lighting conditions. A location and time stamp was over laid on the video feed to facilitate

post processing. All video was recorded using a Sony Digital-8mm recorder and a Sub Sea Video system. Fields notes were confirmed with lab based video processing. Each transect location, start and stop times, errors in recording, substrate and presence of crabs and/or lobster were noted.

Monitoring of the MILCA fishing seasons

The Monhegan Island Lobster Conservation Area (MILCA) is the only closed season lobster fishery in the US lobster fishery and provides an opportunity to compare the compounded impacts of depletion within a determined area.

Three initiatives were used to track the seasonal patterns of the MILCA fishing season and annual catch from 2004 through June 2009. Prior to the 2005 trapping experiments, logbooks were distributed to participating MILCA fishermen. Each participant was asked to record the daily catch and effort. The season ran from December 1, 2004 through May 30, 2005. Specific elements captured were catch, trap hauls, average soak time, depth fished and general location on a daily basis.

In 2007, MILCA participants submitted a bill to the Maine Legislature to extend their season from a December 1, start date to October 1 (Maine Public Law Chapter 219). As part of this law, the Maine DMR Commissioner "…shall establish by rule a trap limit for the open season established… The trap limit may not exceed 475 traps per individual..." (12 MRSA 6472). The subsequent 2007/2008 and 2008/2009 season trap limit was set at 300 traps per individual. Two additional sources of information to monitor the MILCA season became available as part of the law change. MILCA participants were asked to voluntarily submit the prior three season total landings to use a baseline to evaluate the season and trap change. Finally, each MILCA participant is now required to complete daily trip reports similar to those described for the 2004/2005 season.

The average of the three seasons prior to the 2007 MILCA law change (2004/2005, 2005/2006 and 2006/2007) were used to evaluate the median percent change for the 2007/2008 and 2008/2009 seasons.

Data

All experimental catch, biological measurement and video surveys will be available in raw or summarized format by request to Carl Wilson (Carl.Wilson@maine.gov 207.633.9538). Harvester logbook records collected prior to the 2005 trapping experiment and in subsequent seasons are considered confidential information by the Maine Department of Marine Resources, and therefore will only be available in summarized format. The multibeam data is available on request and is currently referenced on the Gulf of Maine Mapping Initiative website (http://www.gulfofmaine.org/gommi/coverage-map.php).

Results and Conclusions

The impact of trap density on catch (September and October, 2005)

During the experimental trapping period, 20,100 trap hauls were conducted with approximately 72,000 lobsters counted, measured, banded and released. The designated number of traps in each area were maintained during the course of the experiment by adding traps as they were lost. The standardized 4-day soak was maintained throughout the experiment with the exception of haul #10, when high seas extended the soak time to 5-days.

Technical errors with the Thistle Marine Electronic Logbooks resulted in the direct loss of 33% of the potential trap hauls information. Difficulties encountered included box malfunction, data entry, modem upload, and database errors. In the six areas where soak time was held constant and trap densities varied between 50, 167 and 500 traps km^{-2} data remained representative as each treatment had a minimum of two participating fishermen and information was recorded for each haul. At sea observers provided detailed catch and effort information on 5,038 trap hauls (25% of the total). In some cases at sea observer data can be used on trips where the electronic logbook failed, lessoning the impact of data losses.

Significant differences in catch rates were observed between all areas. During the course of the experiment, catch rates in all areas significantly increased, independent of the trap density ($p<0.001$). High density areas (500 traps km^{-2}) always had a lower catch rate than medium (167 traps km^{-2}) or low (50 traps km^{-2}) density areas. In aggregate, medium and low density areas had 2-4 times higher catch rate than high density areas. There was one medium density (Figure 3, Area 6M) where catch rates equaled or exceeded low density catch rates.

Increases in catch rates over the duration of the experiment in all areas may indicate a regional scale (10-20 km) increase in lobster availability. We did not observe localized depletion even as legal lobsters were removed from the study areas on every haul.

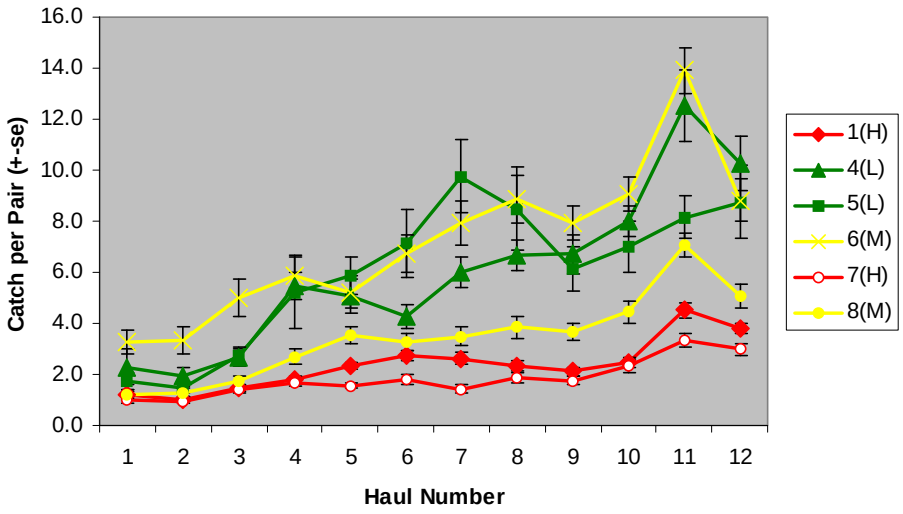

Figure 3. Catch per pair of legal lobster in high (500 traps km^{-2}), medium (167 traps km^{-2}) and low (50 traps km^{-2}) density areas. The experiment began August 30, and ended October 18, 2006. Hauls were on four night soaks except Haul 10 when weather delayed hauling.

There were significant differences between all areas and trap density treatment, however these impacts were local (10-100 m) and were overwhelmed by the regional (10-20 km) changes in lobster availability. The distribution of the legal catch varied within each trapping area. In areas with trap densities of 500 traps km^{-2} the highest legal catch was observed on the edges of the areas. Catch rates often declined within 50 meters of the edge and remained consistent to the center of the area. Traps in the center of high density areas had consistently lower catch rates, the largest incidence of zero catches and were likely influenced by competition from nearby traps.

In low and medium density areas (50 and 167 traps km^{-2}) catch rates were largely uniform throughout the areas. The incidence of trap hauls that recorded zero legal lobsters were rare and catch rates did not decline from the edge to the center of the area. We infer that trap competition was lower between adjacent traps in these areas. In one area (167 traps km^{-2}) directly to the southwest of Monhegan Island, catch rates were consistently high in the northeast corner, or the area closest to the Island. It is speculated that this corner represented a corridor for lobsters moving from shallow waters near the island to deeper waters (Figures 4 and 5).

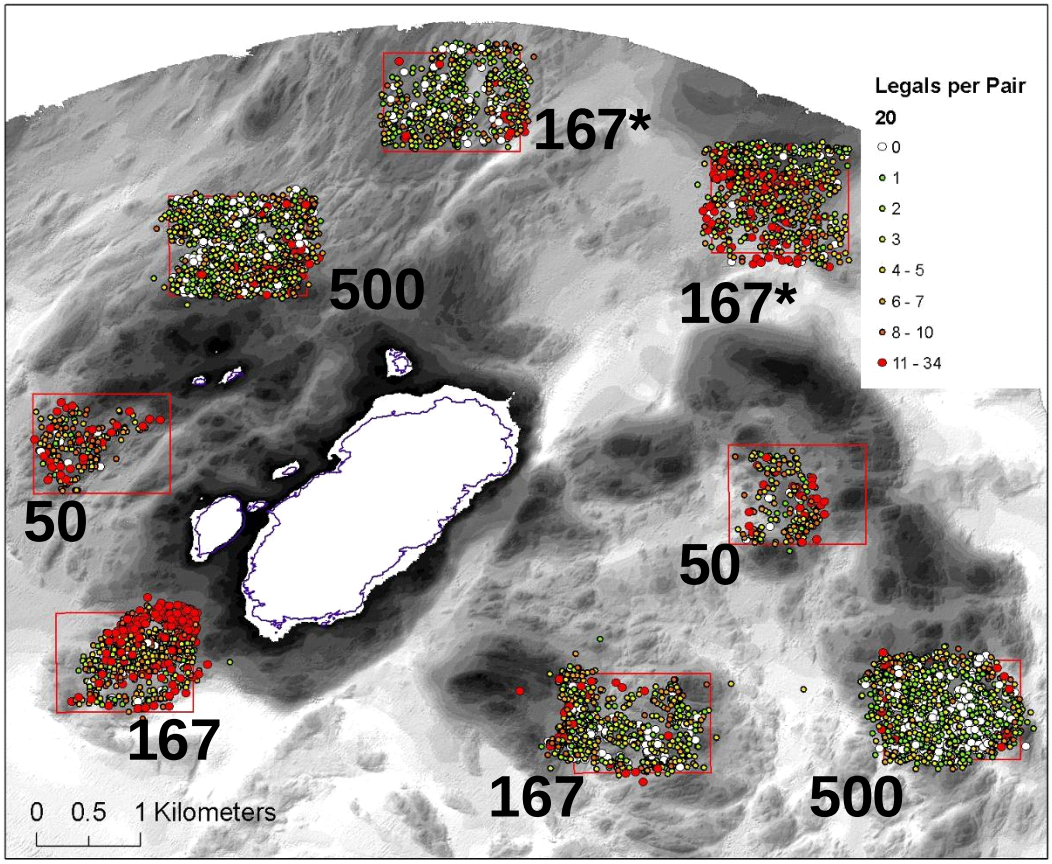

Figure 4. Trap haul location and catch in eight experimental trapping areas. Trap densities of high (500 traps km^{-2}), medium (167 traps km^{-2}) and low (50 traps km^{-2}) were maintained for the duration of the experiment. A total of 20,100 traps were hauled during the experiment. Legal catch per pair is reflected as a color gradient from white (zero) to red (11-34). * Indicates areas where random soak time was applied.

