Northeast Consortium Final Report

POTYEAR: Determining the Seasonality of Cod Pots

Award Number: 09-048A

In memory of Capt. Robert Marcella

Period of Performance: 6/30/2008 - 6/30/2011

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Abstract

Newfoundland-style, large, large-mesh static pots were compared to Norwegian-style, smaller, small-mesh, off-bottom, dynamic pots in a controlled study from a commercial fishing vessel from November 2008-November 2009. Results from analysis indicate that cod were most vulnerable to pots during a limited season, and that the smaller mesh pot caught more small cod. Otherwise, the pots performed similarly. We conclude that either pot style may be effective for further development, that seasonality plays an important role and should be exploited for further testing, and observation of near-field behavior in cod near pots is still vital and problematic.

Introduction

Worldwide interest in investigating and improving fish potting is widespread, with active research projects in Canada, the Faroe Islands, Iceland, Norway, Sweden, France, the United Kingdom, and the United States (ICES, 2011). Interest in potting extends to the Southern Hemisphere, and to Asia (Pol et al., 2010), largely because fish pots possess many characteristics of an idealized fishing gear: they can be highly selective for the target species, and they yield apparently undamaged, high quality, healthy fish for sale, tagging and other scientific studies (Bjordal, 2002; ICES, 2006). Releases of undersized and unmarketable fish from pots have low or zero release mortalities in our previous research (Pol and Walsh, 2005). Pots also provide an alternative survey and harvest method for areas inaccessible to otter-trawling, such as coral reefs and hard bottom (ICES, 2009). As static gears, pots are low energy and low impact to non-target species and habitats and high fuel efficiency may result from their use (Thomsen et al., 2010). On the negative side, wider use of pots would increase buoy lines in the water, a safety concern for marine mammals and sea turtles. Current research suggests that, primarily, pots require improvements in catch per unit effort before commercial viability (Pol et al., 2010, Thomsen et al., 2010).

Interest in Massachusetts in pots arose from occurrence of “overharvest”, otherwise landable fish that are discarded due to catch limits. Where overharvest occurs, unnecessary damage and discard mortality of fish may result. Or, fish may be left in the water for harvest the next day, with loss of quality. In these cases, a gear, such as pots, that can catch and hold fish harmlessly or that allows discard with low or no mortality will improve economic return and stock rebuilding by keeping more fish alive.

Pol and Walsh (2005) reported the first catches of Atlantic cod *Gadus morhua* in a cod pot during scientific trials in New England, up to 13 in one pot haul, using pots designed at the Centre for Sustainable Aquatic Resources, Marine Institute of Memorial University of Newfoundland (CSAR). However, pot-captured cod tended to be below minimum landing size and average catch rates were not economical. Further investigation in the same area in December 2005 - February 2006 comparing catches in CSAR pots to nearby multimesh gillnets showed similar low catch rates, and suggested that cod in pots were smaller and had more empty stomachs than cod caught in nearby gillnets (Pol, unpublished data). However, the sampling area was limited in size and the number of samples and the number of pots used were very low. Underwater filming showed cod attracted to, but not often entering, the pot.

An international workshop on gadoid harvest (GACAPOT) in Gloucester, Massachusetts (2006) examined progress on catching cod, haddock *Melanogrammus aeglefinus*, and related fish in pots (Pol et al. 2010). The meeting concluded that it was necessary to align the bait's scent plume (caused by the movement of water over the bait) with the direction of entry to the pot's entrance. Norwegian scientists (Furevik et al. 2008) designed pots to float and rotate in response to current. Underwater observation of their pots showed >95% of fish approached the pot from the down-current direction. Similar or higher catch rates (3.6 cod per pot) were reported for this design than experienced with the Newfoundland design (Furevik et al. 2008).

A second important conclusion from GACAPOT was that fish in general and Atlantic cod specifically are only vulnerable to pots during certain times of year. This vulnerability may be due to seasonal behavior, hunger levels, presence of prey or predators, migration, spawning status, temperature, or a combination of these and other factors. Therefore, in development of pots, it is of primary importance to establish when cod will be maximally vulnerable. This knowledge can then lead to refinement of the pot design by testing during those time periods.

The Newfoundland-designed and the Norwegian-designed pots were both effective at capturing cod in the regions where they were developed, although their characteristics differed substantially: floating v. static; large v. small; two large entrances v. one small entrance. In a paired, controlled study, we compared the CSAR (Newfoundland) pots to the floating (Norwegian) pots described by Furevik et al. (2008). Paired overnight sets were conducted for four days per month in Massachusetts state waters of both Newfoundland and Norwegian designed cod pots, across eight months of a year (November-June). We planned to film fish behaviors, primarily reaction to bait, using underwater cameras. The results of this work were intended to quantify catch rates in pots across eight months, compare the effectiveness of two pot designs, and determine the best time to catch cod with pots.

Project Objectives

Our goal was to continue to develop cod pots. To accomplish this goal, we identified the following objectives:

1. To compare catch rates and sizes of Atlantic cod captured in Norwegian and Newfoundland cod pots;
2. To compare catch rates and sizes of Atlantic cod over eight months;
3. To observe Atlantic cod behavior in reaction to bait and to cod pots.

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Names in **bold** played a key role in project design and implementation.

Methods

Tests were conducted onboard three similar vessels, primarily used for lobster pot fishing, each approx. 13 m, 260kW, equipped with a pot hauler and a boom. Open transoms simplified setting of pots.

Ten pots each of the Newfoundland and Norwegian design were set singly in pairs approx. 0.25 nm apart for periods within each of eight months: December 2008-June 2009, and November 2009. The Newfoundland design (NF) cod pots are all pyramid-shaped when fishing and are constructed in three different ways: two are approx. 2 m x 2 m x 1 m (6.5 ft x 6.5 ft x 41 in) and consist of a steel frame with netting panels; one of these designs is collapsible, saving deck space (Figure 1). The third construction type is 1.8 m x 1.8 m x 1 m (71 in x 71 in x 3.3 ft) and made from polyvinyl-coated wire 50 mm square mesh. All three have netting attached at the top: 30 meshes of 50 mm diamond mesh with a float whose buoyancy creates the pyramid of netting on

top. Each pot has two entrances on opposite sides with 40 cm diameter circular rings. Attached to the rings are “triggers”: stainless steel 5 mm diam. rods about 50 mm apart that swing in to allow entrance, but do not swing out. The pots are designed to be static on the sea floor. Previous research (Pol and Walsh 2005) showed these three designs did not fish differently from one another, and for the purposes of this study were treated as identical.

