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LOBSTER SAMPLING TRAP

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B.A. Hartwick College, 2003

A THESIS

Submitted in Partial Fulfillment of the

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(in Marine Bio-Resources)

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By William H. Fike

Thesis Advisor: Dr. Robert C. Bayer

An Abstract of the Thesis Presented
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The American Lobster fishery is one of the most valuable in the United States. To properly manage any fishery a large quantity of data is necessary. The Atlantic State Marine Fishery Commission states that the largest factor restricting the ability to manage the lobster fishery is the lack of data.

Today there are many different methods of stock assessment at the government and non-government levels. While there are many different methods for collecting data concerning the lobster fishery, the quantity of data is inadequate and contains gaps in the lobster life cycle. Because of this lack of data new means are necessary to collect information.

A Lobster Sampling Trap was designed, created and tested to assist in the collection of data. This trap allows sublegal sized lobster to enter without allowing legal sized lobster to enter. Several entry sizes were tested on various substrates. The results were compared with those from a ventless trap and showed that the sampling trap caught lobsters that were smaller on average than those caught by the ventless trap. Sampling smaller younger lobster gives additional time to respond to any changes observed in the lobster population. It is believed that the presence of large

lobsters inhibits the smaller lobsters from entering the traps. Therefore, the smaller lobsters are not adequately sampled by ventless traps containing large lobster. A different sampling trap from the ventless trap can fill a gap in data being collected at an earlier stage in the lobster life cycle.

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Introduction

The American Lobster (*Homarus americanus*) has not always been the prized commodity it is today. A century ago lobster was being used as fertilizer and served in prisons. Today the American lobster is looked upon as a delicacy and an economically important resource, especially in the state of Maine.

The lobster industry has a large economic impact with approximately 183,000,000 pounds of lobsters landed annually in the U.S. and Canada. Seventy-five percent of lobster is processed while twenty-five percent are shipped live around the world (Lobster Institute, 2004.) Because of this market the lobster industry does not only affect the economic stability of the fisherman, but also the people that make this market possible; including boat builders, marine suppliers, and the herring industry which supplies 700 to 800 million pounds of bait a year. Also, the economic impact on the tourism industry is difficult to estimate, but is seen in hundreds of restaurants serving lobster, and providing lodging in fishing communities. In the state of Maine the economic impact of the lobster fishery on the state economy was \$500,000,000 in 2004 (Lobster Institute, 2004).

Today technological increases have made it possible for fishermen to locate, set and haul traps more efficiently than ever. This makes it possible for one lobsterman to haul 400 traps a day (Krouse and Thomas, 1974) (Wahle and Steneck, 1997). In 2005, 67,348,674 pounds of lobster were landed in the U.S. with a value of \$311,574,974 (DMR Landing Statistics, 2005). More than twice as many lobsters were caught in 2005 as in 1990.

The question is whether the population can remain stable with so many lobsters being harvested. Because the lobster industry has such a profound effect on our economy including rural areas with limited opportunity for employment, the lobster population must be monitored and protected. At this time there are several methods in place that are used for monitoring the lobster population. These monitoring programs are run by different government agencies and by private organizations. The methods of monitoring vary from bottom trawling to volunteers counting larva on the sea shore (Cowan, 1999).

The objective of this study is to create a lobster sampling trap that would target sub legal sized lobsters, while excluding legal sized lobsters. Compared with the ventless trap, this trap could sample sublegal populations at a smaller size and estimate future populations of legal sized lobsters. Sublegal sampling will also serve as an early warning system to monitor lobster stocks.

Literature Review

Range

American lobsters can be found along the northeastern coast of North America, from North Carolina to Labrador. Lobsters inhabit waters from the shoreline to fifty miles off the coast and from one fathom to 100 fathoms (Herrick, 1911). A range of the northwest Atlantic Ocean continental shelf area crosses national and internal borders (Phillips, Cobb Vol. I, 1980).

Life Cycle

Lobster eggs hatch during the months of June, July, and August when the water is around 22°C. *Homarus americanus* larval life period takes three weeks and involves four stages. Lobsters molt to grow and during the larva period molt to move through the different stages that bring them to their adult form. The lobster's life is defined by stages; each molt brings the lobster to a new stage starting with the first molt and the first stage lobster. The first four stages are in a planktonic state where the larva is free swimming. Of these first four stages only the fourth stage resembles an adult lobster and begins to seek the bottom (Herrick, 1911). The completion of the molt from the fourth stage to the fifth stage marks the end of the larval period (Herrick, 1911). Fifth stage lobsters are bottom dwellers although swimming has been observed at this stage. For the remainder of their life lobsters will continue to molt and grow (Cooper and Uzmenn, 1977). During the fifth stage the lobster instinctively seeks concealment. The lobster will find concealment by digging or hiding under structures. This instinct will continue

for the rest of the lobster's life, leaving protection only to feed, mate, or migrate (Herrick, 1911).

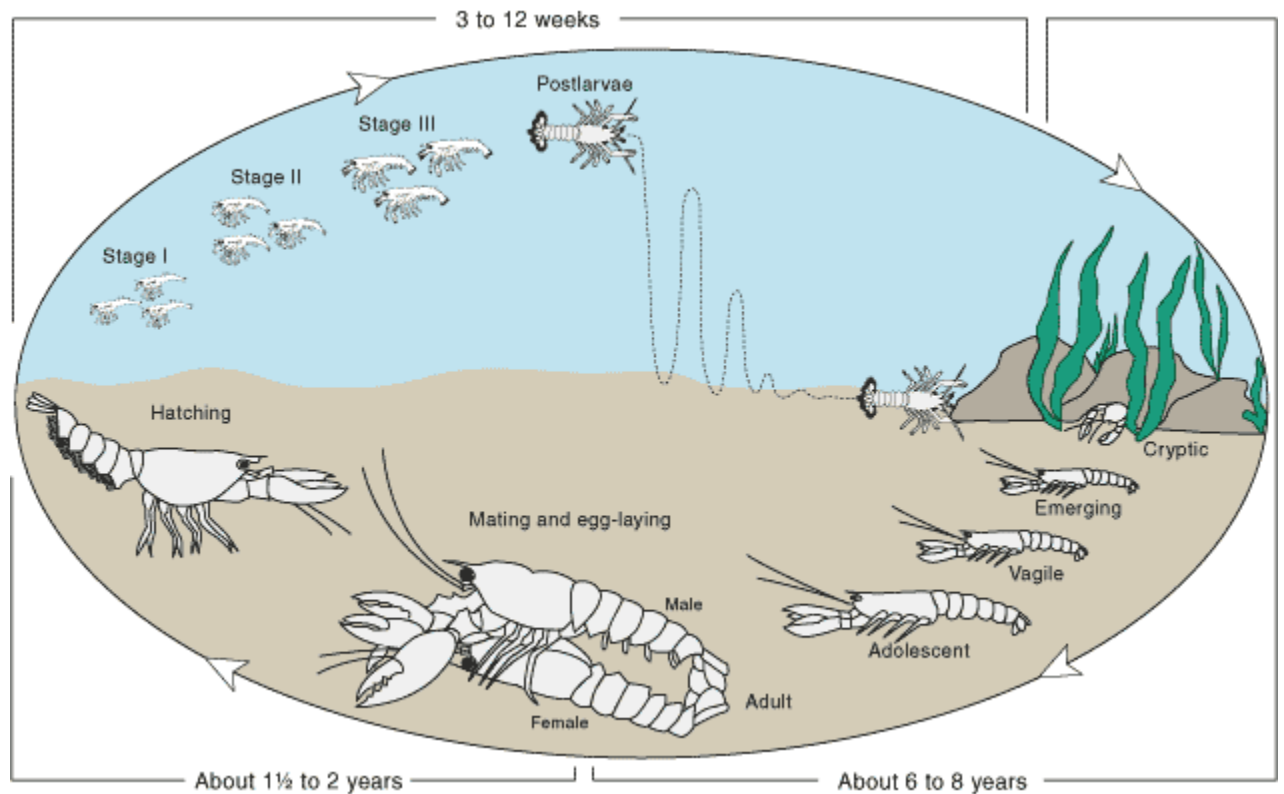


Figure 1. Lobster Life Cycle (Paille and Bourassa, 2007).

Molting/Growth

Lobsters molt their hard calcareous shell, for the purpose of growing and regeneration. The term molt includes the period of preparation and recovery from ecdysis. Ecdysis is the period when the outer cuticle, shell, of an arthropod is shed. Lobsters spend a large period of their life preparing for and recovering from ecdysis. Ecdysis leaves the lobster at its most vulnerable and typically takes place in a sheltered area. During ecdysis the carapace is lifted up and forward away from the new carapace. Then the head appendages are removed with the abdomen being the last removed from

the old exoskeleton. At this point the lobster is placid and can not move. The lobster will now begin to absorb water for the purpose of increasing the new shell's size. This will provide the lobster with enough room to grow before their next molt. During the first year of a lobster's life it will molt nine to twelve times. The next three to six years of the lobster's life will include approximately another nine molts. During this period the male lobster will molt more frequently (McLeese, D.W., 1972).