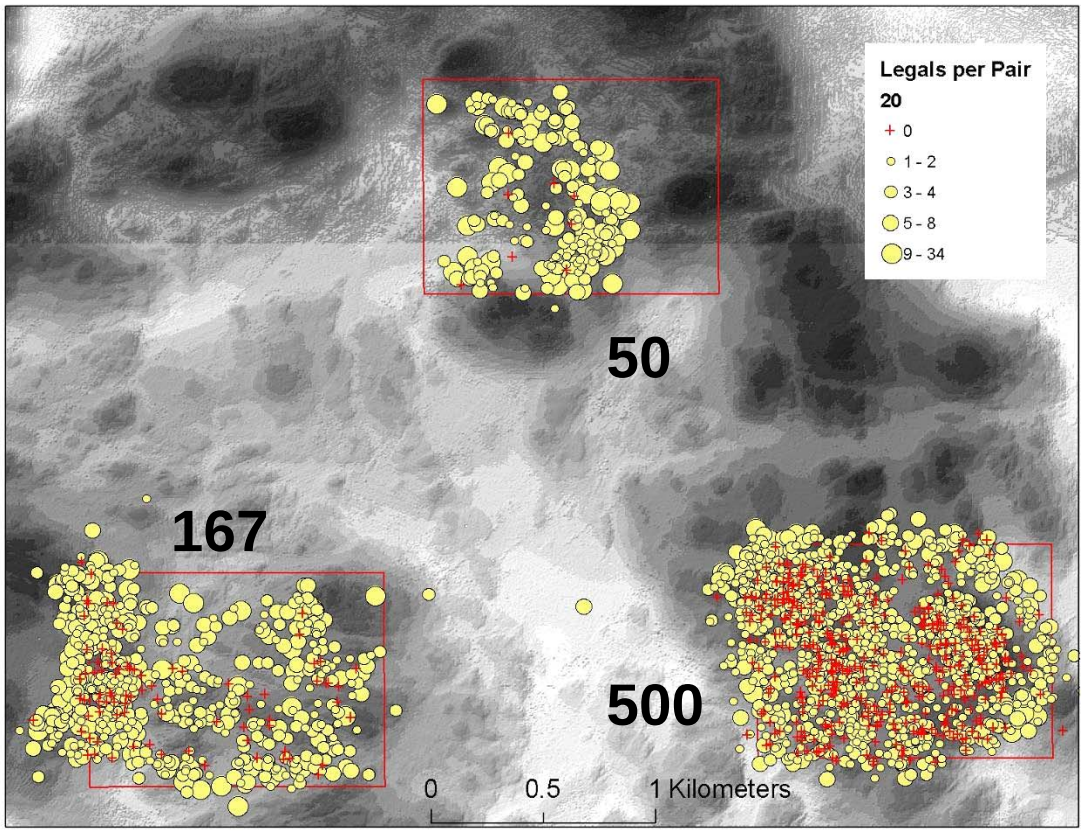

Figure 5. Trap haul locations in three experimental trapping areas. Trap densities of High (500 traps km-2), Medium (167 traps km-2) and Low (50 traps km-2) were maintained during the experiment. Legal catch per trap is represented with red (+) as zero and increasing bubble size to a maximum size representing 9-34 lobster.

When the average cumulative effect of the number of trap hauls and catch is compared between low, medium and high density areas, the medium density areas caught 16% less than the high density areas despite the fact that high density areas had three times more traps. Low density areas had the highest per trap average, but were unable to compensate for the loss in total catch with constant soak times of 4-nights (Figure 3, Figure 6).

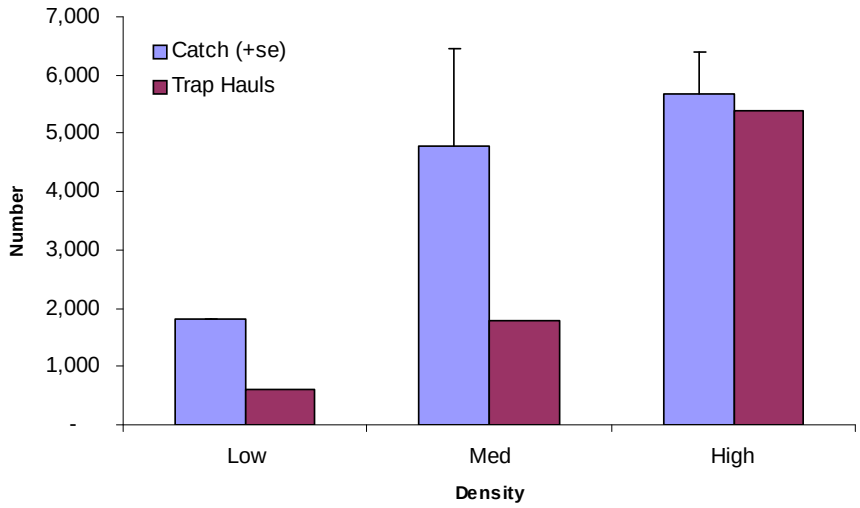

Figure 6. The average legal catch and trap hauls for low, medium and high density areas (50, 167 and 500 trap km^{-2}) with soak time held constant at 4-nights. Error bars indicate standard error between cumulative catch between areas.

The impact of soak time on catch

In the two areas designed to test the impact of variable soak time on catch in 2005, a total of 2,564 trap hauls were recorded. In these traps 11,411 lobsters and 3,493 crabs were counted. Legal lobsters were the most prevalent (n= 5,824) followed by sublegal lobster (n= 4,800) and finally illegal lobster (n= 787).

The most significant loss due to electronic logbook error was encountered in the two areas where soak time was varied randomly, 33% of the potential day/area combinations (10 out of a possible 30) were lost completely. Poor sea conditions and a scarcity of available crew limited this portion of the experiment to days when the larger six area trapping experiments were not hauling and inadvertently increased the maximum planned soak times from six to eight days (Table 3).

Table 3. Haul dates, associated soak times and trap hauls recorded for the 2005 experiment on the impact of soak time in two experimental areas with a density of 167 traps km^{-2}. Electronic logbook errors resulted in the loss of all records in Area 3, and greatly reduced the number recorded in Area 2 after 9/30/2005.

Haul	Date	SOAK	Area 2	Area 3
1	9/3/2005	4	144	128
2	9/9/2005	6	144	144
3	9/11/2005	2	148	136
4	9/15/2005	4	138	142
5	9/19/2005	4	146	146
6	9/20/2005	1	146	140
7	9/24/2005	4	144	134
8	9/30/2005	6	126	140
9	10/19/2005	8	50	
10	10/21/2005	2	54	
11	10/29/2005	8	138	
12	10/31/2005	2	76	

As with the other medium and low density areas, the catch was largely uniform from the edge of each trapping area to the center, indicating minimal competition between traps (Figure 4). Additionally the experimental areas where soak was held constant, a pattern of increasing catch rates from the start of the experiment was observed similar to those areas where soak was held constant (Figures 3 and 7).

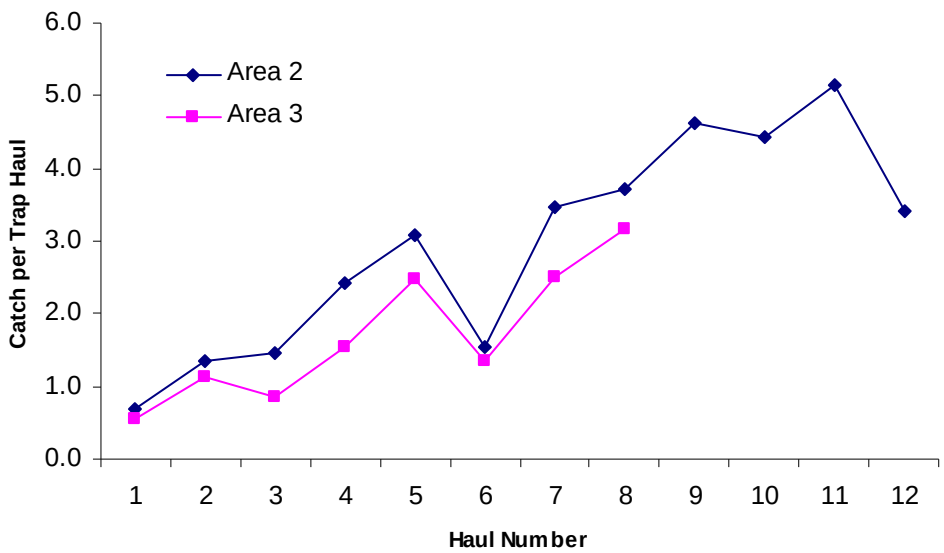

Figure 7. Catch per trap haul of legal lobsters in two 0.9 km^2 areas in 2005 with soak times between 1 and 8 days (Table 3). The trapping experiment began on August 30 and concluded on November 30. Errors uploading catch data from Area 3 resulted in this information being lost after the eighth haul.

Catch rates between the two soak experimental areas were not significantly different ($P > 0.05$); therefore, all trap hauls were combined to determine the

relationship between catch and soak (Figure 8). A non-linear asymptotic relationship was fit to the individual haul data as described by equation 1.0. The maximum catch per trap was estimated to be 5.2 legal lobsters per trap, a number exceeded by less than 9% of all trap hauls recorded. The calculated maximum soak time was 35.2 days, nearly four times the tested maximum soak (Table 4). The estimated catch was 1.3 legal lobster per trap at two days, and 2.2 at four days. This non-linear relationship results suggest that soak times in medium density areas (and by inference low density) could be reduced to increase the frequency of trap hauls and to compensate for the lower number of traps in these areas when compared to high trap density areas.

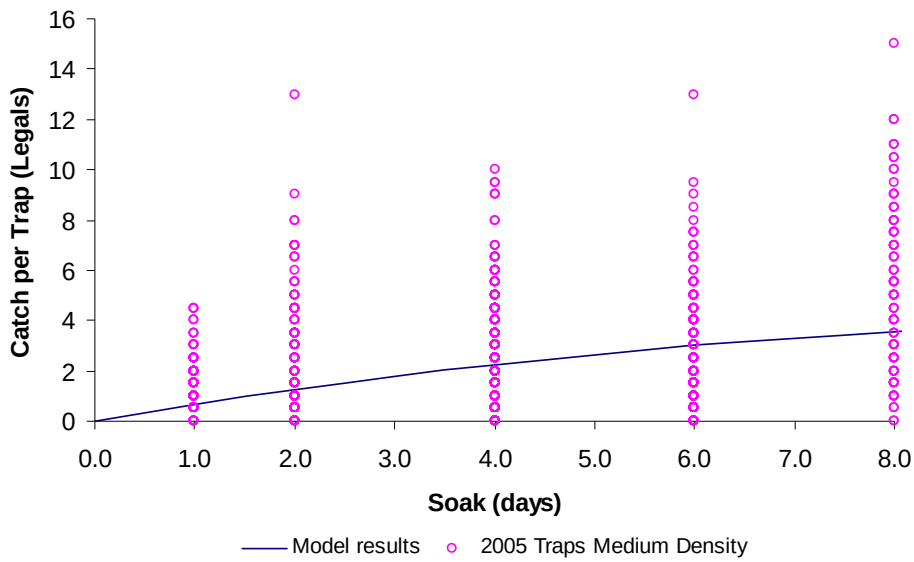

Figure 8 Combined haul data (n=2,564 trap hauls) for the two medium density areas used to test the impact of soak time on catch in September and October 2005. Model results follow least square estimations described in Equation 1.0.

In 2007, the trapping experiment encompassing the entire MILCA to test the impact of soak time on catch recorded a total of 3,474 trap hauls that caught 14,112 legal, 6,194 sublegal, 2,014 illegal and 5,066 crab. A total of 5,679 lobsters were recaptured, and will be discussed below. Industry selected sites accounted for 51% of trap hauls but 65% of the lobsters.

In general industry participants did not change the location of traps after the first haul. Industry traps tended to concentrate in depths less than 40 m with the highest catch rates (Figures 9 and 10).