The Norwegian design (NO) (Figure 2) pots are collapsible two-chamber rectangular pots made of netting, with a single bridle with anchor along the short end of the pot, allowing it to float and to turn with the current, adapted from Furevik et al. (2008). They have one entrance at the opposite end as the bridle, and are made of 50 mm black poly mesh for the trap body and 50 mm white poly for the entrances (into the pot and between chambers). Three frames per pot were constructed of 2 cm diam. PVC electrical conduit, with 13 cm radius corners, glued with cement. The frame sizes were approx. 1.5 m x 1 m (4.79 ft x 3.28 ft), hung 0.7 m (2.3 ft) apart forming two chambers with a widemouth entrance in between. The bridles were anchored with >5 kg links of chain. After several months, observations of cracking in the PVC and catches of lobsters suggested that pots were not floating as expected. A pot was set in a large-scale, laboratory sea water tank, and did not float off bottom. The PVC pipes were then perforated and 11 deep-water gillnet floats were added along the upper frame to achieve proper orientation. All NO pots were subsequently modified in this manner. During the tank investigation, the top of the NO pot was measured to be 3 m off bottom; the bottom of the pot was 1.5 m off-bottom.

Locally caught clams, shelled and frozen, were used for bait during the field research. This bait was shown to be preferential for cod in a prior study (Pol et al. 2007). Bait was purchased in one lot for the entire experiment, and maintained in a commercial bait freezer. Quantities were defrosted prior to setting of the pots as needed. Bait was presented in perforated cups, unprotected on skewers, and in mesh bait bags. The amount of bait per pot was approximately equal, although not strictly controlled.

Pots were set and hauled on three or four consecutive days in each month. Set locations were determined using fishing experience, an echo-sounder, and jigging. Bottom structure in the study area is glacially-influenced, and is composed of cobble/gravel mounds in shallower areas interspersed with deeper areas of a sand/silt matrix (Butman et al., 2007). Depths in the northwestern corner of the area are quite shallow but most of the area is 30-76 m (100-250 ft) deep with dramatic localized relief. Depth generally increases with distance from shore. Bottom current is mainly influenced by tides, with some effect from wind. In each tidal cycle, the current rotates 360 degrees (pers. comm., C. Chen, School for Marine Science and Technology, University of Massachusetts)

Catch was identified, weighed, and measured. Operational and biological data were collected by DMF biologists, including: catch composition and weights for all species, midline lengths for Atlantic cod (and other species as practical) to the nearest cm, set and haul times, locations, weather conditions, depth, and bottom seawater temperature. Data were entered into a customized Access database and analyzed using the open-source statistical program R (R Development Core Team, 2009; Sarkar 2009).

Holst and Revill (2009) described an implementation of Generalised Linear Mixed Models (GLMM) to paired catch experiments. This implementation allows fitting of curves of limited complexity to expected proportions-at-length (in our case, count of cod in NO pots/total count in both pots for each pair). GLMMs in the Holst and Revill (2009) method incorporate between-

pair variance (Fryer, 1991). Four fixed-effect models (constant, linear, 2nd order, and 3rd order polynomial relationships of length) were tested, each using pair as a random effect. We used the penalised quasi likelihood function (glmm-PQL function in MASS package of the *R* statistical software (R Development Core Team, 2009)), where insignificant terms are removed based on the Wald's test (Holst and Revill, 2009).

Additionally, we attempted to conduct at least one filming session each month to observe fish behavior in the vicinity of a pot. An underwater camera was attached to an NF pot using an aluminum outrigger and video was live-fed to the vessel and recorded. A series of observations were planned to assess the effect of different aspects of the pot design on fish behavior. We planned to begin by filming a baited NF pot with side panels removed and top netting opened and rolled down, progressing stepwise to a fully enclosed, normal configuration.

Collected video was reviewed at least twice, by two separate reviewers. Observations of fish were noted, and identified to likely species where possible. Actions of fish relative to entry to the camera frame, direction, level of activity, and activity were noted. Pot motion, direction of current, and visibility of the pot were also recorded.

Data

We completed 383 pot-hauls on 24 trips; 377 pot-hauls were considered valid for analyses. Pairs where no cod were caught in either pot were removed for cod catch analyses, resulting in 114 pairs where at least one cod was present. Overall, pots were set in an area of approx. 16 sq. km (Figure 3), inside of Massachusetts state waters.

Median soak durations generally ranged from 22.5-24.8 hours, with longer durations in December 2008 (median = 43.8 hours) due to weather (Figure 4). Median monthly bottom temperatures ranged from 3.1 (Feb 2009) to 10.0°C (Nov 2009). Median depth fished ranged from 27.5 to 50.6 m.

Catches consisted of 16 species (Table 1) with Atlantic cod, cunner *Tautoglabrus adspersus*, pollock *Pollachius virens*, and lobster *Homarus americanus* the primary species. Catches of lobster in NO pots were dramatically reduced after modification of flotation was made.

A total of 397 cod were caught in pots; counts of cod varied noticeably between months (Figure 5). The catches in the months of April and May accounted for over 50% (n=217) of all cod caught. The highest pot catches (> 9 cod per pot-haul) occurred in these months; the highest median catches (1.5-3 cod per pot-haul) also occurred during these months. December, March, June and November's catches were intermediate. Only five cod were caught in January and February combined.

Few cod above legal size were caught in any month (Figure 6); only 28 fish above the minimum landing size of 55.9 cm were caught in total.

Norwegian pots caught more cod monthly than the Newfoundland designs on several occasions (Figure 5); in some months, performance seemed similar between the two designs. Smaller cod were caught more frequently in the NO pots (Figure 6).

GLMM analysis confirmed that Norwegian pots caught more small fish (Figure 7). The best fit model resulted in a significant ($p<0.05$ for all terms) third order polynomial fitting the proportion of cod caught in the NO pots. The model indicates that the NO pots caught significantly more cod <38 cm ($p<0.05$) than the NF pots. For cod >38 cm, catches were not significantly different ($p>0.05$). Above MLS (56 cm), variability increased a great deal (as seen in the width of the error bands), likely due to low numbers of cod above this size.

Approximately 8.5 hours of underwater video of a NF cod pot were collected on seven days in three months (Table 2), resulting in 11 tapes. Filming was attempted in every month, but unsafe weather and poor visibility limited observations to February, March and April. Only observations of a wire mesh NF pot were possible. While visibility was often low, the entire side of the pot was usually visible. Several parts of the pot provided high contrast in the video view, including the aluminum clips holding the pot together, and the white mesh of the funnels. The netting of the top of the pot appeared semi-transparent; the wiremesh sides were dark against the high contrast of the white funnels.

Movement of the entire pot frame was apparent in 4 of the 11 tapes; the top of the pot did not move with the current independently of the frame. Pot and camera cable motion appeared to disrupt fish swimming direction. On four occasions, the motion of the current was observable from plankton, and was from left to right in the camera view. Fish were observed in seven of 11 videos; cunner were very common and were identified in six and Atlantic cod in four. Most cod appeared to be small (20-30 cm). Pollock and redfish were seen once each.

Fish of all observed species exhibited primarily mild interest in the pot and bait, as demonstrated by slow swimming speed and lack of attempts to enter the pot. Some moderate interest was observed. Fifteen observations of fish in or near pot entrances were made. On two deployments, fish, most likely cunner based on size, were observed eating or tearing at the bait. On two occasions, fish exhibited possible displacement behavior by nibbling on a piece of twine hanging off the outside of the pot.

All catch and video data from this project have been entered into a customized Access relational database, and will be provided to the Northeast Consortium Fisheries & Ocean Database shortly after final report submittal. A file of all scanned data sheets and video logs accompanies this report.