Habitats/Environment

Lobsters wander the sea bottom foraging for food and searching for concealment. Food and shelter are the lobsters' primary concerns. The abundance of food and shelter along with its molting cycle and breeding periods affect the lobsters' location. The animal's instincts drive it to continuously find protection by means of concealment. Concealment can be found by burrowing in the sand and under rocks, where they ambush prey (Herrick, 1911).

Once a lobster reaches stage IV it settles to the bottom and searches for a suitable substrate. While some substrates undoubtedly provide greater protection to the newly settled lobster, finding shelter quickly is their primary goal with a preference for preexisting structures such as cobble. If unsatisfactory substrates are present the stage IV lobster may swim in the water column to test other bottom types (Stenneck, 1989). As the lobster grows and becomes an adult, it chooses to occupy a wider variety of habitats such as cobble, rock, mud, and sand, while in certain areas concealment is limited (Factor, 1995).

The National Marine Fishery Service (NMFS) conducted direct observations and concluded that the most common inshore habitat for the American lobster is a sand base with rock. Observations were conducted using scuba and research submersibles allowing for the substrate classification. In the sand/rock substrate a variety of lobster size is found. The lobsters burrow in the sand under the rock creating a tunnel-shaped shelter. The tunnel of the larger carapace length lobster (50-100mm CL) is typically 30-40 cm below the sediment-water line. The small lobsters (less than 30mm CL) have tunnels ranging from 40-70 cm below sediment-water line and may have several tunnels (Cooper, 1970) (Cobb, 1971).

Two other common substrates that are habitats to lobsters are mud base with burrows and clay base with burrows. These two substrate types are both utilized by the lobster in the same manner, burrowing. These burrows are typically 60-80 cm below the sediment-water line and at an angle of 40-90 degrees from horizontal. The mud bottom is found along the coast of Nova Scotia, the Gulf of Maine, southern Massachusetts, Rhode Island, and in Long Island Sound. The clay substrate dominates the offshore region of the lobster habitat, specifically the outer shelf and upper slope of New England and the Mid Atlantic Bight (Cooper, R. A., et al., 1975).

Throughout the year lobsters are found at different water depths for different environmental reasons. In the spring the lobsters move closer to the shore and then in the fall move further out to sea. This migration is most likely related to the location of sufficient quantities of prey, molting cycle, laying eggs, and water temperature. Lobsters undoubtedly follow food, but must move to warmer waters to distribute their eggs (Herrick, 1911).

During annual migrations lobsters will travel large distances and return to their original area. Another possible reason for the lobsters' seasonal migration could be the avoidance of the increased turbulence in the shallower waters during the winter months.

It is also believed that this migration could assist in maintaining the optimal growing temperature for the lobsters of 8-14°C. For whatever reason lobsters migrate, they do so at a surprisingly fast pace: 7.4-9.3 km a day. Immature tagged lobsters have been recovered an average of 4.7 km away from the tagging site and mature lobsters an average of 15.6 km away, with some lobsters traveling in excess of 93 km. While the reasons for their movement can be questioned, the fact that they do travel great distances is not (Uzmann, J. R., et al., 1977).

Feeding

Lobsters prey upon a large variety of food types that include plants and animals, alive or dead. While they are opportunistic feeders they prefer live prey rather than decomposing food. The adult lobster's diet is primarily composed of different bottom invertebrates such as crabs, polychaetes, mussels, periwinkles, sea urchins, and starfish. Lobster larvae eat a wide variety of prey types with small zooplankton being particularly important to the first two stages (Templeman and Tibbo, 1945) (Juinio and Cobb, 1992). Algae and eel grass have been found in lobster stomachs which some believe is eaten accidentally while searching the sea bottom for food. Calcareous fragments of shells from crustaceans have been found in the lobsters' stomachs during the time of molting. The purpose of eating these shell fragments is to absorb the calcium and phosphorus from shell deposits to harden the lobster shell after molting (Herrick, 1911).

These animals are not particularly selective when it comes to food and are always ready to prey upon those who are smaller and weaker than themselves. Lobsters do not specify between different species and will prey upon its own species if the chance arises (Leavitt, et al., 1979). This act of cannibalism is particularly true of lobster in close proximity, and this author's observations showed lobsters exoskeletons inside of a dissected lobster.

Lobster Fishery Management

Harvest of *Homarus americanus* is strictly managed with several checkpoints for regulating the rules. Two factors that have changed the fishery are technology and competition. Since more lobsters are harvested each year, changes in management are necessary. The primary difficulty managing the fishery is the lack of knowledge of lobster biology including ecology, biology, population statistics, and mortality (ASMFC, 2004).

Country and state laws pertaining to harvestable lobster vary. The reason for the inconsistency in regulations is that different organizations take different approaches to making the lobster fishery sustainable. While there are many management strategies, there are some consistencies in the regulations just as there are inconsistencies. The problem is, not knowing which management strategy will help make the fishery sustainable when there are many other aspects affecting the fishery including weather, predators, and disease.

Canadian Regulations

The Canadian Lobster fishery is regulated by the federal Department of Fisheries and Oceans (DFO). For the purpose of more efficient management the large Canadian fishery is divided into four regions: Newfoundland, Quebec (northern Gulf of St. Lawrence), Gulf (southern Gulf of St. Lawrence), and Scotia-Fundy (Bay of Fundy and Nova Scotia, excluding the Gulf of St. Lawrence). While major changes to the laws must be approved by the DFO, modification to existing rules can be made by any senior DFO manager in a region. Each of the four regions is divided into lobster fishing areas (LFA) that allows for regulation adjustments for reasons of weather, markets, and different approaches to management. Regulations include fishing season dates, minimum size, limited entry to fishery, type and quantity of gear, and the taking of egg bearing females (Department of Fisheries and Oceans, 1993).

Limited entry regulations have prevented any new licenses from being sold since 1968; licenses can only be transferred from one owner to another. This regulation is an effective means to create a sense of ownership in the fishery. Fishers want to conserve so that they can fish tomorrow. This is a much better ideology than 'if I don't catch the fish today someone else will' (Harding, 1968).

Having staggered open season dates by LFA has several benefits. One benefit is that the Canadian fishery is closed during the peak of the U.S. fishing season helping preserve the value of the catch. Having seasons regulated on the local level also allows for the avoidance of fishing during inclement weather such as storms and ice (Factor, 1995).

Minimum size limits are an important management tool in order to keep a fishery sustainable. This is because without this regulation lobsters could be harvested prior to sexual maturity. Harvesting lobsters prior to sexual maturity would drastically reduce the reproductive population and the total population. Depending on the LFA minimum legal size can vary from 61-84mm. The difference in minimum size is a direct effect of the variation of the size at which the lobster reaches sexual maturity in the different locations. There is also the potential to use the minimum size regulation as a marketing tool. If the market is flooded with products the minimum size could be raised to decrease supply and increase the price. Then when the price increases the original minimum size could be reinstated and an increased profit realized. This is an interesting tool to regulate the price of a product (Factor, 1995).

The protection of ovigerous, egg bearing, females has gained much support in the fishing industry. While the number of eggs required to sustain the fishery is unknown, ovigerous females determine future harvests and their protection is supported by the fishing industry (DFO, 1993).

There are several regulations pertaining to gear type. The Canadian fishery allows only the use of fishing traps of a designated size, trawling is not a legal means of catching lobsters. Regulations concerning trap design also include a vent to allow sublegal lobsters to escape. The trap design must also include a time release device that will allow lobsters to escape in case the trap is lost at sea resulting in “ghost fishing” (DFO, 1993).

United States Regulations

The U.S. lobster fishery is divided into federal and individual state areas. Each of the eleven states that have a lobster fishery manages the area to three nautical miles from the coast independently. From the three nautical mile mark to 200 nautical miles is federally regulated by the National Marine Fishery Service (NMFS). When an individual has a federal and a state permit to fish, the more restrictive regulation applies to the fisherman at all times (ASFMC, 2004).

Many of the U.S. lobster fishery regulations are the same from state to state with only small variations. All states have a minimum legal length that is 82.5 mm carapace length except for New Jersey which is 81 mm. All ovigerous females are protected in U.S. waters, with v-notched lobsters being protected in Maine and Federal waters. A v-notch is a cut into the tail of an egg bearing female to identify it as such and to prevent the harvesting of that lobster. Trap escape vents, to allow sublegal lobster to escape, are also mandatory in all U.S. waters, although the size of the opening depends on the area fished. In all areas except New York and New Jersey a timed release opening is necessary to allow animals to escape from lost, “ghost,” traps. Regulations concerning fishing gear type, trap limits, entry to the fishery are more varied from state to state and in Federal waters than are other regulations. The reason for the regulations is the same, to create a sustainable fishery.

The Atlantic States Marine Fishery Commission (ASMFC) was formed by the fifteen U.S. States to coordinate interstate protection of marine fishery resources. Of these resources the American lobster is one of twenty-three shellfish species managed and is the most economically valuable species. To manage a fishery the ASMFC Stock

Assessment Subcommittee conducts stock assessment to collect data concerning the abundance of a species in different areas. The data that is collected is then given to the Model Development Subcommittee in the ASMFC that enter the data into models. Models are used to predict potential future harvests.