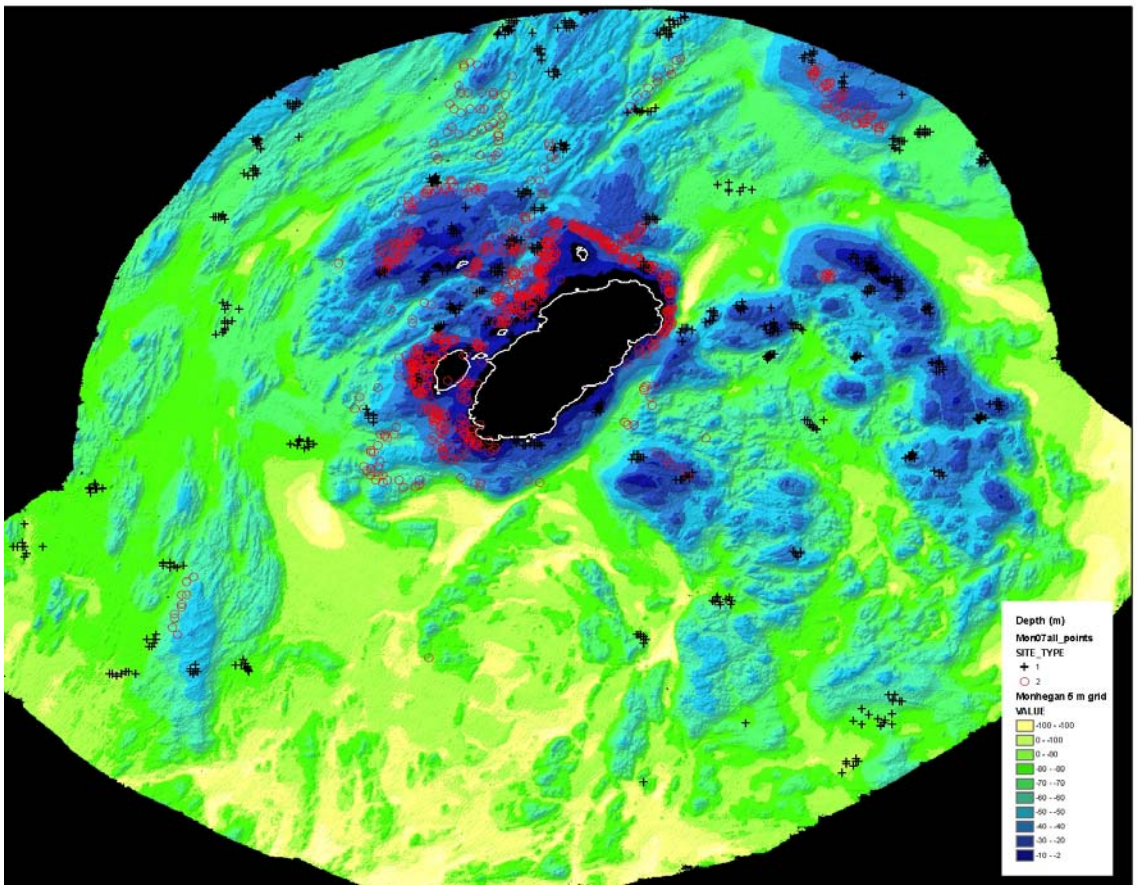

Figure 9. The location of fixed (black "+") and industry selected sites (red "o") for the 2007 experiment to investigate the impact of catch rates on soak. Each location represents one pair of traps. The experiment ran from August 15 through September 15, 2007. Industry participants could change the location traps if desired.

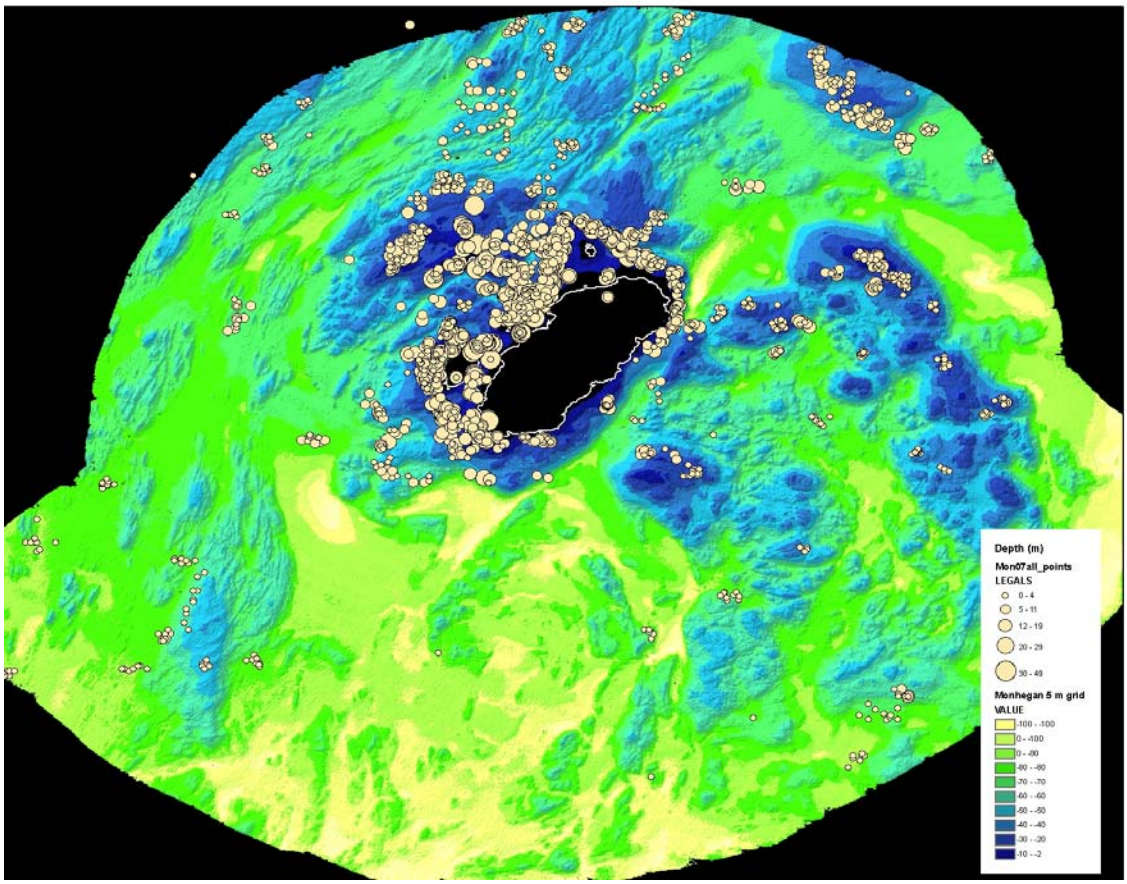

Figure 10. The catch rate of legal lobsters for fixed and industry selected stations for the 2007 experiment to investigate the impact of catch rates on soak. The experiment ran from August 15 through September 15, 2007.

Unlike the 2005 study, we did not observed a difference of catch rates over the course of the 2007 experiment regardless of soak time and depth (Figure 11). The majority of lobsters caught had molted for the season. We speculate that lobsters are less migratory in August/September than in September/October. The catch rates did decline with respect to depth for fixed and industry selected stations (Figure 12).

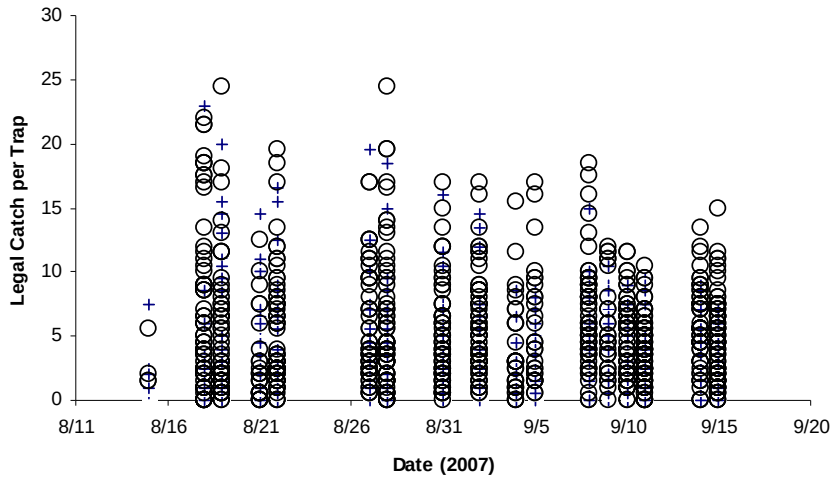

Figure 11. Legal catch per trap for fixed locations (+) and industry selected locations (O) from August 15 through September 15, 2007. A total of 3,474 trap hauls that caught 14,112 legal lobsters.

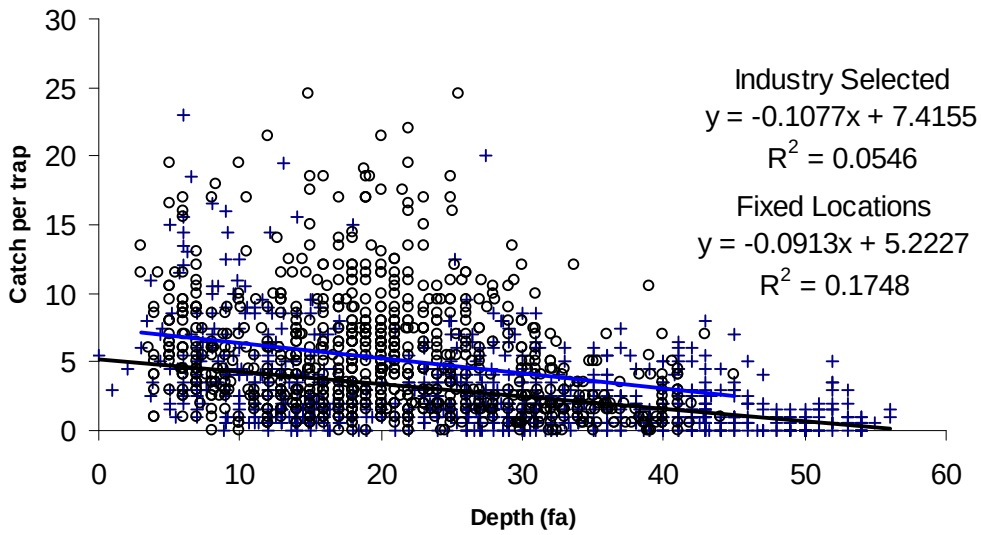

Figure 12. Legal catch per trap for fixed locations (+) and industry selected locations (O) by depth (fathoms) from August 15 through September 15, 2007. Linear regression fit applied independently to industry (solid blue line) and fixed sites (solid black line).

When model parameters are estimated to determine the relationship between soak and catch, following Equations 1.0, 2.0 and 3.0, differences between fixed and industry selected locations are evident. The estimated maximum catch for fixed traps was 3.4 legals per trap and 40% more for industry selected sites at 6.5 legals per trap. The estimated maximum soak time was 9.7 days for fixed locations and 16% more at 22.1 days for industry selected locations. As was

estimated for the 2005 experiment, the maximum soak time exceeded the maximum of 6 days tested. Approximately 23% of trap hauls exceeded the estimated maximum catch for fixed stations and 30% for industry selected sites.