Results and Conclusions

Seasonal variation in cod catches in pots was found. Catch results changed dramatically over the course of the study, indicating that vulnerability or presence of cod varied with season. Very low catches occurred during January and February in mid-winter; highest catches were in April and May. Low water temperature can change the effective area of a pot by reducing the swimming and searching ability of a fish (He and Pol, 2010). However, low catches were not directly related to bottom temperature, as temperatures were similar in these months and months with higher catches. The seasonality of these catches reinforced traditional knowledge and observation of fish on the grounds, but does not coincide exactly with times of higher longline or gillnet catches (some traditional knowledge of fish presence in the area is hindered by long-standing seasonal closures). Traditional knowledge also suggested that larger cod might be caught in November and December. While some evidence was found to support this observation,

too few fish were caught to conclusively demonstrate it. Further research to improve efficiency of pot designs in this region should concentrate on the months of April and May, and avoid the months of January and February.

The efficiency of the two pot designs differed, based on the length of the fish (Figure 7). The smaller size cod (<38 cm) caught by the NO design may be due to the smaller mesh size of the pot construction. While underwater video collected in other studies (Pol et al., 2010) suggests that mesh penetration of the sides of a pot is rare, recent research demonstrates that a large mesh panel in an NO pot results in knife-edge size selectivity, implying passage through pot meshes (Ovegård 2011). It is possible that the hauling method for the NF pots, with the pyramid top trailing, may cause a codend effect, with cod escaping if they can fit through the meshes. If smaller sized fish are desired, the pyramid mesh can be easily replaced. Additionally, the triggers on the entrances to the NF pots may also be selective, as smaller fish have been observed to exit between trigger fingers (Pol and Walsh 2005).

It was thought that the alignment of plume and entrance by the NO-style pots would lead to much greater catches than in the NF pots, based on previous work by others and our own prior underwater observations of Atlantic cod milling around a pot and not actively seeking entrances (Pol et al., 2010). Larger catches were mostly seen for smaller fish only, which suggests a difference in size-selectivity of pot structures. It may be possible that the greater catches of small fish were caused by the plume-entrance alignment, if a behavioral difference related to plume following or entrance can be related to Atlantic cod of that size. Atlantic cod of 38 cm in this stock are approximately 3 years old (Collette and Klein-MacPhee, 2002). Perhaps those fish and smaller sizes more actively search for or react to bait plumes (that is, they have a greater feeding motivation), and thus are more vulnerable to the gear. Alternatively, the circulation patterns in the study area may cancel out the effect of the plume-entrance alignment by rotating 360° approximately every 24 hours.

The pots were equally efficient for a mid-size range of fish. For fish above MLS (56 cm), they were also equally efficient, but the uncertainty in the results is much higher. It has previously been suggested that large pot volumes are necessary for effective cod capture; further, concern over the apparent size of the pot mouths (entrance) in the NO design led to the thought that the smaller NO design would catch fewer large fish. Our results suggest that volume is not a barrier to large catches, and are inconclusive on any size limitation for either design.

Our attempts to comprehend the observed differences in pot catches through underwater video observation were only partly successful. Our observations showed few fish aggregating around pots, in contrast to some other work (Rose et al. 2005). We were unable to observe adequate fish reaction to make conclusions about pot modifications to improve entry and retention. Further observation of Atlantic cod reaction to cod pots is vital. Future attempts to record cod behavior in situ should be as the central focus of a study, so that adequate time and resources can be available to collect conclusive observations.

Why were so few fish seen on video, and why were so few large cod captured in either design? Several explanations are possible: cod of large or any size were absent (supported by jigging and the echo-sounder); they were not vulnerable to the pot, perhaps due to inadequate motivation to feed, seek shelter, or to move; the bait may have been inadequately attractive. It appears unlikely that entry was difficult due to entrance size or design or other factors, or that escape was too easy. Movement of the pot appeared to disturb fish; perhaps in rockier bottom movement is a

factor in low catches. Further investigation of these possibilities is not equally possible, as the in-situ population structure and behavioral motivations are difficult to assess. Testing of modifications to entrances and other aspects of design is more possible, as times of high vulnerability can now be recommended.

The NO design pot has many practical advantages, mostly related to their compact nature. Many more of them can be transported on a vessel and no specialized handling equipment is necessary. Some improvement to the basic design is suggested, including separating the functions of frame structure and flotation so that damage to the structure does not affect flotation.

Both designs are now demonstrated to be effective at catching Atlantic cod in the region. Each design has advantages; the NO design appears especially practical for scientists and others wishing to sample sublegal sized cod for tagging, broodstock, or other purposes. Commercial practicality still appears elusive; while few legal sized fish were caught, the number of pots used was very low. For comparison, ratio of kept lobsters per pot in the local lobster pot fishery is less than 0.5 (DMF, unpubl. data). If a cod pot fishery were scaled to the 600 pots or so allowed in the lobster pot fishery, commercial viability might be achieved. It is also possible that under new stricter cod stock management, the number of fish of legal size will increase, and catches will increase. Additional development of entrances should continue as a primary means of improving efficiency.

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Partnerships

The project was a strong collaboration between DMF and Robert Marcella, with each participant bringing independent and overlapping expertise, with mutual respect of that expertise as well as healthy discussion of decisions. Pol and Marcella worked together to define the project objectives and direction, the study area and times of year when the project should be conducted.

They, along with vessel crew and Mark Szymanski, jointly considered logistics of deck handling of pots and number of pots that could be handled in a day. They worked together to find and acquire an adequate bait supply, storage, and delivery method for the project. Marcella provided lead on determining timing of monthly fishing activity, maintenance and storage of pots, and set location, and has primary responsibility for determining safe working conditions due to weather and deck activity. Pol provided lead on database development, data analysis, and report writing. Szymanski led the sea sampling and coordination with SMAST personnel.

Marcella and three crewmen (one or two at a time) were involved directly with the project, with a network of other fishermen advising us on possible locations of Atlantic cod. Kelo Pinkham adapted the Norwegian design from a diagram, designed, tested, constructed, and delivered the Norwegian pots. More than eleven scientists from DMF and SMAST participated in sampling and tagging.

The project has led to an uncounted number of interactions with fishermen who are interested in using pots commercially. One of the advantages of pots noted by static gear fishermen is that little or no additional deck gear is necessary for pot handling, and therefore the expense of expanding to pots is very low.

The death of Capt. Marcella near the end of the project was a severe loss to the project and to further development of pots, as he was the most experienced cod pot fisherman in the region. The project was lucky to have Capt. Mahoney to complete the necessary work. It was also a severe loss to the other participants, who had established warm relationships with Capt. Marcella during this project and previous work together. It was a measure of the importance of this project that he talked about it in his final days, and a photo taken during pot research was used on his funeral program.

Impacts and Applications

The NO pots are easy to handle and catch a wide variety of sizes of Atl. cod, with low bycatch. The design still needs some adjustment, particularly separating buoyancy from the pot structure, but the use of these pots for capture of sublegal sized Atl. cod with minimal impact has been adequately demonstrated. We have also defined times of year when additional testing can be optimized. At this time, pots are not yet ready for widespread commercial use, but continued development of pots, perhaps by commercial trials, could allow for an alternative gear that has low bottom impact, high species selectivity, high survival, and excellent quality.