In 2004 the ASMFC conducted a review of their stock assessment models. This committee reviewed the different models that could potentially be used to predict the future of the lobster fishery using the data available from the stock assessments. The committee concluded that the largest limitation on the ability to manage the fishery was the lack of data stating that the best well managed fisheries in the world spends at least 2-5% of the landed value on data collection and analysis. This would mean that in the Gulf of Maine an annual investment of \$4-10 million would be necessary, an amount that is much more than currently being invested (ASMFC, 2004).

Stock Assessment

Government

There are many different methods used to study population fluctuations of the lobster. Since 1966 the Maine Department of Marine Resources (DMR) has been conducting lobster studies. The three primary studies are: The Commercial Lobster Port Sampling Program, The Sea Sampling Program, and The Biological Studies Program.

The DMR Commercial Lobster Port Landing Program is the longest running lobster study that involves collecting data directly from lobstermen. From April to December ten randomly selected lobster buying locations have information collected

from lobstermen as they arrive at shore to sell the lobsters. The lobstermen are asked questions pertaining to the number of traps hauled, trap location, bait type, number of crew, depth fished and soak (the period of time between setting the trap and hauling). Also, a portion of the catch is sampled for carapace length, weight, sex, and whether the shell is hard or soft. This sampling method provides data on the lobsters being harvested during the most productive fishing months (Wilson, 2006).

Another method that DMR uses to collect lobster data is The Lobster Sea Sampling Program. Started in 1996 this program involves volunteer lobstermen allowing trained observers to go to sea with them for a day for data collection. Every lobster caught in a trap has data recorded: sex, length, cull status (missing limbs), v-notch condition, egg development, and molt status. Also, general data is collected on location, trap depth, and soak period. This data provides information concerning what is being caught in the lobster traps, not only what is being harvested (Wilson 2006).

The Biological Studies Program's ventless trap survey also collects biological information. The Ventless Trap Survey characterizes the abundance and size-distribution of lobsters. The design of a ventless trap is a standard lobster trap that has had the vent allowing sublegal lobsters to escape, closed off (Wilson, 2006). The lobsters that are caught in the ventless trap vary in age from legal lobster to two years from legal harvest size (Poeschel, C., 2001).

A more recent program is the Maine-New Hampshire Inshore Trawl Surveys initiated in 2000. Up to this time, Maine and New Hampshire were the only East coast states not conducting an inshore trawl survey. This method of collecting data consists of

net trawling at different depths to gain knowledge of the quantity and variety of species in the area.

Non-Government Organization (NGO)

Many different methods are used at the NGO level to monitor the lobster populations. These methods vary from trained volunteers counting lobster in the tidal zone to divers using suction sampling. While the information collected by these means is very useful the primary reason that these methods are used in NGO monitoring instead of government monitoring is the large amount of man hours needed to collect the data.

The Lobster Conservancy is conducting year round data collection with their Volunteer-based Juvenile Lobster Monitoring Program. Overall, the purpose of this program is to measure the health and productivity of lobster nursery habitats over space and time. This program involves trained volunteers counting the number of lobsters in different quadrants on days with especially low tides. They use a mark and recapture method where a binary-coded micro wire tag is inserted into the lobster so that data can be collected upon recapture, concerning growth rate and survival rate. It is their belief that the lower inter tidal zone serves as a nursery ground for recently hatched lobsters (Cowan, 1999).

Suction sampling is another method of evaluating the population densities. This method involves one scuba diver clearing an area of debris and another diver using a vacuum to lift lobsters off the bottom. These lobsters are then brought back to the lab where, number, size, sex, and location, are recorded. One of the notable features of this

method of sampling is that the newly settled 5th stage lobsters that are not leaving their shelter can be sampled (Wahle, Incze, 1997).

Ventless Traps

The latest Joint Fishermen and Scientists Research Society (FSRS) - Gulf of Maine Lobster Foundation (GOMLF) Lobster Science Workshop compared and contrasted the different lobster recruitment and ventless trap projects. Four of the five research projects used ventless traps, a highly effective tool for collecting data. Ventless traps are used in the following FSRS and GOMLF programs: Lobster Recruitment Index from Standard Traps, the Gulf of Maine Lobster Foundation Ventless Trap Survey, the Random Stratified Ventless Trap Survey in Massachusetts, and the Regional Ventless Trap Survey as well as in the State of Maine DMR Ventless Trap Survey (see page 13). All of these programs are large scale with thousands of hauls a year, allowing for the collection of a large amount of data for tracking the fluctuations in the lobster populations (MacKenzie, 2007) (Poeschel, C., 2001).

Pre-harvest Monitoring

One of the monitoring tools used in Australia is the Puerulus collector. Puerulus is the post larva stage of the rock lobster that swims towards the coast. The collector is built to a standard design and the number of lobsters found on each collector each month creates data that can be compared from month to month. The collector has rope strands that hang on the outside of a box that act as artificial seaweed that the puerulus settle on. The data collected is used to predict catches four years later when the sampled puerulus

have grown to legal size. This means of data collection is used to assist in the management of the rock lobster fishery in Australia (Gray, 1992).

In 2000 the Australian rock lobster received an international certification by the Marine Stewardship Council (MSC) as being a well managed, sustainable fishery. MSC is an independent nonprofit organization with the purpose of promoting sustainable fisheries (Rogers, 2000). The MSC has a well defined process to certify a fishery as achieving sustainability that involves assessments, reviews, and public objections. The MSC has taken a step towards creating sustainable resources by rewarding and promoting fisheries that meet a standard of renewability (Marine Stewardship Council, 2006).

Objectives

The objective of this study was to design a trap to fill a gap in the collection of data concerning lobster abundance. The trap design should allow sublegal sized lobsters to enter the trap while excluding legal sized lobsters. It is believed that the larger legal sized lobsters inhibit the smaller lobsters from entering the traps and therefore these smaller sized lobsters are not represented in the data collected at this current time. Having the ability to base stock size estimates on smaller size lobsters will help individuals estimate future catch.

Methods and Materials

Trap Design

Initially four sample traps were designed. All sample traps were constructed of 0.5" inch square shrimp mesh plastic covered wire with outside dimensions of 24" inches long, 12" inches wide, and 10" inches high. The size of the trap is approximately 1/6th the volume of a legal size trap. The sample trap heads were rectangular openings that were all 4" inches wide with the large opening 2" inches tall and the small size 1.5" inches tall. There were two head angles one with a rise of 5" inches and a run of 7" inches. The second head angle has a rise of 2.5" inches and a run of 7" inches. Eight trap variations were constructed for a total of 32 sample traps. These traps were set and hauled with each string including four different sample traps and one ventless trap as a control.

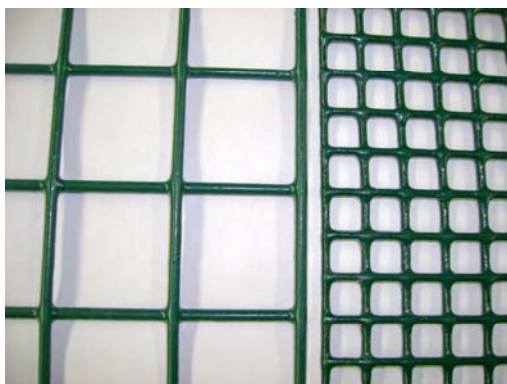


Figure 2. Wire Mesh Construction. Two types of plastic covered wire. On left the standard for lobster traps with a mesh of one square inch. On the right is shrimp mesh that was used to make the sample traps, with a mesh of 1/9 of a square inch.



Figure 3. Sample Trap with Head Removed. View from top with lid open. By building the trap and the heads separately, the heads can be changed without major construction.

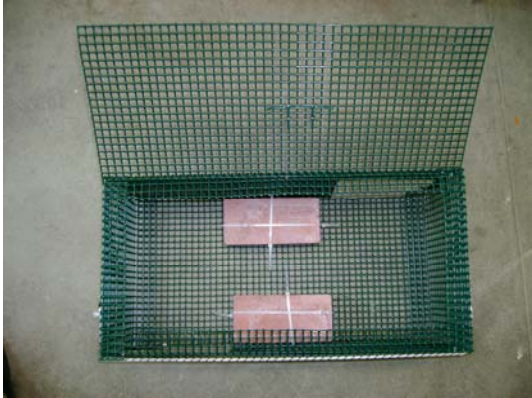


Figure 4. Sample Trap with Heads Removed: view from above; lid is open, two bricks tied to the bottom of the trap to keep the trap on the sea floor.



Figure 5. Trap Comparison. Standard lobster trap 11,466 cubic inches and Sample Trap 2,880 cubic inches.