Finally, when parameters are estimated for the relationship between soak and catch based on the 2000-2007 Lobster Port Sampling Program (LPS), the maximum catch and the maximum soak was 40 to 85% lower than was observed in the 2005 or 2007 experiments (Table 4). The variability in the maximum soak and maximum catch may indicate that trap capacity had not been reached. If longer soak times, in excess of 10-14 days, had been tested, the escape parameter, *c,* may have been estimated with more certainty.

The non-linear relationship between soak and catch for all scenarios tested above indicates that there is efficiency to be gained, by decreasing soak and competition between traps, that would offset reductions in catch by reducing traps (Figure 13 A). It is important to note that the current Maine lobster fishery, largely regarded as a intensively trapped fishery, with an average catch of 1.4 at the average soak time of 5.2 days could increase by 4.2 times to achieve the catch rates observed in the 2007 industry selected sites (Table 5).

The asymptotic relationship expressed by Equation 1.0 allows an interpretation of the maximum catch at a maximum soak time and an interpretation of catch per trap per day. For all scenarios tested in Table 4, there is an inverse relationship for maximum catch per trap per day with soak. The maximum catch per trap per day is observed after one day of soak for all scenarios, followed by values declining rapidly until approximately six nights. The disparity between the average soak of 5.2 days measured by the LPS and the maximum catch per trap per day for all tested scenarios suggests the current lobster fishery is fishing 80% below maximum efficiency with regards to soak time (Figure 13 B).

Table 4. Estimated model results and parameters to determine the relationship between catch and soak from Saila et al. (2002). Model results for the 2005 and 2007 Monhegan trapping experiments are based on trap haul data. Results for the 2000-2007 Lobster Port Sampling program are based on daily trip results. Parameters were estimated using least square methods with MS Excel Solver.

		Max	Max	Model parameters		
Survey	Number	Catch per Trap	Soak	*a*	*b*	*c*
Initial values				2.9	-0.62	0.16
2005 Medium Density*	1,282	5.2	35.2	0.21	25.12	0.1
2007 Fixed Stations*	888	3.4	9.7	0.46	7.33	0.42
2007 Industry Selected Stations*	925	6.5	22.1	0.32	20.45	0.59
2000-2007 Port Sampling**	3,915	1.4	5.6	0.52	1.81	0.27

* pairs ** interviews

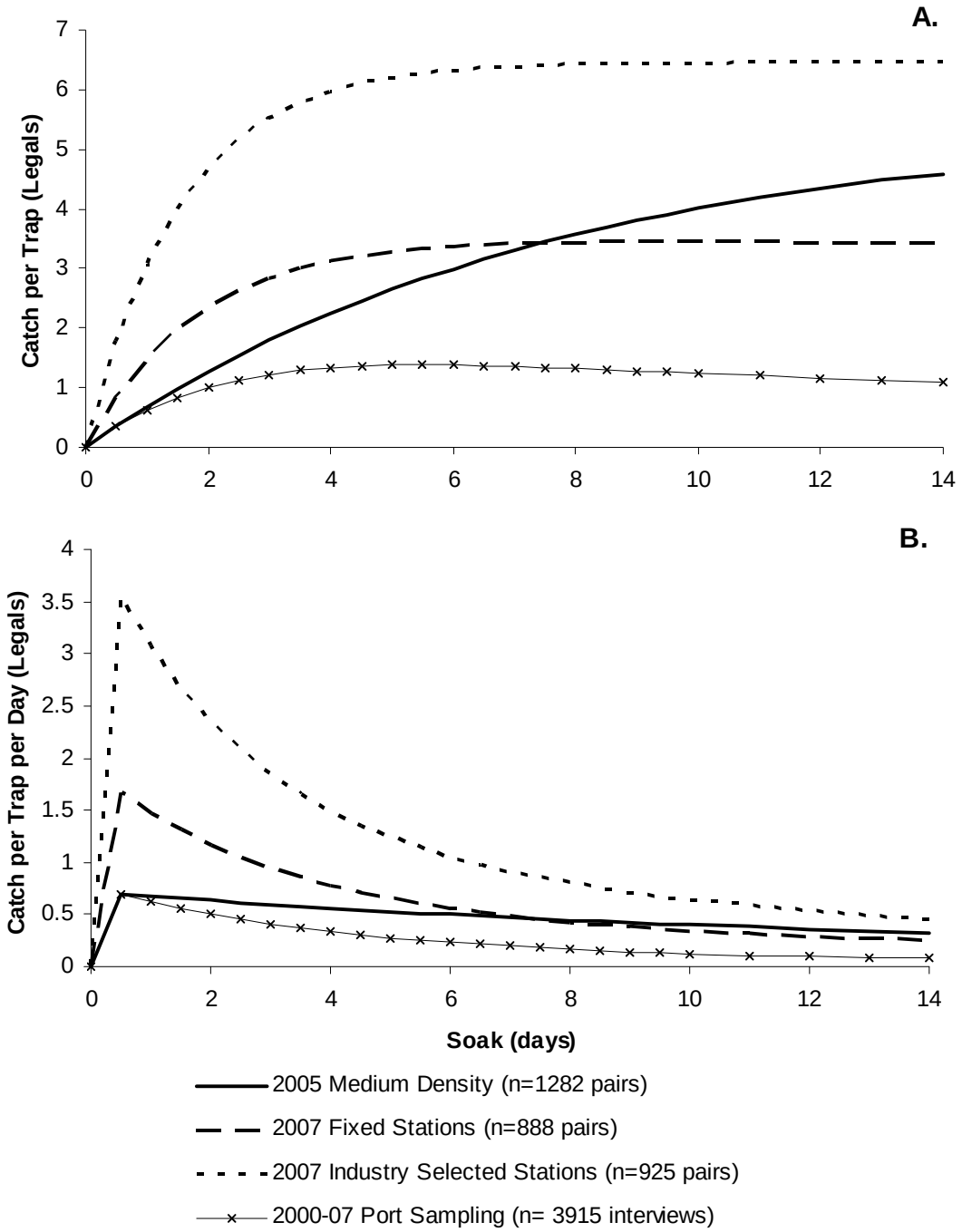

Figure 13. The relationship between soak time and catch (A) for the 2005 and 2007 experiments and the 2000-2007 Lobster Port Sampling Program following Equation 1.0. The projected catch per trap per day (B) for each scenario tested.

Table 5. Model fit catch per trap at five nights soak, from Equation 1, for the 2005 and 2007 soak time experiments and the 2000-2007 Lobster Port Sampling Program.

Survey	Catch per Trap at five nights	Catch per Trap per day
2005 Medium Density*	6.2	1.24
2007 Fixed Stations*	3.3	0.66
2007 Industry Selected Stations*	2.6	0.52
2000-2007 Port Sampling**	1.4	0.28

* pairs ** interviews

Tag and recapture results

Of the estimated 72,000 lobsters captured and tagged in the 2005 trapping experiments, less than 15% were recaptured in subsequent hauls. In areas where legal lobsters were removed after each haul, on average recapture rates were consistently less than 10%. In the two areas (medium density and random soak times) where legal lobsters were tagged and returned to the same area a greater, yet still low, percentage of 10-15% were recaptured on the next haul (Figure 14).

When recaptures are interpreted as a function of days at large in areas with fixed 4-night soak times, we find that less than 5% of lobsters were recaptured after twelve days (3 hauls) (Figure 15). Even in the two areas where soak time was varied randomly, legals were returned to the same area, and initial recapture rates were the highest, less than 5% returns were observed after three subsequent hauls (Figure 16). These results suggest that movement into and out of each experimental area was an important factor in this experiment as a complete overturn in each area likely occurred on a continual two-week basis.

The observations that recapture rates decline significantly after initial capture and were consistent among trap density treatments violates assumptions of a closed population needed for tag based estimates of population structure and fishing removals.

There were distinct biological differences in the make up of recaptures from areas where legal lobsters were removed and in areas where legals were returned immediately to the same area. In the six trapping areas where legal lobster were removed, a total of 3,575 were recaptured one or more times. Nearly 70% of recaptures in these were female (n = 2,526), suggesting females were 2.5 times more likely to be recaptured than males in these areas. Of the total recaptures in the fixed soak time areas, 32% were “legal”, indicating movements of legal lobsters from the common drop off location or from random soak areas back through trapping areas (Figure 17 A).

In the two areas where legal lobsters were immediately returned to the same trapping areas 2,326 lobsters were recaptured. Of these, only 49% of the

recaptures were females, indicating males were just as likely to be recaptured as females in these areas. Additionally, 72% of the returns were “legal” in size and disposition (Figure 17 B). Although the increases in catch rates in all areas over the course of the experiment and low recapture rates have suggested no depletion in the experimental areas, the differences in the biological composition of the catch suggest that removing legals from the trapping areas did have an impact at some level.

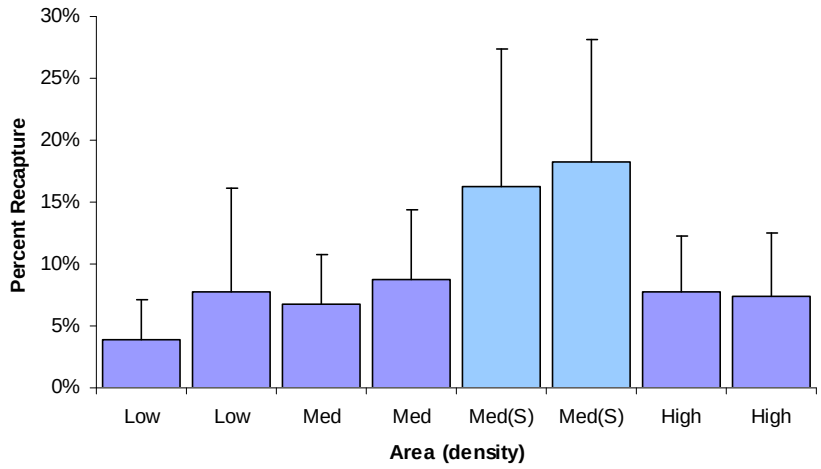

Figure 14. The average percentage recaptures after one haul for the eight experimental trapping areas. The areas in dark blue indicate treatments where legal lobsters were removed from the study areas. Light blue (Medium density, random soak times), indicates treatments where legal lobsters were returned to the study areas. Error bars are the standard deviation of the percentage of first day recaptures by area.

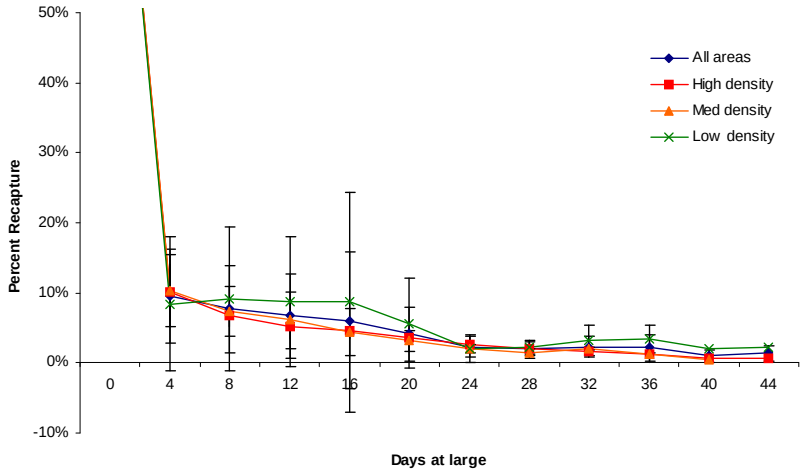

Figure 15. Average percentage of recaptures as a function of days at large and trap density in areas where soak time was standardized to 4-nights.