Related Projects

This project provided tagging opportunities for SMAST personnel, overseen by David Martins and Steven Cadrin, and through them, fin clips for genetic research by Dr. David Berlinsky of the University of New Hampshire.

Presentations

Pol, M. 2009. Fishing Inside the Box? [poster]. Northeast Consortium Annual Meeting.

Portsmouth, NH, 25 March 2009.

Pol, M. 2009. Determining the Seasonality of Cod Pots - Halfway Results. Presentation to the ICES Study Group on Fish Pots (SGPOT). Ancona, Italy, 16 May 2009.

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Szymanski, M. 2010. Determing the Seasonality of Cod Pots. [poster] Northeast Consortium Annual Project Participant's Meeting. Portsmouth, NH, October 2010.

Student participation

Graduate students, University of Massachusetts School for Marine Science and Technology
Crista Bank, Greg Decelles, Dan Goethel, Jon Loehrke, David Martins, Doug Zemeckis

Published Reports and Papers

Marcella, R., M. Pol, and M. Szymanski. 2010. Determining the seasonal catchability of Atlantic cod *Gadus morhua* pots. ICES CM 2010/I:10. Report to the International Council for Exploration of the Seas Annual Science Conference.

Images

Approximately 385 MB of images were collected as part of the project and will be submitted on CD or DVD by mail. Captions are listed below.

Folder	Date	File Name	Caption
POTYEAR	8/13/2008	IMGP0208.JPG	Pre-repair cod pots in Bob Marcella's yard
POTYEAR	8/13/2008	IMGP0209.JPG	Pre-repair cod pots in Bob Marcella's yard
POTYEAR	8/13/2008	IMGP0210.JPG	Pre-repair cod pots in Bob Marcella's yard
POTYEAR	8/13/2008	IMGP0211.JPG	Pre-repair cod pots in Bob Marcella's yard
POTYEAR	2/25/2009	IMGP0217.JPG	First setting trip - pots loaded on Bob's boat
POTYEAR	2/25/2009	IMGP0218.JPG	Sean McMullen with pots loaded on Bob's boat
POTYEAR	2/25/2009	IMGP0219.JPG	Sean McMullen and Eric Lorentzen prepare buoylines
POTYEAR	2/25/2009	IMGP0220.JPG	Pot prepared for filming
POTYEAR	2/27/2009	IMGP0221.JPG	Sunrise
POTYEAR	2/27/2009	IMGP0222.JPG	Sunrise
POTYEAR	11/12/2009	IMGP0754.JPG	Mark Szymanski and Bob Marcella in wheelhouse of Channing Anne
POTYEAR	11/12/2009	IMGP0759.JPG	David Chosid and Mark Szymanski in wheelhouse of Channing Anne
POTYEAR	3/19/2009	MTNFpot.tif	Screen shot of filming pot underwater with top rolled down and sides off
April 2009	4/25/2009	HPIM3035.JPG	Bob Marcella preparing to jig for cod
April 2009	4/25/2009	HPIM3036.JPG	Bob Marcella jigs at sunrise
April 2009	4/25/2009	HPIM3037.JPG	Bob Marcella jigs at sunrise
April 2009	4/25/2009	HPIM3038.JPG	Bob Marcella jigs at sunrise
April 2009	4/25/2009	HPIM3039.JPG	Bob Marcella jigs at sunrise
April 2009	4/25/2009	HPIM3040.JPG	Bob Marcella jigs at sunrise while Lisa Kerr looks on
April 2009	4/25/2009	HPIM3041.JPG	Bob Marcella jigs at sunrise while Lisa Kerr looks on
April 2009	4/25/2009	HPIM3042.JPG	Bob Marcella jigs at sunrise while Bob's dog looks on
April 2009	4/25/2009	HPIM3043.JPG	Bob Marcella jigs at sunrise while Bob's dog looks on
April 2009	4/25/2009	HPIM3044.JPG	Bob Marcella jigs at sunrise
April 2009	4/25/2009	HPIM3045.JPG	Blurry view of pot buoys in water
April 2009	4/25/2009	HPIM3046.JPG	Blurry view of pot buoys in water
April 2009	4/25/2009	HPIM3047.JPG	Bob's dog inside a Newfoundland pot on deck with cod
April 2009	4/25/2009	HPIM3048.JPG	Bob's dog inside a Newfoundland pot on deck with cod
April 2009	4/25/2009	HPIM3049.JPG	Bob's dog inside a Newfoundland pot on deck with cod