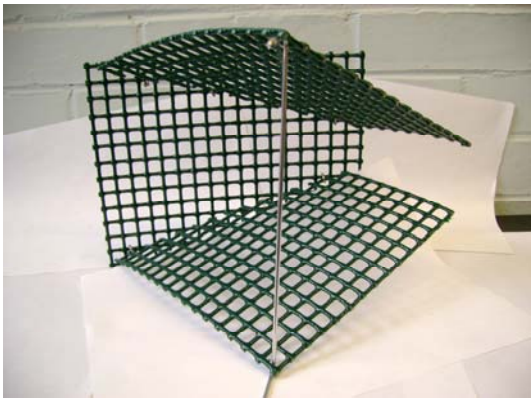


Figure 6. Wire head, closest wall removed. Lobsters enter head from left, walk up angled head and through the opening to the right.



Figure 7. Wire head, one wall removed. Looking through one of the heads sidewalls, lobster would enter the trap from the right. Far head wall removed.

The traps were set in four locations outside Southwest Harbor on different bottom types and at different depths. All traps were set and hauled during the same time period.

For each trap haul, data was recorded for number of lobsters, size of lobsters, depth, bottom type and tide.

On the basis of these results the next step was to modify each head design. One design had a wire mesh head that was oriented horizontally instead of vertically, to make the trap opening taller and narrower. These modified traps were tested using an underwater video camera placed inside the trap. The umbilical cord ran from the camera to the boat where a monitor and recorder were used to view the test.

The next head design to be tested contained knitted heads instead of the wire mesh used in previous trials. Also a knitted head with a round 2.5” inch diameter head designed by Joe Chalmers, a lobsterman with a B.S. in mechanical engineering, was also tested at this time. The Chalmers Trap also contained a parlor unlike the other sample traps. These traps were tested alongside of the wire mesh heads.

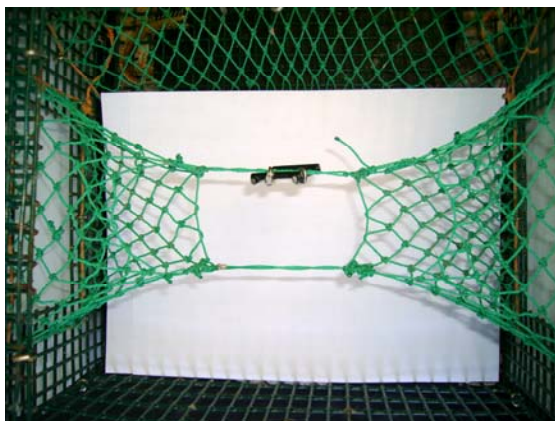


Figure 8. Chalmers Trap Head Design. Two heads facing each other one entry point on right and one entry point on the left, view from above.



Figure 9. Chalmers Trap Head Opening. Showing the entry point of lobsters, view from inside trap.

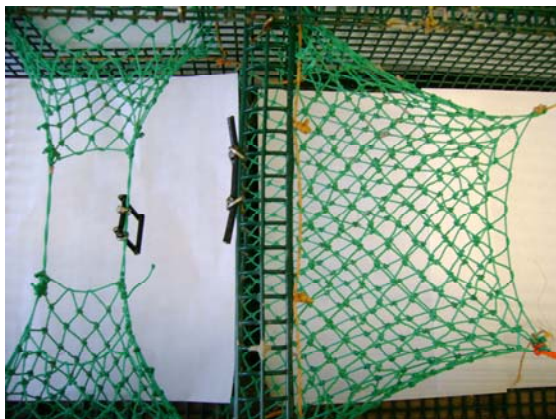


Figure 10. Chalmers Trap Internal Design. Left is the kitchen with the two head entry points, right is the parlor with a large head entry point allowing lobsters to enter the parlor from the kitchen, view from above.



Figure 11. Chalmers Trap Overview. Trap with lid open on the side of fishing boat.



Figure 12. Fike Trap 1 Head Opening. View from above, cloth mesh head with wire ring hoop creating the entry point size, 2 inches. Zip ties hold head in place.



Figure 13. Fike Trap 1 Head Angle. View from side, showing the angle at which the lobster must climb to enter the trap.

These traps were set inside of South West Harbor instead of outside the harbor.

The number of crabs in each trap was recorded in addition to the rest of the data collected.

Subsequently all traps had the heads modified from wire mesh to knitted heads. The trap strings included ventless, Chalmers Trap, Fike Trap 1 with soft knitted, and a square opening design. The square opening design trap had no head, but instead had several square openings along the bottom of the trap.

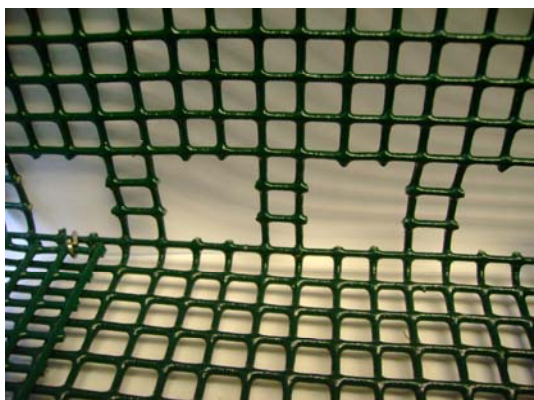


Figure 14. Sample Trap Square Opening. View from inside trap square openings were cut into the wire mesh to simulate the mesh of the standard lobster trap wire.

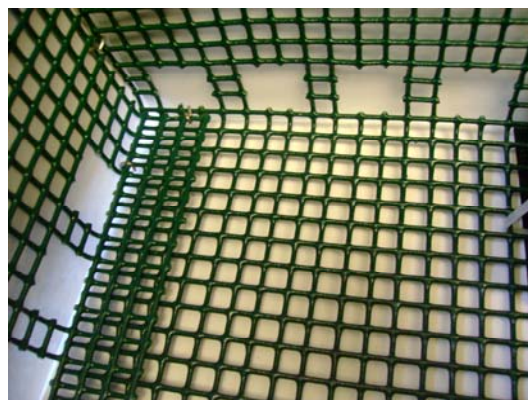


Figure 15. Sample Trap Square Opening Overview. View from above, the square openings cut around the bottom edge of $\frac{1}{2}$ of the sample trap to act as an entry point.

A final trap with a knitted head replaced the square head trap on the experimental string. Fike Trap 2 has a mesh head with an opening ring size of 1.75”.

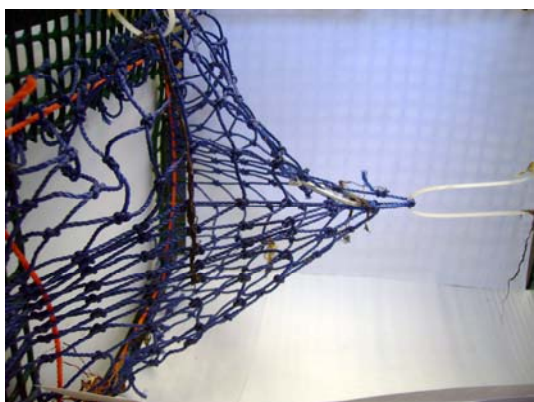


Figure 16. Fike Trap 2 Head Angle. View from side.



Figure 17. Fike Trap 2 Head Opening. Wire ring creating the size of the entry, 1.5 inches, view from above.

The string of traps that would be tested for the remainder of the sampling consisted of a ventless trap, Fike Trap 1, Fike Trap 2, and the Chalmers Trap. Four strings of four traps were set and hauled five times. These hauls all took place in the area of South West Harbor, and took on average an hour to complete (See Appendix).

Table 1. Sample Trap Overview

Sample Trap Head Name	Head Design	Number of type made	Number of Hauls	Purpose	Results
Large High	plastic covered wire mesh large horizontal opening high angle	7	1	Catch sublegal lobster, exclude legal size lobster	Caught lots of crabs
Large Low	plastic covered wire mesh large horizontal opening low angle	7	1	Catch sublegal lobster, exclude legal size lobster	Caught one lobster, lots of crabs
Small High	plastic covered wire mesh small horizontal opening high angle	7	1	Catch sublegal lobster, exclude legal size lobster	Caught lots of crabs
Small Low	plastic covered wire mesh small horizontal opening low angle	7	1	Catch sublegal lobster, exclude legal size lobster	Caught one lobster, lots of crabs
Vertical Opening	plastic covered wire mesh vertical rectangular opening	1	Several in one day, used video camera	Discover crab capabilities of entering different head designs	Showed the ability of crab to access traps
Chalmers	cloth mesh head opening has no wire ring	4	24	Catch sublegal lobster, exclude legal size lobster and crabs	Caught sublegal lobster, excluded legal size lobster, caught crabs
Fike 1	cloth mesh head has wire ring with 2.5 inch opening	4	24	Catch sublegal lobster, exclude legal size lobster and crabs	Caught sublegal lobster, excluded legal size lobster, caught crabs
Square	Trap has no head instead one inch openings are present around the trap	4	4	Openings in the trap simulates mesh of standard legal trap, discover if sublegal lobster move freely through the mesh	Caught no lobsters or crabs
Fike 2	cloth mesh head has wire ring opening of 1.75 inches	4	20	Discover the smallest size head opening that lobster will enter through	Caught 2 very small lobsters and no crabs

Collecting Data

The ventless trap, the control, was set with the sample traps attached to it by a tether several meters long with the next sample tethered to it in line. The bait was typical of the industry standard, herring. After being set the traps were hauled as soon as possible, preferably the next day.