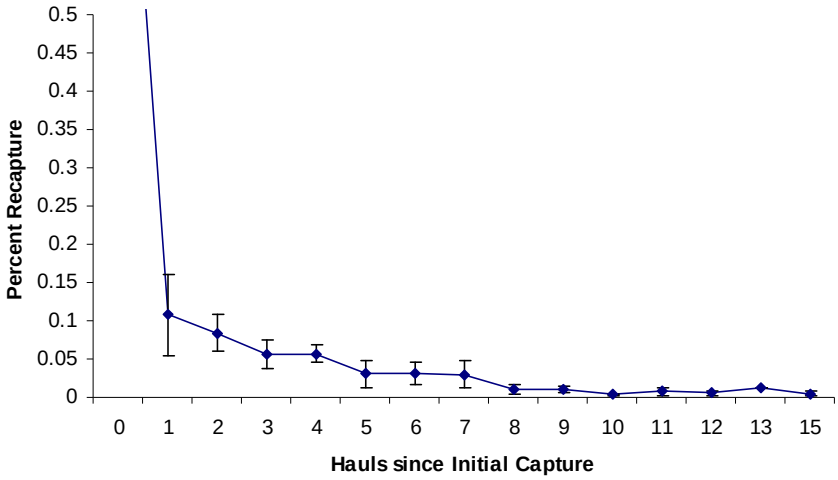

Figure 16. Average percentage of recaptures as a function of hauls since initial capture in areas where soak time was randomly selected between one and eight nights.

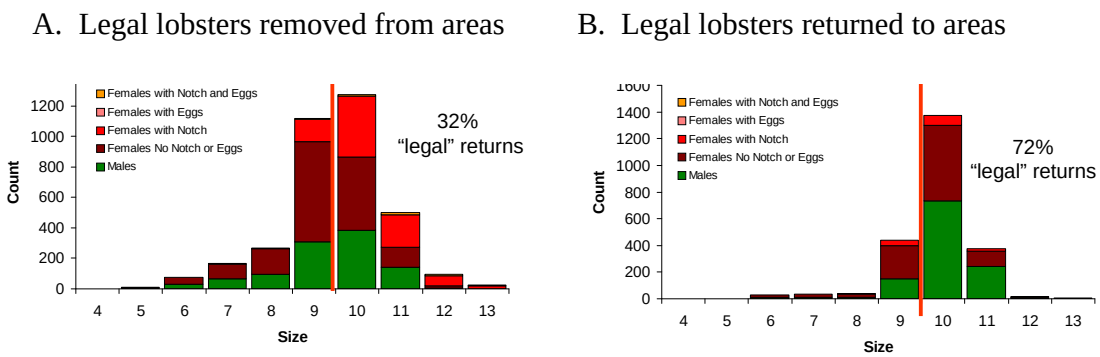

Figure 17. Size composition and biological makeup of recaptured lobster in (A) areas where legal lobsters were removed and (B) areas where legal lobsters were immediately returned. Red line indicated the break between sublegal and legal size.

In contrast to the 2005 trap density experiment, the 2007 trap study did see compounding impacts of trapping on the incidence of recaptures. Over the course of the experiment covering 30 days and spanning five weeks, the proportion of legal recaptures increased from 10-15% after the first week, to 25-35% in the final week of the experiment (Figure 18). Industry selected traps tended to be clustered in string of pairs which may have resulted in a consistently higher proportion of legal recaptures than the fixed stations which were relatively isolated. Regardless of industry selected stations or fixed stations, a higher proportion of legal recaptures were observed than was recorded in the 2005

experimental trapping areas. This disparity may be a reflection of water depth and timing of the experiment. The 2005 trapping had medium depth of 55 m while the 2007 experiment was 40 m. The 2007 experiment was conducted in August/September while the 2005 experiment covered October/November.

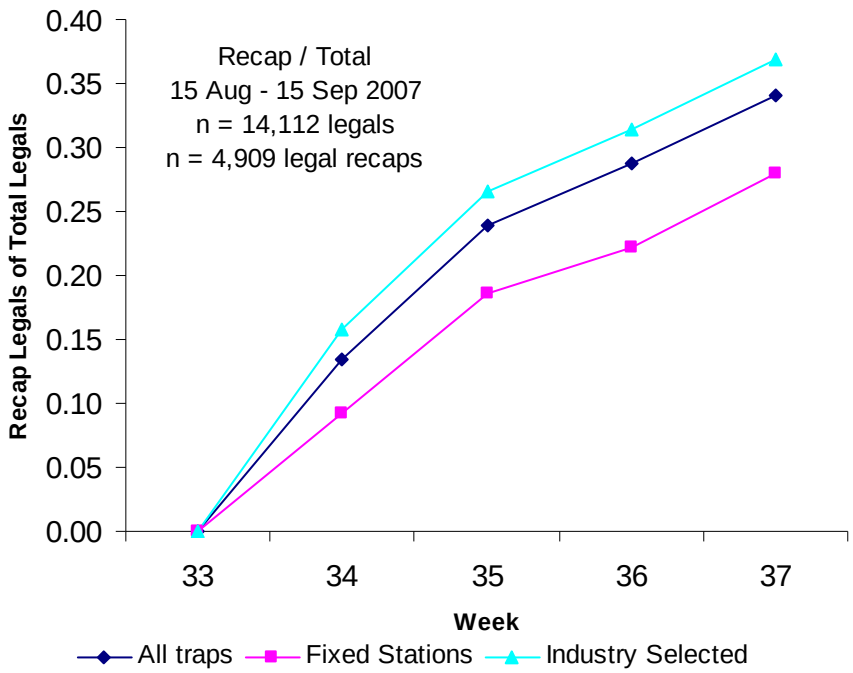

Figure 18. The proportion of legal recaptures to the total legal lobsters caught by week in the 2007 experiment. The experiment began on August 15, and concluded September 15, 2007. Lobsters were "knuckle-banded" and immediately returned to the water in the same location.

Monitoring the MILCA fishery

The 2004/2005 MILCA fishing season ran for 180 consecutive days from December 1, 2004 through May 30, 2005. Each of the 12 MILCA participants was licensed to fish 600 traps. Four MILCA participants (or 4 of 7 listed as participants on this project) completed daily trip reports.

At the beginning of the season the average soak time was three days with participants averaging 3.75 pounds per trap haul. Within six weeks the average soak time had increased to seven days and catch rates had dropped to less than 2.5 pounds per trap (Figure 19). The first month of the MILCA is very important, 50% of the annual catch is caught within the first three weeks of the season (Figure 20). The rapid decline in catch rates and increases in soak time are thought to be a result of the cumulative impact of the removal of legal lobster,

lobster movement out of MILCA waters and a decrease in water temperatures lowering the propensity of lobster to enter traps.

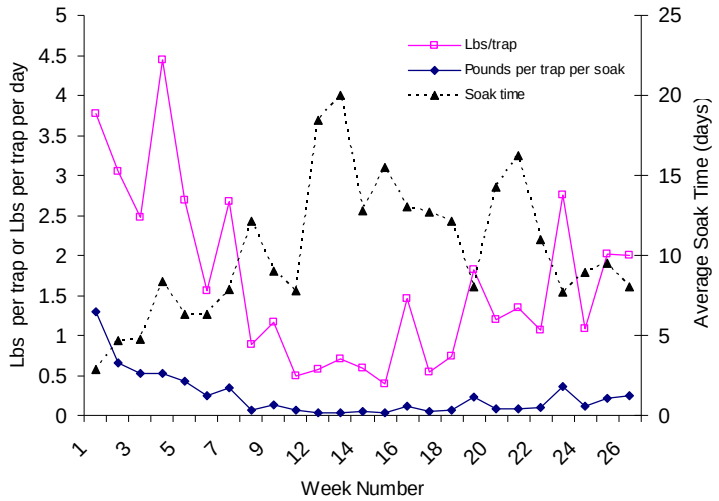

Figure 19. Average pounds per trap haul, pounds per trap per day soak and soak observed during the 2004/05 MILCA season. The season started December 1, 2004 (week 1) and ended May 30, 2005 (week 26).

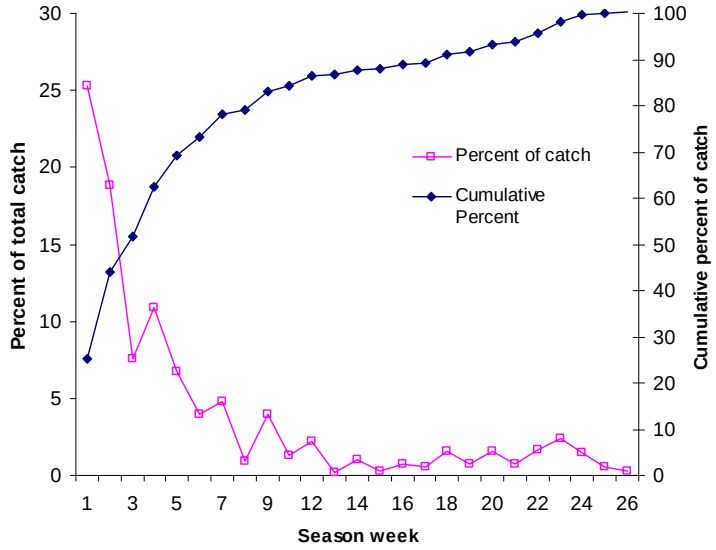

Figure 20. The percent catch and cumulative percent of the annual catch by week during the 2004/05 MILCA season. The season started December 1, 2004 (week 1) and ended May 30, 2005 (week 26).

Following the 2006/2007 season MILCA participants successfully facilitated a legislative change to expand their season from 180 to a maximum of 240 days. In doing so they accepted a lower trap limit, not to exceed 475, but set by the MEDMR Commissioner. In letters to the MEDMR from MILCA participants, it

was generally understood that MILCA goals were to increase their profits by 25% relative to the previous three seasons. The 2007/2008 season was set with a start date of October 1, 2007 and closing June 7, 2008 with a trap limit of 300 traps. The dates and trap numbers for the 2008/2009 season remained at these levels.

A direct result of the 2007 law change was that fewer traps were hauled more often for a longer period of time that resulted in a higher catch. Relative to the average of the three seasons prior to the 2007 law change, the catch of MILCA participants who submitted information (n=7) increased by a median of 72 and 67% for the 2007/2008 and 2008/2009 season (Figure 21). When total annual trap hauls, a gross measure of effort, is compared before and after the 2007 law change (n= 4 participants), there was an 18% increase in trap hauls for the 2007/2008 season and a 18% decrease for the 2008/2009 season as compared to the 2004/2005 season (Figure 22).