Folder	Date	File Name	Caption
April 2009	4/25/2009	HPIM3050.JPG	Bob hauling a pot
April 2009	4/25/2009	HPIM3051.JPG	Sean McMullen handling a line
April 2009	4/25/2009	HPIM3052.JPG	Bob hauling a Norwegian pot with Sean and the dog
April 2009	4/25/2009	HPIM3053.JPG	View of floats added to Norwegian pot
April 2009	4/25/2009	HPIM3054.JPG	Lisa Kerr awaits fish from a Norwegian pot
April 2009	4/25/2009	HPIM3055.JPG	Bob's dog waits for fish, too.
April 2009	4/25/2009	HPIM3056.JPG	Sean removing fish from pot
April 2009	4/25/2009	HPIM3057.JPG	Closeup of urogenital opening on measuring board
April 2009	4/25/2009	HPIM3058.JPG	Sean on stern with Norwegian pot ready for setting
April 2009	4/25/2009	HPIM3059.JPG	Dog on stern with Norwegian pot ready for setting
April 2009	4/25/2009	HPIM3060.JPG	Sean setting Norwegian pot
April 2009	4/25/2009	HPIM3061.JPG	Sean setting Norwegian pot
April 2009	4/25/2009	HPIM3062.JPG	Dappled sunshine on water
April 2009	4/25/2009	HPIM3063.JPG	Sean McMullen on deck
April 2009	4/25/2009	HPIM3064.JPG	View of Bob in wheelhouse
April 2009	4/25/2009	HPIM3065.JPG	Lisa Kerr in wheelhouse with clipboard
April 2009	4/25/2009	HPIM3066.JPG	Lisa Kerr attaching a DST tag to a cod on deck
April 2009	4/25/2009	HPIM3067.JPG	Sea herring on measuring board
April 2009	4/25/2009	HPIM3068.JPG	Sea herring on measuring board
April 2009	4/25/2009	HPIM3069.JPG	Redfish on measuring board
April 2009	4/25/2009	HPIM3070.JPG	Cunner on measuring board
April 2009	4/25/2009	HPIM3071.JPG	View of filming pot with top mesh rolled down, and Sean
April 2009	4/25/2009	HPIM3072.JPG	View of filming pot with top mesh rolled down, and Sean
April 2009	4/25/2009	HPIM3073.JPG	View of inside of filming pot with bait cup and skewers
April 2009	4/25/2009	HPIM3074.JPG	View of camera on outrigger
April 2009	4/25/2009	HPIM3075.JPG	View of outrigger attachment to pot with cable ties and twine
April 2009	4/25/2009	HPIM3076.JPG	View of outrigger attachment to pot with cable ties and twine
April 2009	4/25/2009	HPIM3077.JPG	View of camera, cable reel, and filming pot
April 2009	4/25/2009	HPIM3078.JPG	View of camera, cable reel, and filming pot
April 2009	4/25/2009	HPIM3079.JPG	View of partial setup of power supply, clipboard and camcorder
April 2009	4/25/2009	HPIM3080.JPG	Bob in captain's chair, with dog
April 2009	4/26/2009	HPIM3081.JPG	Sean preparing bait
April 2009	4/26/2009	HPIM3082.JPG	Sean preparing bait
April 2009	4/26/2009	HPIM3083.JPG	Dave Martins and Sean McMullen, early morning jigging
April 2009	4/26/2009	HPIM3084.JPG	Bob Marcella jigging
April 2009	4/26/2009	HPIM3085.JPG	Bob Marcella jigging
April 2009	4/26/2009	HPIM3086.JPG	Bob Marcella jigging
April 2009	4/26/2009	HPIM3087.JPG	Sean McMullen jigging
April 2009	4/26/2009	HPIM3088.JPG	Newfoundland pot hauled to rail
April 2009	4/26/2009	HPIM3089.JPG	Sean McMullen brings Newfoundland pot over rail
April 2009	4/26/2009	HPIM3090.JPG	Sean McMullen brings Newfoundland pot over rail
April 2009	4/26/2009	HPIM3091.JPG	Sean McMullen and David Martins handling lines
April 2009	4/26/2009	HPIM3092.JPG	Sean McMullen brings Newfoundland pot over rail
April 2009	4/26/2009	HPIM3093.JPG	Sean McMullen brings Newfoundland pot over rail
April 2009	4/26/2009	HPIM3094.JPG	Sean McMullen brings Newfoundland pot over rail
April 2009	4/26/2009	HPIM3095.JPG	Sean McMullen brings Newfoundland pot over rail
April 2009	4/26/2009	HPIM3096.JPG	TidBit temperature logger on Norwegian pot
April 2009	4/26/2009	HPIM3097.JPG	Trap tag on Norwegian pot
April 2009	4/26/2009	HPIM3098.JPG	Flotation on Norwegian pot
April 2009	4/26/2009	HPIM3099.JPG	Bait on skewers
April 2009	4/26/2009	HPIM3100.JPG	Chain used to anchor Norwegian pots
April 2009	4/26/2009	HPIM3101.JPG	David Martins filling out data sheets
April 2009	4/26/2009	HPIM3102.JPG	David Martins filling out data sheets
April 2009	4/26/2009	HPIM3103.JPG	Bait on skewers hanging in pot
April 2009	4/26/2009	HPIM3104.JPG	Bait on skewers hanging in pot
April 2009	4/26/2009	HPIM3105.JPG	Red hake
April 2009	4/26/2009	HPIM3106.JPG	View of Boston across the water
April 2009	4/26/2009	HPIM3107.JPG	View of Boston Light across the water
April 2009	4/26/2009	HPIM3108.JPG	David Martins reviewing data sheets
April 2009	4/27/2009	HPIM3109.JPG	Norwegian pot with good catch of cod
April 2009	4/27/2009	HPIM3110.JPG	Norwegian pot with good catch of cod
April 2009	4/27/2009	HPIM3111.JPG	Blurry, off-kilter view of deck
Mar 09	3/23/2009	cod post 073.jpg	Sean McMullen with Newfoundland pot on deck
Mar 09	3/23/2009	cod pots 058.jpg	Newfoundland pot on deck, ready to be set
Mar 09	3/23/2009	cod pots 059.jpg	Mark Szymanski with Newfoundland pot on deck
Mar 09	3/23/2009	cod pots 060.jpg	View of Bob Marcella at the wheel
Mar 09	3/23/2009	cod pots 061.jpg	View of hauling block
Mar 09	3/23/2009	cod pots 062.jpg	Newfoundland pot at surface after hauling
Mar 09	3/23/2009	cod pots 063.jpg	Newfoundland pot along rail
Mar 09	3/23/2009	cod pots 064.jpg	Newfoundland pot along rail with fish visible
Mar 09	3/23/2009	cod pots 065.jpg	Tote with live cod and measuring board
Mar 09	3/23/2009	cod pots 066.jpg	View of freighter through wheelhouse window
Mar 09	3/23/2009	cod pots 067.jpg	Newfoundland pot at hauler