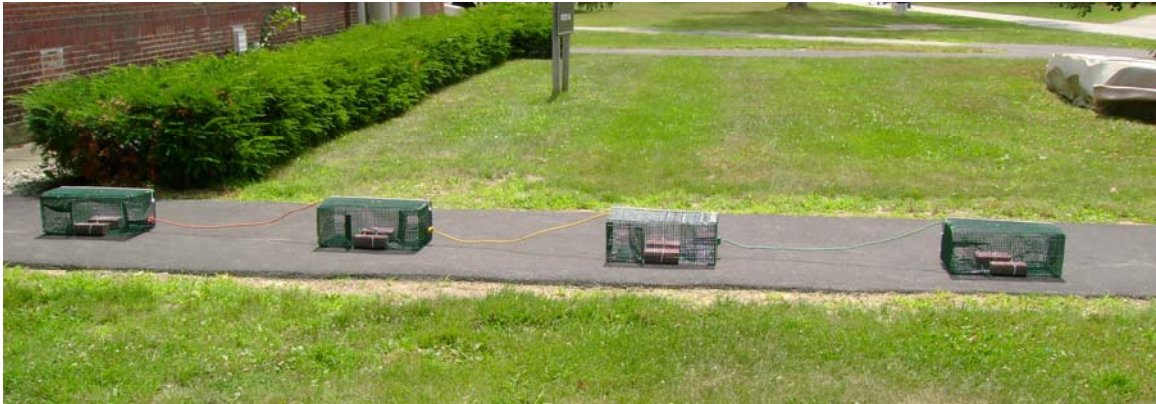


Figure 18. String of Traps. A string of four sample traps attached to each other in the same manner as when being fished. Connections are by three foot sections of line with the string over twelve feet long.

When a string was hauled all of the lobsters in the traps had their carapace measured, and the number of crabs in the trap were counted. Other data collected included location, tide, depth, bottom type, and soak period.

Data Analysis

The data was entered into Microsoft Excel. All data that was recorded while at sea was transferred to a spreadsheet (See Appendix). Data was organized in Excel for the purpose of entering the data into the statistical program Systat.

The Systat program was used to conduct an Analysis of Variance for analyzing each trap type: ventless, Fike 1, Fike 2, and Chalmers trap. The dependent variable was

lobster carapace length (mm), with trap type, date, location, soak period, and number of crabs in trap as independent variable (Table 2). Insignificant main effects ($P > .05$) were removed and a reduced model was evaluated. Three variables, depth, bottom type, and catch, which is the number of lobsters caught in each trap, were found not significant and were removed. The Analysis of Variance was then run a second time, excluding these three variables (Table 3). Effects of trap type, soak period, number of crabs, and location on lobster size were included in a prediction equation (Table 4). A final model included significant main effects with interaction terms between main effects (Table 5). Results were presented graphically.

Statistical Analysis

Table 2. Analysis of Variance with Lobster Length as the Dependent Variable and Trap, Location, Depth, Bottom Type, Soak Period, Number of Crabs and Total Number of Lobsters Caught as Independent Variables.

Dep. Var. Length N: 398 Multiple R: 0.694 Squared multiple R: 0.482
 Number of observations equals 398 and square multiple R is 0.482

Analysis of Variance

<u>Source</u>	<u>Sum-of-Squares</u>	<u>df</u>	<u>Mean-Square</u>	<u>F-Ratio</u>	<u>P</u>
Trap	9663.163	3	3221.054	53.230	0.000
Location	414.475	1	414.475	6.849	0.009
Depth	1.791	1	1.791	0.030	0.863
Bottom Type	19.756	1	19.756	0.326	0.568
Soak Period	301.585	1	301.585	4.984	0.026
Number of Crabs	293.841	1	293.841	4.856	0.028
Lobsters Caught	45.385	1	45.385	0.750	0.387
Error	22752.576	376	60.512		

Table 3. Analysis of Variance for Reduced Model with Lobster Length as Dependent and Trap, Location, Soak Period, and Crabs as Independent Variables.

Dep. Var. Length N: 396 Multiple R: 0.693 Squared multiple R: 0.481

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-Ratio	P
Trap	1697.507	3	5657.502	93.760	0.000
Location	1653.609	2	826.804	13.702	0.000
Soak Period	323.164	1	323.164	5.356	0.021
Number of Crabs	355.860	1	355.860	5.898	0.016
Error	22808.525	378	60.340		

Table 4. Estimates of effects for prediction equation.

$$\hat{Y} = b_0 + \begin{matrix} b_1x_1 \\ b_2x_2 \\ b_3x_3 \end{matrix} + \begin{matrix} b_4x_4 \\ b_5x_5 \\ b_6x_6 \end{matrix} + b_7x_7 + b_8x_8$$

With $x_1, x_2, x_3, x_4, x_5,$ and x_6 equal to 0 or 1 either trap or location effect, x_7 soak of days and x_8 number of crabs in trap.

Length		\hat{Y}
Ventless Trap (Constant)	b_0	53.871
Chalmers Trap	b_1	13.741
Fike Trap 1	b_2	-5.163
Fike Trap 2	b_3	-0.086
Location 1	b_4	-1.011
Location 2	b_5	-4.557
Location 3	b_6	0.174
Soak Period	b_7	0.174
Number of Crabs	b_8	-0.164

Table 5. Model Estimate for Reduced Model with Interactions.

Dep. Var. Length N: 396 Multiple R: 0.749 Squared multiple R: 0.561

Analysis of Variance

<u>Source</u>	<u>Sum-of-Squares</u>	<u>df</u>	<u>Mean-Square</u>	<u>F-Ratio</u>	<u>P</u>
Model	24663.148	36	685.087	12.403	0.000
Error	19276.575	349	55.234		

Results

Initially forty traps were baited with herring and set. Working with strings of five traps was very difficult. This string of five traps included one ventless trap and four sample traps and was twenty-three feet long. Because of the size of the string it was hard to haul onto the boat, to keep on the rail of the boat, and to move. Also fishing a string this long on the sea floor can create tangles with other fishing gear (a tangle between two pieces of gear should be avoided.) It was also discovered that the escape vent on legal traps allowed for the escape of not only sublegal lobsters but also a large number of crabs. The first set of sample traps contained wire head designs. Ventless traps caught legal and sublegal size lobster, while the sample traps, with wire mesh heads, caught no legal lobsters and a total of two sublegal lobsters from the thirty-two sample traps hauled. All of the traps caught a large number of crabs which were not counted. From that point the numbers of crabs caught in each trap were recorded.

Underwater video equipment was used to discover the capabilities of crab to enter the sample traps. The underwater video showed that the crabs could enter the traps at a variety of angles. The first head design using plastic covered wire had a horizontally rectangular opening that allowed a large number of crabs to enter. The trap used in the video demonstration had a different head made of the plastic covered wire with a rectangular opening in a vertical orientation. The video shows a crab attempting to enter through the head of the trap three times, successfully in the last attempt. To enter the trap successfully the crab moved to a vertical position with its right legs on the bottom of the head opening and the left legs at the top of the head opening.



Figure 19. Image from underwater video (A). Entry point is a 2x4 inch vertical rectangular opening. Crab is walking with eyes facing the surface in a vertical manner.



Figure 20. Image from underwater video (B). 2x4 inch vertical opening with crab entering trap by walking inverted, anterior end down. If the crab can physically fit it can potentially enter no matter the entry point's orientation.

After preliminary testing three designs were chosen to be tested alongside the ventless trap. All of these sample traps caught sublegal size lobsters while not catching any legal lobsters. The ventless, control trap, caught both legal and sublegal lobsters. The ventless trap caught 241 lobsters with a mean carapace length of 62.04 mm. The ventless trap caught six legal lobsters with the largest having a length of 92.7 mm, ten

mm longer than the minimum legal size for harvest. The Chalmers Trap caught 100 lobsters with a mean size of 55.23 mm. Fike Trap 1 caught 44 lobsters with a mean size of 53.78 mm. The smallest head design in Fike Trap 2 caught two lobsters with a mean carapace length of 46.46 mm.