The success of the two seasons following the change to the MILCA season and subsequent 50% reduction of the maximum trap limit should not be considered a "real-world" application of reducing traps in the lobster fishery. While the reduction in traps was significant, the opportunity to expand the MILCA to previously un-fished months far exceeded the loss of traps. The overall trap density within MILCA is less than 100 traps km^{-2}. At this density traps are likely competing with each other when set nearby, but are not saturating the MILCA waters with traps relative to the rest of the Coast of Maine. There are no other areas along the Coast of Maine that are seasonally closed; therefore, an expectation of increasing total catch as a result of a trap reduction, as was seen within the MILCA, are unlikely.

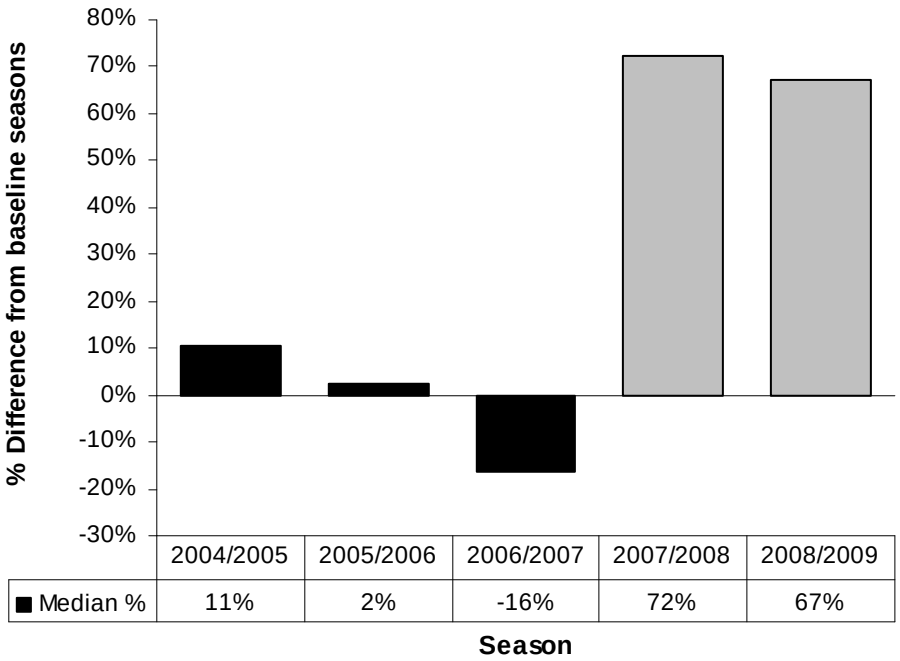

Figure 21. The median percentage difference of each seasons' landings relative to the average of 2004/2005, 2005/2006 and 2006/2007 landings. Values for the 2007/2008 and 2008/2008 seasons (shaded gray) follow the change in MILCA law that extended the season by two months and reduced the maximum number of traps fished from 600 to 300.

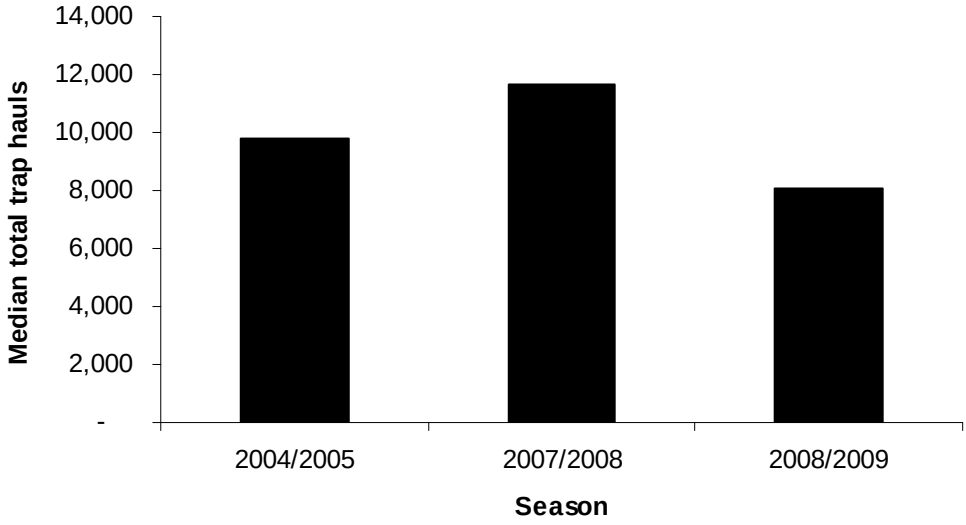

Figure 22. Median total trap hauls for four MILCA participants spanning the 2004/2005, 2007/2008 and 2008/2009 seasons. Values for the 2007/2008 and 2008/2008 seasons follow the change in MILCA law that

extended the season by two months and reduced the maximum number of traps fished from 600 to 300.

Independent monitoring of MILCA during experimental trapping

A total of 128 video transect were conducted over four days and among the eight experimental areas on the F/V Pandora. The average transect length was 130 m with a minimum of 70 m and a maximum of 240 m (Figure 23). A total of 16,582 m^2 were surveyed, with 298 lobster and 1,299 crabs observed. Lobster densities on the bottom increased over the course of the experiment (Figure 24). The average density of lobster was 0.02 m^{-2}, with a low of 0.006 m^{-2}on September 2, and a high observed on October 19 (of 0.026 m^{-2}).

The consistent increase in lobster density over the course of the experiment substantiates the regional pattern of increased catch rates observed.

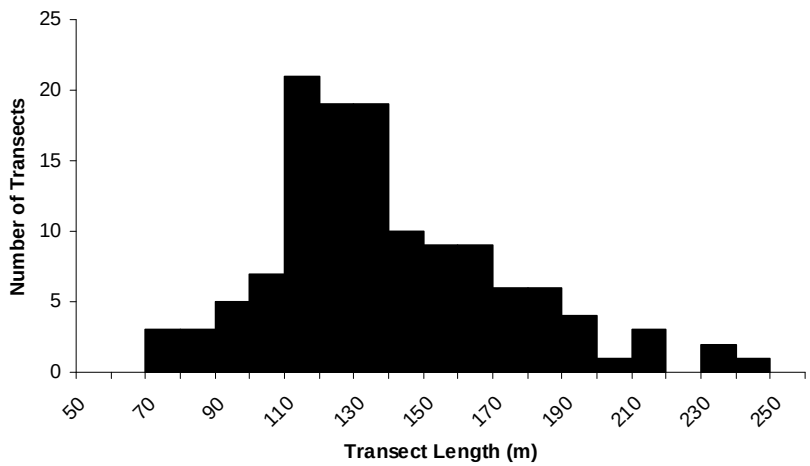

Figure 23. The number (n = 128) and length (mean = 130 m) of video transects conducted before during and after the trapping experiments.

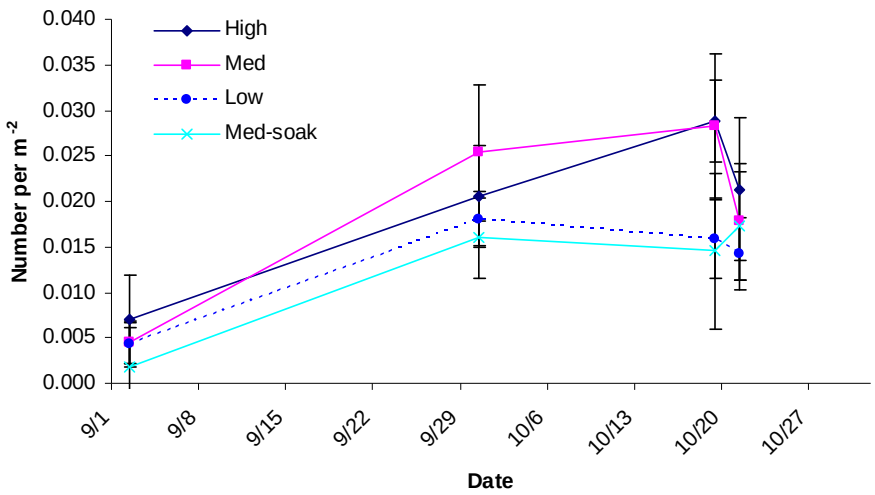

Figure 24. The average lobster density (number per m-2) in four experimental treatments conducted during September 2 and 30 and October, 19 and 21, 2005.

Partnerships

This project could not have been completed with out direct industry involvement in all aspects of the project. As the project was designed to "simulate" fishing, there was a natural fit of collaboration with 7 of 12 fishermen licensed to fish in MILCA waters. In total over 25 members of the commercial industry directly participated in this project.

Impacts and Applications

This project has broad impacts for trap fisheries in the US and Canada. Understanding how traps catch lobster helps to make informed decisions when changes in traps are proposed or interpreting results of previous trap reductions/changes. In general terms, understanding that reductions in traps (in this case trap density), can be partially or fully compensated by decreasing average soak time is an important component to any decision. These results present a double edge sword to proponents and opponents of trap reductions. Catch rate increased with decreasing trap density. However, total catch and therefore fishing mortality are likely not impacted until traps are reduced to the point where increases in catch rates and decreases in soak times can not make up for the loss in total catch.

This project has identified that individual trap catch rates are influenced by surrounding traps in the area. Across the scale of trap densities tested in this experiment, somewhere between 167 and 500 traps km^{-2}, there is a transition from saturating an area with traps and saturating individual traps. This tipping point is an important level to know, and could in part be investigated by

conducting additional controlled trapping experiments, where lobster competition in and around traps could be monitored through video.

The MILCA is the only seasonally closed area for lobster fishing in the US. Experimental areas for the 2005 experiment were isolated “islands” of traps, surrounded by unfished areas. It is unknown if the baited traps in these islands may have attracted lobster from surrounding unfished areas and influenced the catch rates. The 2007 trapping experiment to test the impact of soak time was conducted in the entire MILCA, with traps having little to no competition among traps. Regardless of the experiment in MILCA water’s, we have demonstrated that traps at known densities or in relative isolation can have a cumulative biological and fishery impact on the local lobster resource even when 70% or more or captured lobsters were never recovered.

Future trap density experiments should be conducted in defined areas, in regions where there is active fishing. We observed significant differences in catch between high density and low density areas at times when lobster density was low and high. Based on the 2005 trap density experiments, it is reasonable to assume if trap densities could be reduced in actively fished areas, then catch rates should increase and compensate for any reduction.

Testing the cumulative impacts of the lobster fishery on the resource may be difficult to do by manipulating defined areas (km) as we have demonstrated that lobsters are unlikely to be caught in the same area in as little as two weeks. Fixed areas would not adequately capture the natural movements of lobsters and the fishery that pursues them. A more appropriate test would be to manipulate trap numbers at a scale that would reasonably capture regional movement of lobsters in one year (10s km).