Folder	Date	File Name	Caption
Mar 09	3/23/2009	cod pots 068.jpg	Newfoundland pot along rail
Mar 09	3/23/2009	cod pots 069.jpg	Mark Szymanski hauling line
Mar 09	3/23/2009	cod pots 070.jpg	Newfoundland pot hoisted
Mar 09	3/23/2009	cod pots 071.jpg	Newfoundland pot on deck after hauling
Mar 09	3/23/2009	cod pots 072.jpg	Newfoundland pot on deck, Mark handling lines
Mar 09	3/23/2009	cod pots 074.jpg	Mark and Sean moving Newfoundland pot on deck
Mar 09	3/23/2009	cod pots 075.jpg	Mark and Sean moving Newfoundland pot on deck
Mar 09	3/23/2009	cod pots 076.jpg	Mark and Sean moving Newfoundland pot on deck
Mar 09	3/23/2009	cod pots 077.jpg	Mark and Sean moving Newfoundland pot on deck
Mar 09	3/23/2009	cod pots 078.jpg	Sean baiting Newfoundland pot
Mar 09	3/23/2009	cod pots 079.jpg	Mark putting rubber bands on line
Mar 09	3/23/2009	cod pots 080.jpg	View of freighter
Mar 09	3/23/2009	cod pots 081.jpg	View of freighter
Mar 09	3/23/2009	cod pots 082.jpg	Mark getting fish out of Norwegian pot
Mar 09	3/23/2009	cod pots 083.jpg	Catch of lobsters and cod on deck with Mark and Sean
Mar 09	3/23/2009	cod pots 084.jpg	View of freighter and Newfoundland pot on deck
Mar 09	3/23/2009	cod pots 085.jpg	Lobster boat off stern
Mar 09	3/23/2009	cod pots 087.jpg	View of Newfoundland pot just before setting
Mar 09	3/23/2009	cod pots 088.jpg	View of Newfoundland pot just before setting
Mar 09	3/23/2009	cod pots 089.jpg	Terrible view of Mark Szymansk on deck
Mar 09	3/23/2009	cod pots 090.jpg	Mark and Sean prepare Newfoundland pot
Mar 09	3/23/2009	cod pots 091.jpg	Mark prepares a Newfoundland pot
Mar 09	3/23/2009	cod pots 092.jpg	Mark and Sean jigging
Mar 09	3/23/2009	cod pots 093.jpg	View of bait and entrance in a Newfoundland pot
Mar 09	3/23/2009	cod pots 094.jpg	View of bait and entrance in a Newfoundland pot
Mar 09	3/23/2009	cod pots 095.jpg	Mark happily jigging, with Norwegian pot nearby
Mar 09	3/23/2009	cod pots 096.jpg	Sean jigging
Mar 09	3/23/2009	cod pots 097.jpg	Sean jigging
Mar 09	3/23/2009	cod pots 098.jpg	Sean jigging
Mar 09	3/23/2009	cod pots 099.jpg	Mark happily jigging, with Norwegian pot nearby
Mar 09	3/23/2009	cod pots 100.jpg	Sean jigging
Mar 09	3/23/2009	cod pots 101.jpg	Sean jigging
Mar 09	3/23/2009	cod pots 102.jpg	Sean with fish on
Mar 09	3/23/2009	cod pots 103.jpg	Sean dehooking sea raven
Mar 09	3/23/2009	cod pots 104.jpg	Sean dehooking sea raven
Mar 09	3/23/2009	cod pots 105.jpg	Sean bringing Newfoundland pot over rail
Mar 09	3/23/2009	cod pots 106.jpg	Sean, Mark, and Bob bringing Norwegian pot over rail
Mar 09	3/23/2009	cod pots 107.jpg	Mark and Sean with Newfoundland pot
Mar 09	3/23/2009	cod pots 108.jpg	Cod in Newfoundland pot on deck
Mar 09	3/23/2009	cod pots 109.jpg	Mark with cod
Mar 09	3/23/2009	cod pots 110.jpg	Bob with N. Stone Crab, while Sean mugs for camera
Mar 09	3/23/2009	cod pots 111.jpg	Ventral view of N. Stone Crab
Mar 09	3/23/2009	cod pots 112.jpg	View of face of N. Stone Crab
Mar 09	3/23/2009	cod pots 113.jpg	View of people working on deck
Mar 09	3/23/2009	cod pots 114.jpg	View of rough seas off stern
Mar 09	3/23/2009	cod pots 115.jpg	Sean handling lines (through window)
Mar 09	3/23/2009	cod pots 116.jpg	Bob hauling pot
Mar 09	3/23/2009	cod pots 117.jpg	Sean handling lines
Mar 09	3/23/2009	cod pots 118.jpg	Sean handling lines
Mar 09	3/23/2009	cod pots 119.jpg	Bob, Sean and Mark (?) haul Newfoundland pot over rail
Mar 09	3/23/2009	cod pots 120.jpg	Newfoundland pot on deck.
Mar 09	3/23/2009	cod pots 121.jpg	Newfoundland pot on deck with sunshine
Mar 09	3/23/2009	cod pots 122.jpg	View of waves through wet window
Mar 09	3/23/2009	cod pots 123.jpg	Pots crowded on deck
Mar 09	3/23/2009	cod pots 124.jpg	Pots on Anne Marie at dock
Mar 09	3/23/2009	cod pots 125.jpg	Pots on Anne Marie at dock
Mar 09	3/23/2009	cod pots 126.jpg	Pots on Anne Marie at dock
Mar 09	3/23/2009	cod pots 27.jpg	Anne Marie loaded with cod pots at dock
June trip	7/31/2009	Picture 001.jpg	Crewman jigging
June trip	7/31/2009	Picture 002.jpg	Foulhooked dogfish
June trip	7/31/2009	Picture 003.jpg	Dehooking dogfish
June trip	7/31/2009	Picture 004.jpg	Bob's dog resting on deck
June trip	7/31/2009	Picture 005.jpg	Sean McMullen, Eric Lorentzen, and Doug Zemeckis on deck
June trip	7/31/2009	Picture 006.jpg	Sean McMullen, Eric Lorentzen, and Doug Zemeckis on deck
June trip	7/31/2009	Picture 007.jpg	One cod in a basket
June trip	7/31/2009	Picture 008.jpg	Doug measuring a cod
June trip	7/31/2009	Picture 009.jpg	Eric with a Newfoundland pot
June trip	7/31/2009	Picture 010.jpg	Sean McMullen, Eric Lorentzen, and Doug Zemeckis on deck
June trip	7/31/2009	Picture 011.jpg	Doug weighing a basket
June trip	7/31/2009	Picture 012.jpg	Doug weighing a basket
June trip	7/31/2009	Picture 013.jpg	Doug measuring a cod
June trip	7/31/2009	Picture 014.jpg	Doug measuring a cod
LastTrip	6/16/2004	IMGP0811.JPG	Chad Mahoney at wheel