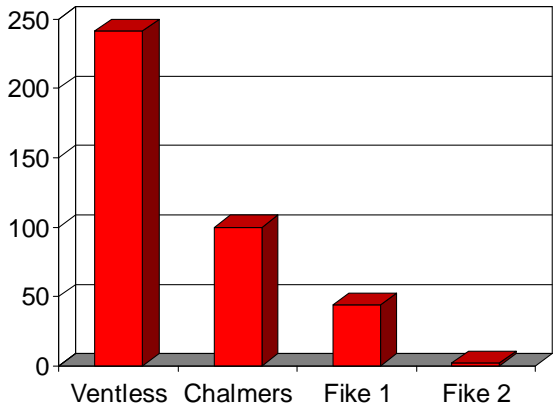


Table 6. Total Number of Lobsters Caught by Trap Type

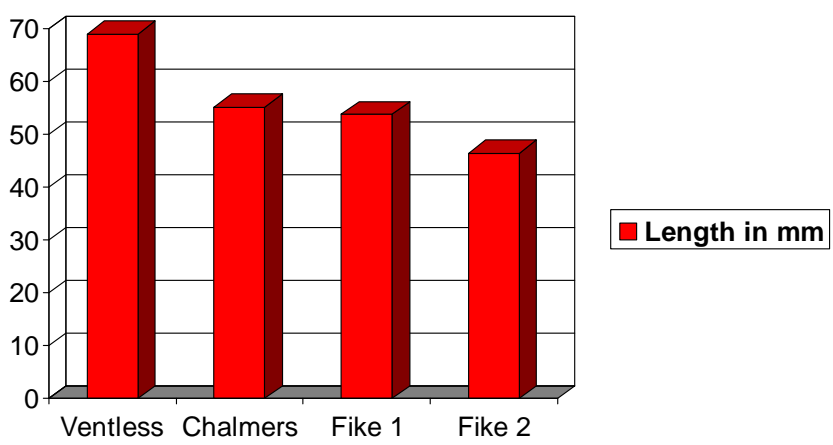


Table 7. Mean Carapace Length of Lobster Caught by Trap Type

This raw data needs be adjusted before comparisons are made since the different trap designs were not hauled the same number of times. The ventless trap was hauled 31 times while the sample traps were hauled 24 times for both the Chalmers and Fike Trap 1. Fike Trap 2 was hauled a total number of 20 times, which is the lowest of all the trap hauls since it was the last to be designed. Because of this another means of measuring the traps success rate was calculated as Catch per Trap Haul (CPTH).

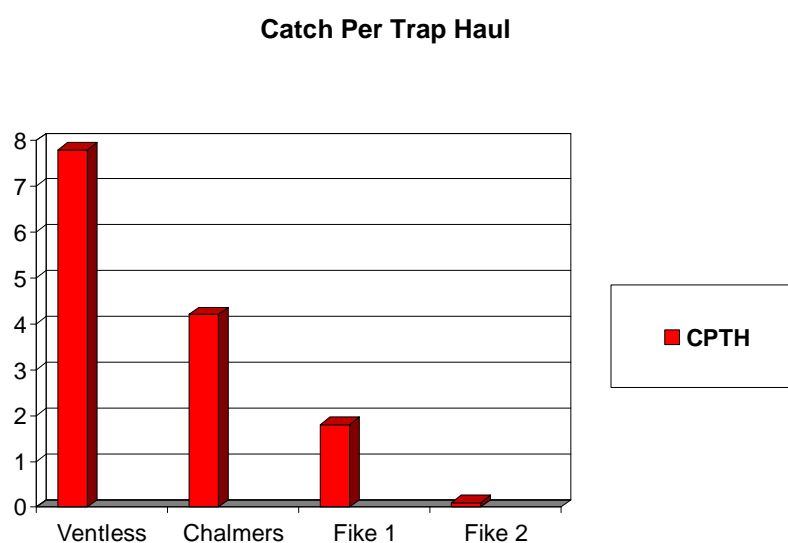


Table 8. Catch Per Trap Haul. CPTH (Total Catch/Total Hauls)

One factor that should be noted is the size difference between the ventless trap and the sample traps. The volume of the sample traps are 2,880 cubic inches while a standard trap is 11,466 cubic inches, or about four times the volume of the sample trap. The effect of trap size was not included in this analysis.

Other variables besides trap design also had a significant effect on the size of the lobsters caught. The period of time that the trap was fished and the number of crabs in the trap at the time of haul, and fishing location affected the size of the lobster in the trap.

With a squared multiple R of 0.481, a prediction of lobster size can be made using location, trap, soak, and number of crabs with 48 percent accuracy with a model including only significant main effects ($df=8$). A complete model including interactions ($df=36$) had a small increase in predictive capability with an R^2 of .561. Subsequent discussion will cover main effects.

Discussion

This project required matching numerous skills and techniques. In the construction of the sample traps it quickly became evident that machinery and tools were necessary. Building lobster traps of plastic covered wire by hand is not recommended. The most difficult part of the trap building process was the cutting of the plastic covered wire. Initially the process of cutting the wire was conducted by a hand held wire cutter. This process was slow, with the large number of cuts needed to make the trap which was unsatisfactory. The use of a sheet metal cutter was the solution to this problem and speeded up the process. The necessity of using machinery to cut the wire became even clearer when the production of the wire heads began requiring cuts at angles across the wire with each head being constructed of three separate sheets of wire.

After setting the first trap designs, it was evident that the heads needed to be modified in order to prevent the entry of crabs. The escape vent that is mandatory in all legal lobster traps, undoubtedly allows large numbers of crabs to escape. Previous research concerning the catchability of lobsters in traps occupied by crabs or lobsters

found no significant effect (Richards, Cobb, Fogarty, 1983). We found that there is a significant effect of the decrease in lobster size when crabs are present (Table 3 and 4).

One modified design was the trap that had no head opening but instead had square openings at the bottom of the trap to simulate the square mesh of the legal traps. The purpose of this design was to discover whether or not small lobsters were traveling freely through the legal traps. While no lobsters were caught in the Square Trap this does not conclusively show that small lobsters are not passing through the legal traps. Lobsters that were small enough to move through 1" mesh were caught in the sample traps with mesh head designs.

After evaluating several head designs, three designs were chosen to be further tested. The Chalmers Trap was chosen for its similarity to a miniature legal design, containing both a kitchen and a parlor. The Fike Trap 1 was chosen to learn more concerning head ring sizes that lobsters could enter. Little was known concerning this because the legal traps use a ring size that is considerably larger. Sample Trap 2 was designed after it was discovered that Sample Trap 1 caught sublegal lobsters and excluded legal lobsters. By creating a head ring size smaller than in Fike Trap 1, Fike Trap 2 was designed to determine the smallest ring size that lobsters would enter.

ANOVA statistical analysis resulted in several conclusions. Of the final string of traps with knitted heads all caught sublegal lobsters while excluding legal lobsters. The traps caught different size sublegal lobsters and in different quantities, creating the conclusion that head design did have a significant effect.

Sample trap 2 while catching the smallest mean size caught only two lobsters. These results lead to the conclusion that this ring size while allowing lobsters to enter

was on the threshold for not allowing lobsters to enter. Because this head allows so few lobsters to enter it would not be effective for conducting sublegal lobster assessments.

Sample Trap 1 and the Chalmers trap both caught lobsters of very similar sizes. The mean size difference is less than two millimeters, not enough of a difference to outweigh the difference of a CPTH of 4.2 with the Chalmers trap compared to 1.8 with Sample Trap 1. Because of the CPTH the Chalmers trap was chosen as the best choice for a Lobster Sampling Trap.

Comparison of trap designs was conducted to discover the reason for the CPTH of the Chalmers Trap that was double that of Sample Trap 1. The most obvious difference between the two traps was that the Chalmers Trap contains a kitchen and a parlor while Sample Trap 1 contains only the kitchen. The true effect of the sample trap parlor is unknown and further research will be necessary.

The Chalmers Trap catches lobsters with a mean carapace size of 55mm which is two to three years, depending on time of year, from recruitment. These lobster need to molt three times to reach the legal size of 82.5mm carapace length. This provides data on a specific age group of lobster that is at this time going unmonitored.

Conclusion

Today the largest problem with managing the American Lobster fishery is the lack of data. While there are many data collecting programs being conducted at this time, the ASMFC states that more data is necessary to run modeling programs that can assist in managing the fishery. The Lobster Sampling Trap targets a specific size lobster that is

currently not being represented in the data. By conducting a sampling program with this trap additional data will be available to assist in the management of the American Lobster.

To properly manage a fishery a large amount of data concerning all the factors affecting the fishery is necessary. More data is needed to manage the fishery properly. In order to collect more data the programs that are in effect at this time need to increase the area covered. New methods of collecting biological data need to be created so that more data is available at different points in the lobster's life cycle. By collecting data of lobster at all points of their life cycle the fishery can be managed with more certainty. An increase in the amount of data concerning lobster biology would help manage the fishery with the goal of sustainability.

For the Lobster Sampling Trap to assist in evaluating the sustainability of the fishery several events need to occur. A standard Lobster Sample Trap needs to be used for sampling. This trap needs to be distributed and set at designated locations and times throughout the year. Data should be collected in a standardized method that allows for it to be used by the management group. By having this standardized method of setting and collecting, the information can be compared from year to year to understand changes in the status of the juvenile lobster stock.

LITERATURE CITED

Atlantic States Fisheries Commission (ASMFC), 2007. *American Lobster Stock Assessment Model Technical Review*. National Oceanic and Atmospheric Administration.

Cadrin, Steven X., Estrella, Bruce T., 1993. *Massachusetts Coastal Commercial Lobster Trap Sampling Program May-November, 1992*. Division of Marine Fisheries, Commonwealth of Massachusetts.

Cobb, J. S., 1977. A review of the habitat-related behavior of clawed lobsters (*Homarus* and *Nephrops*) In Proc. U.S.-Australia Lobster Workshop eds. B. F. Phillips and J. S. Cobb, *Circular.-CSIRO, Division of Fisheries and Oceanography*. (Aust.) 7, p. 143-158.