Finally, the trapping experiments were conducted at an opportunistic time for MILCA participants. The 2005 experiment followed the first of three consecutive years with declining catch. In meetings prior to submission and funding of this project, some MILCA participants expressed skepticism to the availability of lobsters in MILCA waters outside of their fishing season and to the risks associated with reducing traps. However; the 2005 experiment, regardless of trap density treatment, demonstrated an increase in lobster availability in the early Fall within the MILCA waters. It is this knowledge that may have reduced some of the uncertainties and risk MILCA participants undertook by expanding their season in 2007 while reducing the maximum trap limit from 600 to 300. In the two seasons following the 2007 legislative change, total catch has increased dramatically, but a significantly lowered boat price and increases in the cost of bait and fuel have dampened the success of the season/trap change. At the writing of this report it is clear that the perceived success of the MILCA is more closely linked to the financial success of participants and the Monhegan Island community then to the undefined standards of exclusive fishing rights in a state sanctioned Lobster Conservation Area.

Presentations

This project has been presented to many different groups and audiences. A partial list is as follows:

February 2006
- Monhegan Island Fisherman, Monhegan Maine
- Commissioner of Marine Resources, Hallowell Maine
- Zone D, Rockland Maine

March 2006
- Phippsburg Public Library, Phippsburg, Maine
- Wiscassett Public Library, Wiscassett, Maine
- Zone D, Rockland, Maine
- Cutler Fishermen, Cutler, Maine

April 2006
- Swans Island Fishermen, Swans Island, Maine
- Isle Au Haut Fishermen Co-op, Isle Au Haut, Maine
- Maine Sea Grant Review, Orono, Maine
- Lobster Advisory Council, Augusta, Maine
- University of New Hampshire, Durham, NH

May 2006
- Irish Lobster Fishery Conference, Gallway, Ireland
- Lobster Conservation Mangement Team, Portsmouth, NH
- Lobster Advisory Council, Augusta, ME

September 2006
- Maine Offshore Lobstermen Association, Brunswick, ME
- Downeast Lobsterman Association, Ellsworth, ME
- Chewonki Foundation, Boothbay Harbor, ME
- Commissioner of Marine Resources, Hallowell Maine

November 2006
- Lobster Advisory Council, Augusta, ME

February 2007
- Fishermen and Scientist Research Society, Truro, NS
- Zone C, Bucksport, ME
- Zone E, Wiscassett, ME
- Zone F, Cape Porpoise, ME

March 2007
- Outward Bound Science Educators, Portland, ME
- GMRI Fish Tank, Portland, ME

April 2007
- Zone B, Bar Harbor, ME
- Zone D, Rockland, ME

August 2007
- Gulf of Maine Research Foundation, Damariscotta, ME

September 2007

8th International Conference on Lobster Biology and Management, Charletown, PEI
February 2008
University of Southern Maine, Portland, ME
March 2008
Maine Fishermans Forum, Rockland ME
April, June and July 2008
Tenants Harbor Fishermen, St. George, ME.

Published reports and papers

This project has not been submitted for peer review. However, extensive coverage of the preliminary results were published in the Fisherman Voice (March 2006) and featured in the NEC contribution to the Commercial Fisheries News (May 2006).

Images

All images are available on request in full resolution. Maine Department of Marine Resources should be credit for all photos, unless otherwise specified.

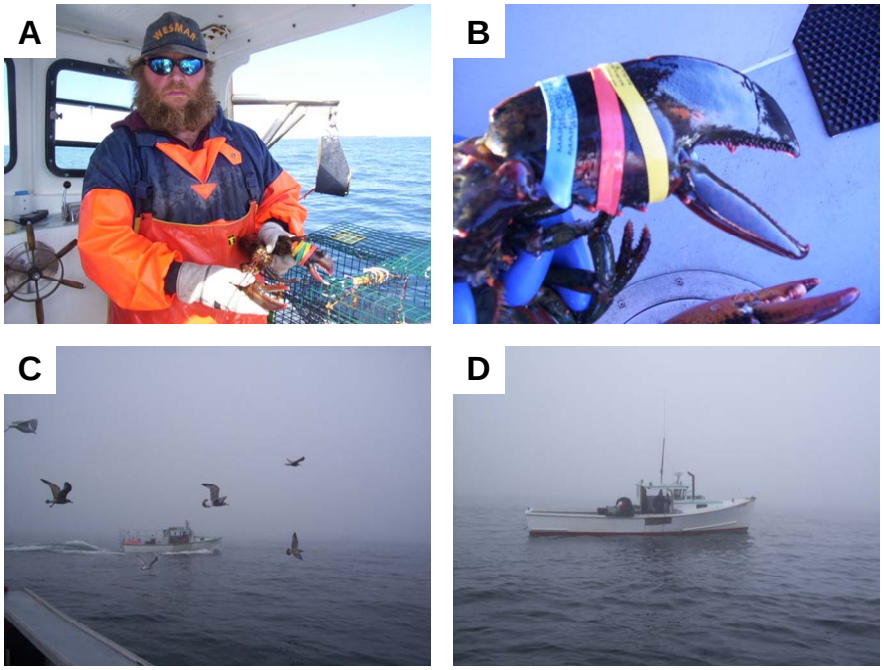

Figure 25. (A) Captain Mathew Thomson, F/V Pats Girl. (B) Lobster tagged and re-caught three times during the 2005 soak time experiment. (C) F/V Seldom Seen and (D) F/V Kathleen.

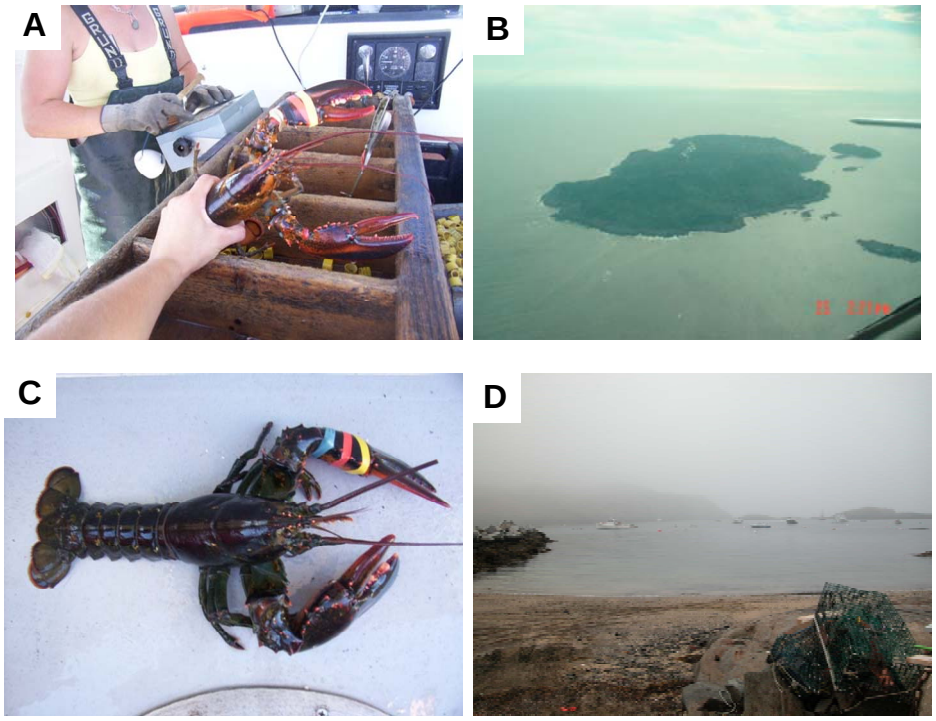

Figure 26. (A) Entering trap haul information on Thistle Marine Electronic Logbook. (B) Monhegan Island from air. (C) A lobster that was recaught three times during the 2005 soak time experiment. (D) View of Monhegan Harbor from Fish Beach.

Figure 27. (A) The Monhegan Island fish house, location of project meetings. (B) F/V Pandora. (C) Jessica Stevens, primary sea sampler for the 2005 experiments. (D) F/V Pandora loading traps on trap day, December 2005.

Figure 28. (A) Captain Robert Bracy, F/V Pandora. (B) F/V Pats Girl, (C) Captain Dan Murdock, F/V Sylvia Anne and (D) Captain David Boegel and crew Rusty Spear, F/V Kathleen.

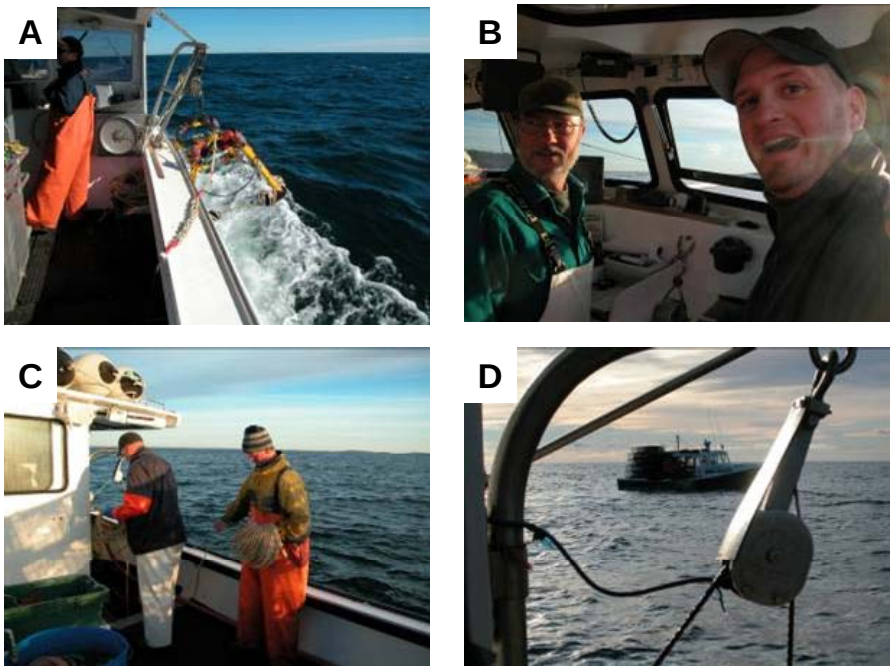

Figure 29. (A) Drop camera system onboard the F/V Pandora. (B) Captain Sherm Stanley and Matt Schweier, F/V Legacy. (C) Kohl Lord coiling rope at the conclusion of the 2005 trapping experiment. (D) F/V Sylvia Ann taking up traps.