Folder	Date	File Name	Caption
LastTrip	6/16/2004	IMGP0812.JPG	Filming pot on deck with top rolled down
LastTrip	6/16/2004	IMGP0813.JPG	Norwegian pot being hauled with fish
LastTrip	6/29/2004	IMGP0814.JPG	Mark with big cod
LastTrip	6/29/2004	IMGP0815.JPG	Mark with big cod
NECMeeting2009	3/25/2009	0325091610.jpg	Poster and Norwegian pot on display
NECMeeting2009	3/25/2009	0325091610a.jpg	Poster and Norwegian pot on display
NECMeeting2009	3/25/2009	0325091611.jpg	Poster and Norwegian pot on display
NECMeeting2009	3/25/2009	0325091611a.jpg	Closeup of poster
new boat loaded	4/22/2009	P4220121.JPG	Eric and Sean secure pots dockside on the Channing Anne
new boat loaded	4/30/2009	P4220122.JPG	Pots loaded dockside on the Channing Anne
new boat loaded	4/22/2009	P4220123.JPG	Sean and pots on the Channing Anne dockside
new boat loaded	4/22/2009	P4220124.JPG	Eric and Sean secure pots dockside on the Channing Anne
new boat loaded	4/22/2009	P4220125.JPG	Eric and Sean secure pots dockside on the Channing Anne
new boat loaded	4/22/2009	P4220126.JPG	Eric and Sean secure pots dockside on the Channing Anne
new boat loaded	4/22/2009	P4220127.JPG	Pots loaded dockside on the Channing Anne
new boat loaded	4/22/2009	P4220128.JPG	Pots loaded dockside on the Channing Anne
new boat loaded	4/22/2009	P4220129.JPG	Sean and pots on the Channing Anne dockside
new boat loaded	4/22/2009	P4220130.JPG	Loaded Channing Anne leaving the dock
new boat loaded	4/22/2009	P4220131.JPG	Loaded Channing Anne leaving the dock
new boat loaded	4/22/2009	P4220132.JPG	Loaded Channing Anne leaving the dock
SMASTtank	4/3/2009	IMGP0223.JPG	Mike Pol and Mark Szymanski prepare to drill Norwegian pot
SMASTtank	4/3/2009	IMGP0224.JPG	Mike and Mark drill Norwegian pot
SMASTtank	4/3/2009	IMGP0225.JPG	Mike Pol, Derek Perry, and Mark Szymanski drill Norwegian pot near SMAST tank
SMASTtank	4/3/2009	IMGP0226.JPG	Norwegian pot in test tank, top view
SMASTtank	4/7/2009	IMGP0226Edit.jpg	Norwegian pot in test tank, top view
SMASTtank	4/3/2009	IMGP0227.JPG	Mark on gantry overlooking Norwegian pot
SMASTtank	4/3/2009	IMGP0228.JPG	Norwegian pot in test tank, top view
SMASTtank	4/3/2009	IMGP0229.JPG	Norwegian pot in test tank, top view
SMASTtank	4/3/2009	IMGP0230.JPG	Norwegian pot in test tank, top view
SMASTtank	4/7/2009	IMGP0230Edit.jpg	Norwegian pot in test tank, top view
SMASTtank	4/3/2009	IMGP0231.JPG	Mark and Mike on gantry, preparing pot
SMASTtank	4/3/2009	IMGP0232.JPG	Mark and Mike on gantry, preparing pot
SMASTtank	4/3/2009	IMGP0233.JPG	Derek Perry and David Chosid in wetsuits on gantry, confer with Mike
SMASTtank	4/3/2009	IMGP0234.JPG	Derek Perry and David Chosid in wetsuits on gantry, confer with Mike
SMASTtank	4/3/2009	IMGP0235.JPG	Derek in wetsuit on gantry
SMASTtank	4/3/2009	P4030036.JPG	Mike and Mark set Norwegian pot in tank
SMASTtank	4/3/2009	P4030037.JPG	Diver with video housing underwater
SMASTtank	4/3/2009	P4030038.JPG	Diver with video housing underwater
SMASTtank	4/7/2009	P4030038Edit.jpg	Diver with video housing underwater
SMASTtank	4/3/2009	P4030039.JPG	View of pot underwater
SMASTtank	4/3/2009	P4030040.JPG	View of pot underwater
SMASTtank	4/3/2009	P4030041.JPG	View of pot underwater
SMASTtank	4/3/2009	P4030042.JPG	View of diver
SMASTtank	4/3/2009	P4030043.JPG	View of pot underwater
SMASTtank	4/3/2009	P4030044.JPG	View of pot entrance underwater
SMASTtank	4/3/2009	P4030045.JPG	View of pot underwater
SMASTtank	4/3/2009	P4030046.JPG	View of diver, pot, and added floats
SMASTtank	4/3/2009	P4030047.JPG	View of pot underwater
SMASTtank	4/3/2009	P4030048.JPG	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030048Edit.jpg	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030049.JPG	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030049Edit.jpg	View of diver, pot, and added floats
SMASTtank	4/3/2009	P4030050.JPG	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030051.JPG	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030051Edit.jpg	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030052.jpg	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030052Edit.jpg	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030053.JPG	View of pot and anchor
SMASTtank	4/3/2009	P4030054.JPG	View under pot
SMASTtank	4/3/2009	P4030055.JPG	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030055Edit.jpg	View of diver, pot, and added floats
SMASTtank	4/3/2009	P4030056.JPG	View of pot underwater
SMASTtank	4/3/2009	P4030057.JPG	View of pot underwater
SMASTtank	4/7/2009	P4030058.JPG	View of diver, pot, and added floats
SMASTtank	4/7/2009	P4030058Edit.jpg	View of diver, pot, and added floats
SMASTtank	4/3/2009	P4030059.JPG	View of diver, pot, and added floats

Future research

The two directions most needed for research are assessing the commercial viability of the current design and further understanding of cod behavior near the pots. A proposal to test commercial viability is nearing completion by the Northeast Coastal Communities Sector. Further underwater observation of pots has been tentatively discussed with Pingguo He of UMass Dartmouth. Once commercial viability can be established, either through fishermen's experience with the pots, or modifications based on behavioral observations, avoidance of risk to marine mammals will become vital before widespread use. Further research in other North Atlantic countries on capture efficiency, bait formulas and release mechanisms (for example, Westerberg and Westerberg 2011), and other directions is continuing and should be monitored for new developments.

Table 1: Counts of all species caught in pots, separated by design

		Pot Type	
Species		**Norwegian**	**Newfoundland**
Cod, Atlantic	*Gadus morhua*	231	184
Cunner (Yellow Perch)	*Tautogolabrus adspersus*	79	3
Pollock	*Pollachius virens*	69	2
Lobster, American	*Homarus americanus*	45	10
Dogfish, Spiny	*Squalus acanthias*	16	
Crab, Jonah	*Cancer borealis*	13	4
Hake, Red (Ling)	*Urophycis chuss*	7	1
Crab, Rock	*Cancer irroratus*	4	
Sea Raven	*Hemitripterus americanus*	2	5
Ocean Pout	*Macrozoarces americanus*	2	2
Herring, Atlantic	*Clupea harengus*	2	
Redfish, Nk (Ocean Perch)	*Sebastes sp*	1	1
Cusk	*Brosme brosme*	1	
Lumpfish	*Cyclopterus lumpus*	1	
Crab, Northern Stone	*Lithodes maja*		5
Flounder, Winter (Blackback)	*Pseudopleuronectes americanus*		1

Table 2: Video collected during the study

DMF ID Name	Date	Title	Tape Length (min)
09MADMF983	1/23/2009	POTYEAR DECK FOOTAGE	0:22
09MADMF980	2/25/2009	CODPOT UNDERWATER FILMING	0:31
09MADMF981	3/17/2009	NEWFOUNDLAND POT UNDERWATER	0:36
09MADMF984	4/3/2009	SMAST TANK - SURFACE - POTYEAR	0:47
09MADMF985	4/3/2009	POTYEAR TANK UNDERWATER	0:09
09MADMF986	4/25/2009	UNDERWATER POTYEAR - APRIL 2009	0:03
10MADMF1041	4/7/2010	COD BEHAVIOR	0:55
10MADMF1046	4/7/2010	POTYEAR, CODPOTS TAPE 2 HAUL 2	1:00
10MADMF1047	4/7/2010	POTYEAR TAPE 3 HAUL 3	1:00
10MADMF1048	4/8/2010	POTYEAR TAPE 1 HAUL 1 OF DAY	0:45
10MADMF1049	4/8/2010	POTYEAR TAPE 2 HAUL 2 OF DAY	1:00
10MADMF1050	4/8/2010	POTYEAR TAPE 3 SETS 3 & 4	0:31
10MADMF1051	4/20/2010	POTYEAR TAPE 1, HAULS 1&2	1:00
10MADMF1052	4/20/2010	POTYEAR TAPE 2 FOR DAY	0:32
10MADMF1053	4/21/2010	POTYEAR TAPE 1 OF THE DAY	0:58
10MADMF1054	4/21/2010	POTYEAR TAPE 2 FOR DAY	0:59