Cooper, R. A., Clifford, R. A., and Newell, C. D., 1975. Seasonal abundance of the American lobster, *Homarus americanus*, in the Boothbay Region of Maine. *Transaction of American Fishery Society*, p. 104.

Cooper, R.A., 1970. Retention of marks and their effects on growth, behavior, and migrations of the American lobster, *Homarus americanus*. *Transaction American Fishery Society* 99, p. 409-417.

Cooper, R. A., Uzmann, J.R., 1977. Ecology of juvenile and adult clawed lobsters, *Homarus americanus*, *Homarus gammarus*, and *Nephrops norvegicus*. *Circular-CSIRO, Division of Fisheries and Oceanography*. (Aust.) No. 7.

Cowan, D., 1999. Method for assessing relative abundance, size distribution, and growth of recently settled and early juvenile lobsters (*Homarus americanus*) in low inter tidal zone. *Journal of Crustaceans*, Vol. 19(4) p.738-751.

Department of Fisheries and Oceans, 1993. *Canadian Fisheries Landings*. Department of Fisheries and Oceans, Ottawa, Ontario, Canada.

Factor, Jan Robert, 1995. *Biology of the Lobster Homarus americanus*, Academic Press, New York, New York.

Gray, Howard, 1992. *The Western Rock Lobster Panulirus Cygnus Book 1: A Natural History*, Westralian Books, West Australia.

Harding, Garrett, 1968. The Tragedy of the Commons, *Science* 162:1243-8.

Herrick, Francis Hobart, 1911. *Natural History of the American Lobster*, Government Printing Press, Washington.

Juinio, M. A. R., and Cobb, J. S., 1992. Natural diet and feeding habits of the postlarval lobster *Homarus americanus*. *Marine Ecology Progress Series*, 85, 83-91.

Krouse, J., Thomas, C., 1975. Effects of Trap Selectivity and Some Population Parameters on Size Composition of the American Lobster, *Homarus americanus*, Catch Along the Maine Coast. *Fishery Bulletin*, Vol. 73 No.4.

Leavitt, D.F., Bayer, R.C., Gallagher, M.L., Rittenburg, J.H., 1979. Dietary Intake and Nutritional Characteristics in Wild American Lobsters (*Homarus americanus*). *Journal of the Fisheries Research Board of Canada*, Vol. 35 Number 8 p. 965-969.

Lobster Institute, 2004. *Estimated Economic Impact of Lobster Industry*. Lobster Institute Library, University of Maine, Orono, Maine.

MacKenzie, Christine, 2007. Gulf of Maine Lobster Foundation Lobster Science Workshop, *Fishermen & Scientists Research Society*.

Maine Department of the Secretary of State, *Marine Resources Regulations 2007*.
<http://www.maine.gov/sos/cec/rules/13/chaps13.htm>

Marine Stewardship Council, 2006, *Western Rock Lobster*.
http://www.msc.org/html/content_1277.htm

McLeese, D.W., 1972. Effects of several factors on the growth of the American lobster (*Homarus americanus*) in captivity. *Journal of Fisheries Research Board of Canada* Vol. 29, 1725-1730.

Paille, Nathalie and Bourassa, Luc 2007. *St. Lawrence Observatory: The American Lobster Reproduction and Life Cycle*.

<http://www.osl.gc.ca/homard/en/schema-cycle-de-vie.html>

Phillips, Bruce F., Cobb, R. S., 1980. *The Biology and Management of Lobsters: Vol. 1 Physiology and Behavior*. Academic Press, Inc., New York, New York.

Phillips, Bruce F., Cobb, R. S., 1980. *The Biology and Management of Lobsters: Vol. 2 Ecology and Management*. Academic Press, Inc., New York, New York.

Poeschel, C., 2001. *Spatial Analysis of a Pilot Juvenile Ventless American Lobster (*Homarus americanus*) Trap Survey*. Masters Thesis, University of Maine, Orono, Maine.

State of Maine Department of Marine Resources, *State of Maine American Lobster Landing, 2005 Preliminary Data*.

<http://www.maine.gov/dmr/commercialfishing/lobster.mht>

Richards, R. Anne, Cobb, J. Stanely, Forgarty, Michael J., 1983. Effects of Behavioral Interactions on the Catch ability of American Lobster, *Homarus Americanus*, and Two Species of Cancer Crab. *Fishery Bulletin*: Vol. 81. No. 1.

Rogers, Peter, 2000. "WA on Target for Rock Lobster Record" *Western Fisheries: WA's Journal of Fishing and the Aquatic Environment*.

Stenneck, R. S., 1989. The ecological ontogeny of lobsters: In situ studies with demographic implications. In "*Life History of the American Lobster. Proceeding of a Workshop, November 29-30, 1989, Orono, Maine*" (I. Kornfield, ed.), pp. 30-33 Lobster Institute, Orono, Maine.

Templeman, W., and Tibbo, S. N., 1945. Lobster Investigations in Newfoundland 1938 to 1941. *Newfoundland Department of Natural Resources, Resources Bulletin (Fish.)* 16.

Uzmann, J. R., Cooper, R. A. and Pecci, K. J., 1977. Migration and Dispersion of Tagged American Lobsters, *Homarus americanus*, on the Southern New England Continental Shelf. *NOAA Tech. Rep. NMFS SSRF-705*.

Wahle, R., Incze, L., 1997. Pre- and post-settlement processes in recruitment of the American lobster. *Journal of Experimental Marine Biology and Ecology*, Vol. 217, Pg. 179-207.

Wahle, R, Stenneck, R., 1992. Habitat restrictions in early benthic life: experiments on habitat selection and in situ predation with American lobster. *Journal of Experimental Marine Biology and Ecology*, Vol. 157, p.91-114.

Wilder, D. G., 1953. The Growth Rate of the American Lobster (*Homarus americanus*). *Journal of Fisheries Research Board of Canada*, 10(7), Canada.

Wilson, Carl 2006. DMR Lobster Research, Monitoring, and Assessment Program, *State of Maine Department of Marine Resources*.

<http://www.maine.gov/dmr/rm/lobster/research.htm>

Appendix

Table A1. Experimental Data

Date	Trap	Legal Size	Sublegal Size	# of Crabs	Location	tide	depth	Bottom	Soak Period
7/1/2006	ventless	82.8	62.1, 75.5, 71.0, 79.1, 69.4(cull), 72.9, 74.3, 75.2, 77.4, 73.5, 75.0, 77.2,76.8, 74.0, 73.5, 57.1, 60.5, 61.5, 59.4		1a		18 ft	mud	
7/1/2006	large high	0	0		1a		19 ft	mud	
7/1/2006	large low	0	0		1a		20 ft	mud	
7/1/2006	small high	0	0		1a		21 ft	mud	
7/1/2006	small low	0	0		1a		22 ft	mud	
7/1/2006	ventless	0	77.3, 71.0, 77.6, 68.3, 80.7, 75.7, 79.7, 74.5, 71.1		2a		74ft	cobble	
7/1/2006	large high	0	0		2a		74ft	cobble	
7/1/2006	large low	0	0		2a		74ft	cobble	
7/1/2006	small high	0	0		2a		74ft	cobble	
7/1/2006	small low	0	50.3,		2a		74ft	cobble	
7/1/2006	ventless	0	77.9, 80.8, 73.0, 78.0, 72.7, 76.5, 79.0, 71.8, 74.5, 80.7, 79.5, 77.3, 64.0		2b		93ft		
7/1/2006	large high	0	0		2b		93ft		
7/1/2006	large low	0	0		2b		93ft		
7/1/2006	small high	0	0		2b		93ft		
7/1/2006	small low	0	0		2b		93ft		
7/1/2006	ventless	0	0		3a		125ft	cobble	
7/1/2006	large high	0	0		3a		125ft	cobble	
7/1/2006	large low	0	0		3a		125ft	cobble	
7/1/2006	small high	0	0		3a		125ft	cobble	
7/1/2006	small low	0	0		3a		125ft	cobble	
7/1/2006	ventless	0	78.5, 78.1, 79.9, 73.0, 72.9, 71.1, 77.4, 69.3, 81.2, 78.0, 73.2, 58.3, 57.5, 78.0, 63.4, 59.4, 80.0, 72.0		3b		140ft	mud	
7/1/2006	large high	0	0		3b		140ft	mud	
7/1/2006	large low	0	0		3b		140ft	mud	
7/1/2006	small high	0	0		3b		140ft	mud	
7/1/2006	small low	0	0		3b		140ft	mud	