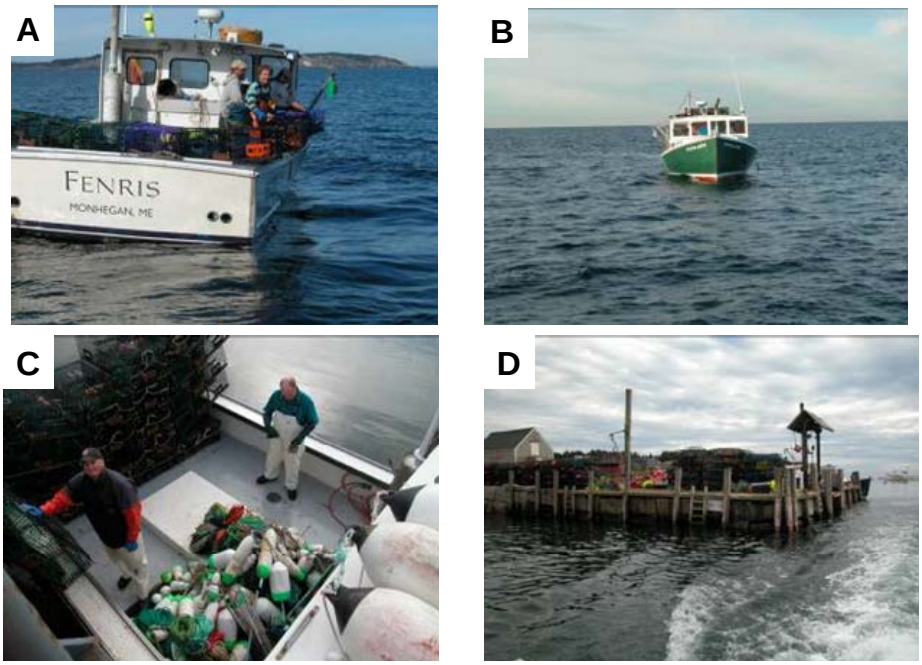

Figure 30. (A) F/V Fenris, (B) F/V Sylvia Anne, and (C) M. Schweier and S. Stanley unloading traps. (D) Traps on the Monhegan wharf at the conclusion of the 2005 trap density experiments.

Figure 31. (A) Monhegan Harbor. (B) Angela Iannicelli and Matt Weber rowing to F/V Seldom Seen. (C) Captain Matt Weber, F/V Seldom Seen, with a standard 4-foot trap hauled in a medium density area. (D) F/V Sylvia Anne in the distance.

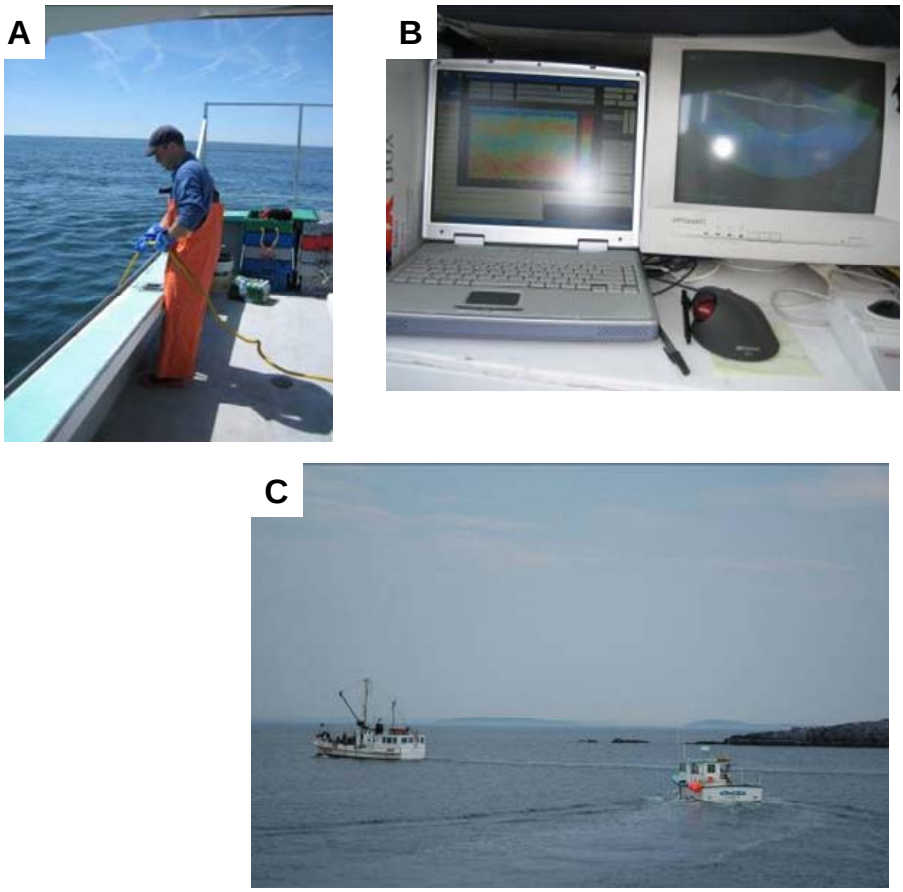

Figure 32. (A) Dr. Tom Weber, UPENN now at UNH, during the April 2005 multibeam survey. (B) Multibeam display on board the F/V Seldom Seen. (C) F/V Seldom seen, leaving Monhegan Harbor while conducting the multibeam survey. Monhegan Boat Line ferry, M/V Laura B, in the distance.

Figure 33. (A) S. Stanley and K. Lord haul typical trap from industry selected sites for the 2007 experiment on soak time. (B) M. Weber and Chris Smith hauling a pair, while Jeni Menendez, DMR sea sampler, records and measures lobsters. (C) Lucas Chioffi, captain F/V Fenris recovers a pair of traps while Carl Wilson, DMR, records and measures lobsters.

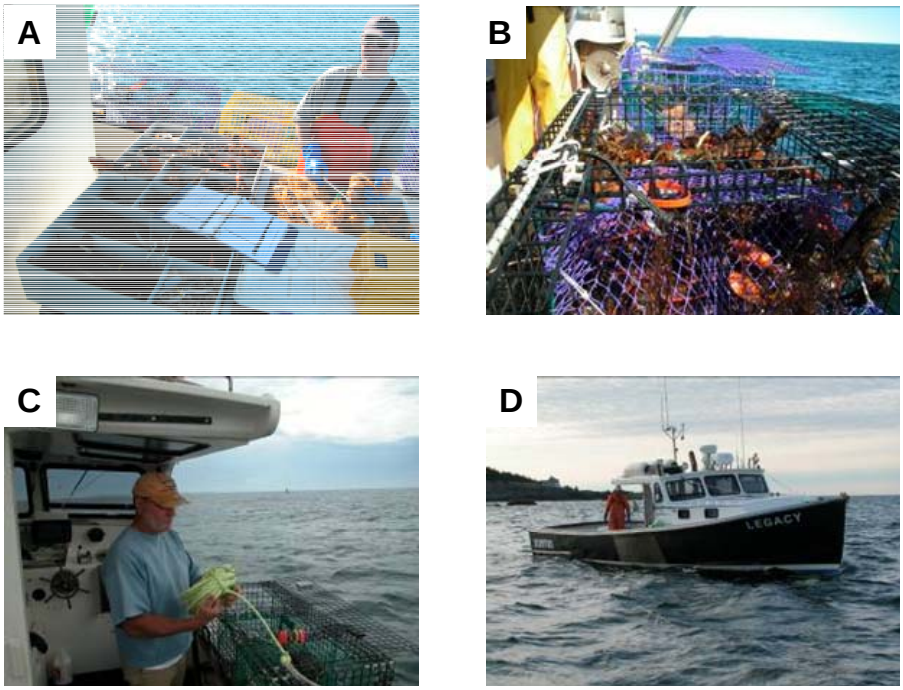

Figure 34. Lucas Chioffi rebaits a trap, with lobsters and the 2007 logbook in the foreground. (B) An exceptional catch. (C) S. Stanley prepares to set traps using experimental low profile whale line. (D) F/V Legacy.

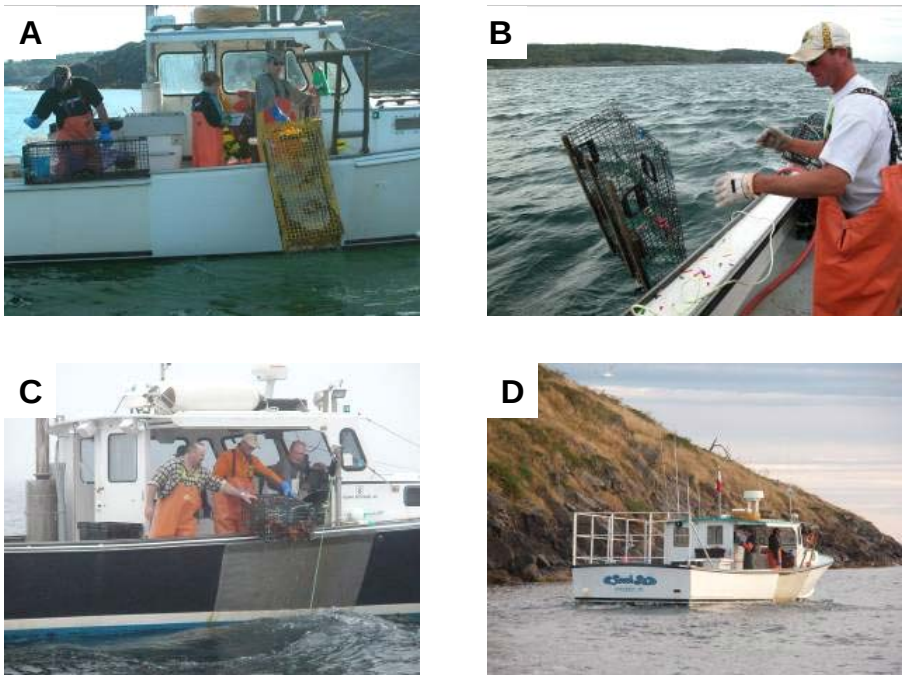

Figure 36. (A) L. Chioffi and M. Weber haul and rebait traps while J. Menendez records and measures lobsters aboard the F/V Fenris. (B) K. Lord sets a trap. (C) S. Stanley, K. Lord and Tasmanian Rock Lobster fisherman, Neville Perryman recover a pair of trap. (D) F/V Seldom seen having just set a pair of traps in Monhegan Harbor.

Future research

The MILCA offers a unique opportunity to conduct controlled experiments on lobster in a trap free environment. The basic findings of this project that relate to trap density, soak time and recapture rates have broad implications for the Maine lobster fishery and lobster biology. However; caution should be used if specific results are applied to other areas of the Coast of Maine. The preliminary results of the trap density studies have been presented to various industry councils and to public audiences. The potential application of experimental results to areas outside the MILCA is the largest criticism received and presents the strongest case for future research.

The Maine DMR was approached, by fishermen in Tenants Harbor, Maine, to conduct a trap density experiment in their fishing area. Tenants Harbor is a heavily fished area, approximately 30 km from Monhegan Island. Nearly 90 licensed fishermen, fish up to a maximum of 800 traps, in an area the size of the MILCA. Fishermen report that trap densities in excess of 2,000 traps km^{-2} are not uncommon during summer months when fishermen shift traps to inshore waters to catch newly molted lobsters.

In August 2009, a two week experiment was conducted in two ½ nm^2 experimental areas near Tenants Harbor. The objective of this study was to document the impact of removing 50% of the traps. Aerial over flights prior to the start of the experiment recorded nearly 3,000 buoys in the experimental areas, and on the water observations suggested as many 40 fishermen fished there. Fishermen were asked to remove traps on a voluntary basis and were compensated to do so. Preliminary results suggest that an insufficient number of traps were moved to test the impacts of reduced trap density. However; the challenges of conducting controlled experiments in an open fishing area were revealed and can serve to guide additional studies.