Table A1. Experimental Data

11/18/2006	ventless	0	74, 61, 59, 78	34	Center Harbor	low	47 ft	mud	
11/18/2006	Joe	0	52,	11	Center Harbor	low	48 ft	mud	
11/18/2006	square	0	0	0	Center Harbor	low	49 ft	mud	
11/18/2006	Fike 1	0	47,	40	Center Harbor	low	50 ft	mud	
11/18/2006	ventless	0	79, 64, 76, 75	0	Shore Pond	low	17ft	Rock	
11/18/2006	Joe	0	32, 58	0	Shore Pond	low	17ft	Rock	
11/18/2006	Fike 1	0	27,	0	Shore Pond	low	17ft	Rock	
11/18/2006	square	0	0	2 hermit	Shore Pond	low	17ft	Rock	
11/18/2006	ventless	0	0	80	Middle channel	low	25ft	cobble	
11/18/2006	Joe	0	0	27	Middle channel	low	25ft	cobble	
11/18/2006	Fike 1	0	0	17	Middle channel	low	25ft	cobble	
11/18/2006	square	0	0	0	Middle channel	low	25ft	cobble	
11/18/2006	ventless	0	0	93	Great Head	low	6ft	sand eel grass	
11/18/2006	Joe	0	0	42	Great Head	low	6ft	sand eel grass	
11/18/2006	Fike 1	0	0	49	Great Head	low	6ft	sand eel grass	
11/18/2006	square	0	0	0	Great Head	low	6ft	sand eel grass	
1/9/2007	ventless	0	70, 59, 67,	8	Center Harbor	low	50ft	mud	6days
1/9/2007	Joe	0	39,	0	Center Harbor	low	50ft	mud	6days
1/9/2007	Fike 1	0	41,	3	Center Harbor	low	50ft	mud	6days
1/9/2007	Fike 2	0	0	0	Center Harbor	low	50ft	mud	6days
1/9/2007	ventless	0	61,	50	Shore Pond	low	23ft	rock	6days
1/9/2007	Joe	0	0	25	Shore Pond	low	23ft	rock	6days
1/9/2007	Fike 1	0	0	8	Shore Pond	low	23ft	rock	6days
1/9/2007	Fike2	0	0	0	Shore Pond	low	23ft	rock	6days
1/9/2007	ventless	0	0	75	Middle channel	low	36ft	coble	6days
1/9/2007	Joe	0	0	33	Middle channel	low	36ft	coble	6days
1/9/2007	Fike 1	0	0	9	Middle channel	low	36ft	coble	6days
1/9/2007	Fike 2	0	0	0	Middle channel	low	36ft	coble	6days
1/9/2007	ventless	0	0	50	Great Head	low	9ft	sand eel grass	6days
1/9/2007	Joe	0	0	22	Great Head	low	9ft	sand eel grass	6days
1/9/2007	Fike 1	0	0	31	Great Head	low	9ft	sand eel grass	6days
1/9/2007	Fike 2	0	0	1 spider	Great Head	low	9ft	sand eel grass	6days
5/12/2007	ventless	0	59.5, 64.5, 75.5, 71, 59, 71, 59, 71, 70, 73.5, 55.5		Inside Harbor				
5/12/2007	Joe	0	42, 43.5		Inside Harbor				
5/12/2007	Fike 1	0	48.5,		Inside Harbor				
5/12/2007	Fike 2	0	62, 58		Inside Harbor				
5/12/2007	ventless	0	0		Inside Harbor				
5/12/2007	Joe				Inside Harbor				
5/12/2007	Fike 1	0	42,		Inside Harbor				
5/12/2007	Fike 2	0	0		Inside Harbor				
5/12/2007	ventless	0	0	large#	Inside Harbor				
5/12/2007	Joe	0	0	large#	Inside Harbor				
5/12/2007	Fike 1	0	0	large#	Inside Harbor				
5/12/2007	Fike 2	0	0	large#	Inside Harbor				
5/12/2007	ventless	0	0	large#	Inside Harbor				
5/12/2007	Joe	0	0	large#	Inside Harbor				
5/12/2007	Fike 1	0	0	large#	Inside Harbor				

Table A1. Experimental Data

5/12/2007	Fike 2	0	0	large#	Inside Harbor		
5/12/2007	ventless	0	0	large#	Inside Harbor		
5/12/2007	Joe	0	0	large#	Inside Harbor		
5/12/2007	Fike 1	0	0	large#	Inside Harbor		
5/12/2007	Fike 2	0	0	large#	Inside Harbor		
5/16/2007	ventless	84 v-notched	80, 67, 77, 60	2	Center Harbor	low	50
5/16/2007	Joe	0	63, 57, 53	2	Center Harbor	low	50
5/16/2007	Fike 1	0	56, 41, 43, 53	0	Center Harbor	low	50
5/16/2007	Fike 2	0	0	0	Center Harbor	low	50
5/16/2007	ventless	0	77,	4	Shore Pond	low	12
5/16/2007	Joe	0	49,	1	Shore Pond	low	12
5/16/2007	Fike 1	0	69,	1	Shore Pond	low	12
5/16/2007	Fike 2	0	0	0	Shore Pond	low	12
5/16/2007	ventless	0	59, 55, 70, 56	24	Center Harbor	low	53
5/16/2007	Joe	0	48, 54	12	Center Harbor	low	53
5/16/2007	Fike 1	0	0	4	Center Harbor	low	53
5/16/2007	Fike 2	0	0	0	Center Harbor	low	53
5/16/2007	ventless	83	65, 58, 79, 62	0	Inside Harbor	low	9
5/16/2007	Joe	0	50, 44, 52, 60	1	Inside Harbor	low	9
5/16/2007	Fike 1	0	52, 47, 57 Head	0	Inside Harbor	low	9
5/16/2007	Fike 2	0	0	0	Inside Harbor	low	9
6/4/2007	ventless	0	74, 82, 70, 71	0	Inside Harbor	mid	15
6/4/2007	Joe	0	41, 54, 50, 46	0	Inside Harbor	mid	15
6/4/2007	Fike 1	0	54, 60, 56, 55	1	Inside Harbor	mid	15
6/4/2007	Fike 2	0	42,	0	Inside Harbor	mid	15
6/4/2007	ventless	0	55, 67, 78, 75, 82, 73, 61, 69, 72, 74, 56, 73, 62, 64	0	Center Harbor	mid	54
6/4/2007	Joe	0	57, 63, 62	0	Center Harbor	mid	54
6/4/2007	Fike 1	0	46	0	Center Harbor	mid	54
6/4/2007	Fike 2	0	0	0	Center Harbor	mid	54
6/4/2007	ventless	0	79, 68, 68, 81	30	shore pond	mid	19
6/4/2007	Joe	0	60, 63 Head b	0	shore pond	mid	19
6/4/2007	Fike 1	0	69,	3	shore pond	mid	19
6/4/2007	Fike 2	0	0	0	shore pond	mid	19
6/4/2007	ventless	0	70, 62, 66, 67	12	Center Harbor	mid	57
6/4/2007	Joe	0	65, 61	15	Center Harbor	mid	57
6/4/2007	Fike 1	0	46, 51	0	Center Harbor	mid	57
6/4/2007	Fike 2	0	0	0	Center Harbor	mid	57
6/12/2007	ventless	0	75, 75, 69, 76, 60, 57, 74, 74, 71, 55, 57, 67, 55, 64, 57, 53, 63, 63, 56, 69, 58, 67, 65, 81, 69, 61	1	Inside Harbor	low	9

Table A1. Experimental Data

6/12/2007	Joe	0	48, 54, 50, 58, 43, 41, 56, 45, 49, 51, 48, 57, 51, 55, 52, 48, 46, 31	2	Inside Harbor	low	9
6/12/2007	Fike 1	0	71, 53, 51, 48	1	Inside Harbor	low	9
6/12/2007	Fike 2	0	44,	0	Inside Harbor	low	9
6/12/2007	ventless	0	65, 73, 65, 69	5	Center Harbor	low	51
6/12/2007	Joe	0	0	26	Center Harbor	low	51
6/12/2007	Fike 1	0	0	22	Center Harbor	low	51
6/12/2007	Fike 2	0	0	0	Center Harbor	low	51
6/12/2007	ventless	0	80, 80, 74, 66, 67, 67, 68, 79, 58, 60, 66, 80, 66,	5	shore pond	low	16
6/12/2007	Joe	0	0	4	shore pond	low	16
6/12/2007	Fike 1	0	63, 54, 50, 41	2	shore pond	low	16
6/12/2007	Fike 2	0	0	0	shore pond	low	16
6/12/2007	ventless	0	80, 76, 81, 60, 80, 78, 78, 79, 77, 80, 81, 75, 67, 70, 75, 55, 58, 58, 66, 79, 60, 56, 70, 71, 67, 56, 59, 52,	0	Middle Harbor	low	44
6/12/2007	Joe	0	62, 68, 56, 56	0	Middle Harbor	low	44
6/12/2007	Sample 2.5'	0	49, 52,	0	Middle Harbor	low	44
6/12/2007	Sample 1.75'	0	0	0	Middle Harbor	low	44

BIOGRAPHY OF THE AUTHOR

William Fike was born in Greenwich, Connecticut on January 23, 1979. He was raised in Greenwich, Connecticut and graduated from Berkshire Academy in Sheffield, Massachusetts in 1997. He attended Hartwick College and graduated in 2002 with a Bachelor's degree in History. After working for several years he entered the Marine-Bio Resources program at The University of Maine in the fall of 2005. William is a candidate for the Master of Science degree in Marine-Bio Resources from The University of Maine in December 2007.