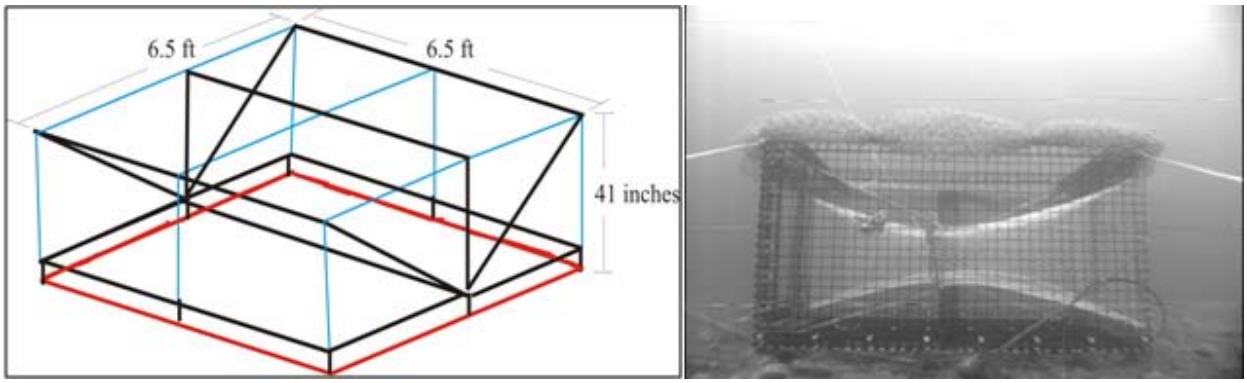

Figure 1: Diagram and underwater view of Newfoundland-style pot

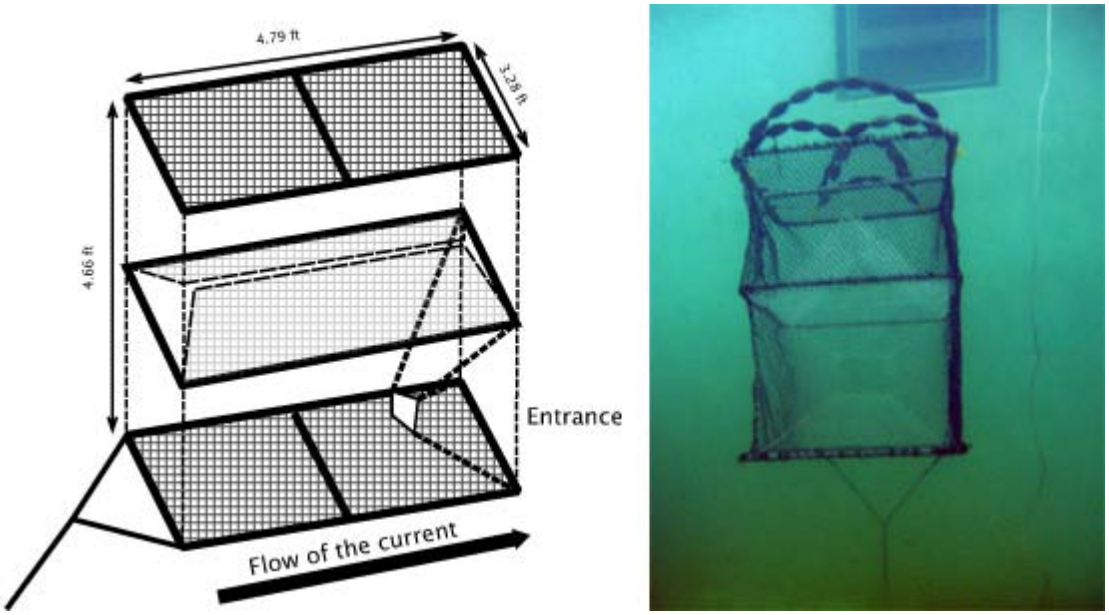

Figure 2: Diagram and underwater view of a Norwegian-style pot

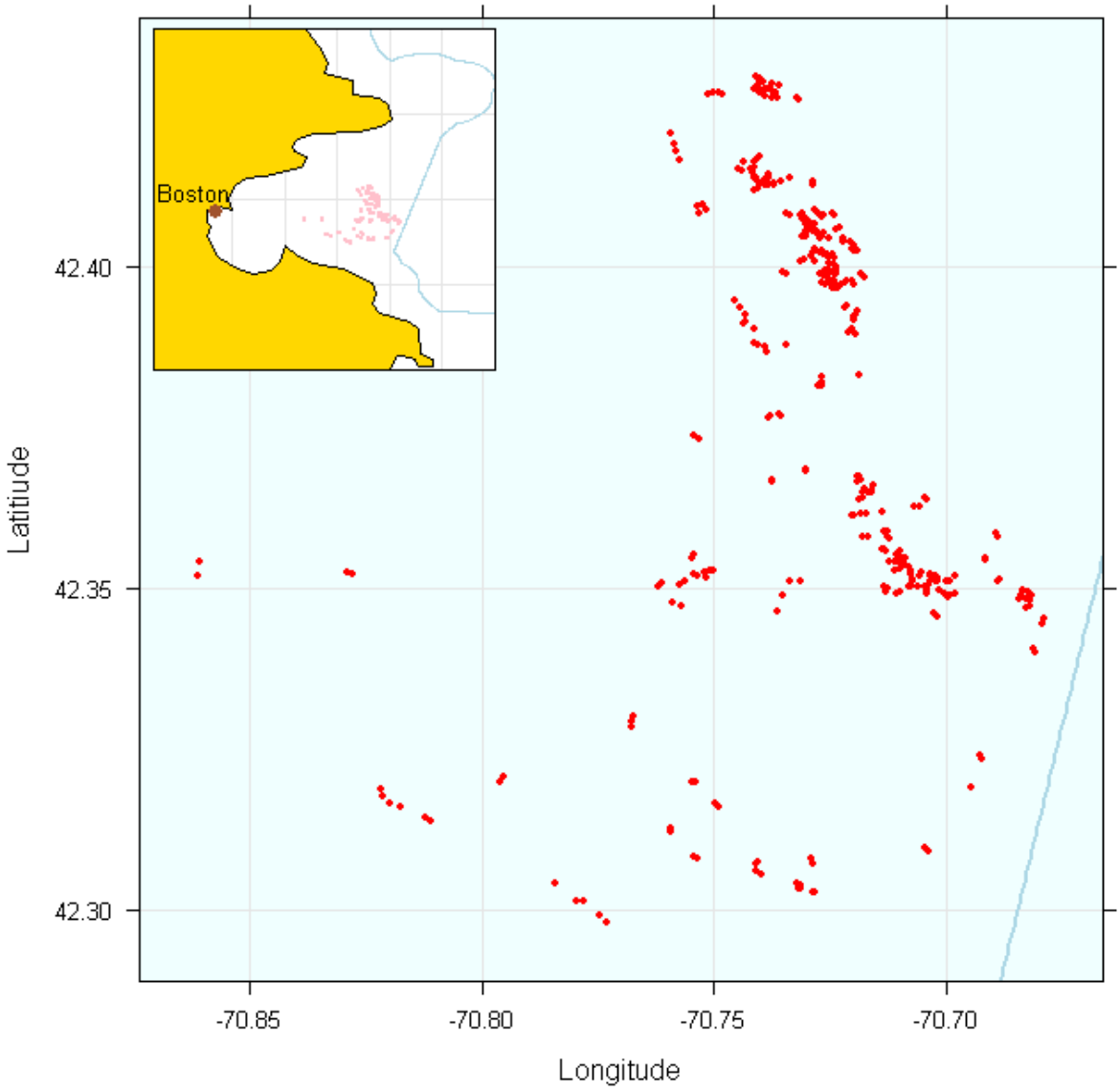

Figure 3: Study area showing all pot-haul locations for the entire study (red dots). The blue line in the lower corner is the boundary of Massachusetts waters. The inset shows Boston for reference.

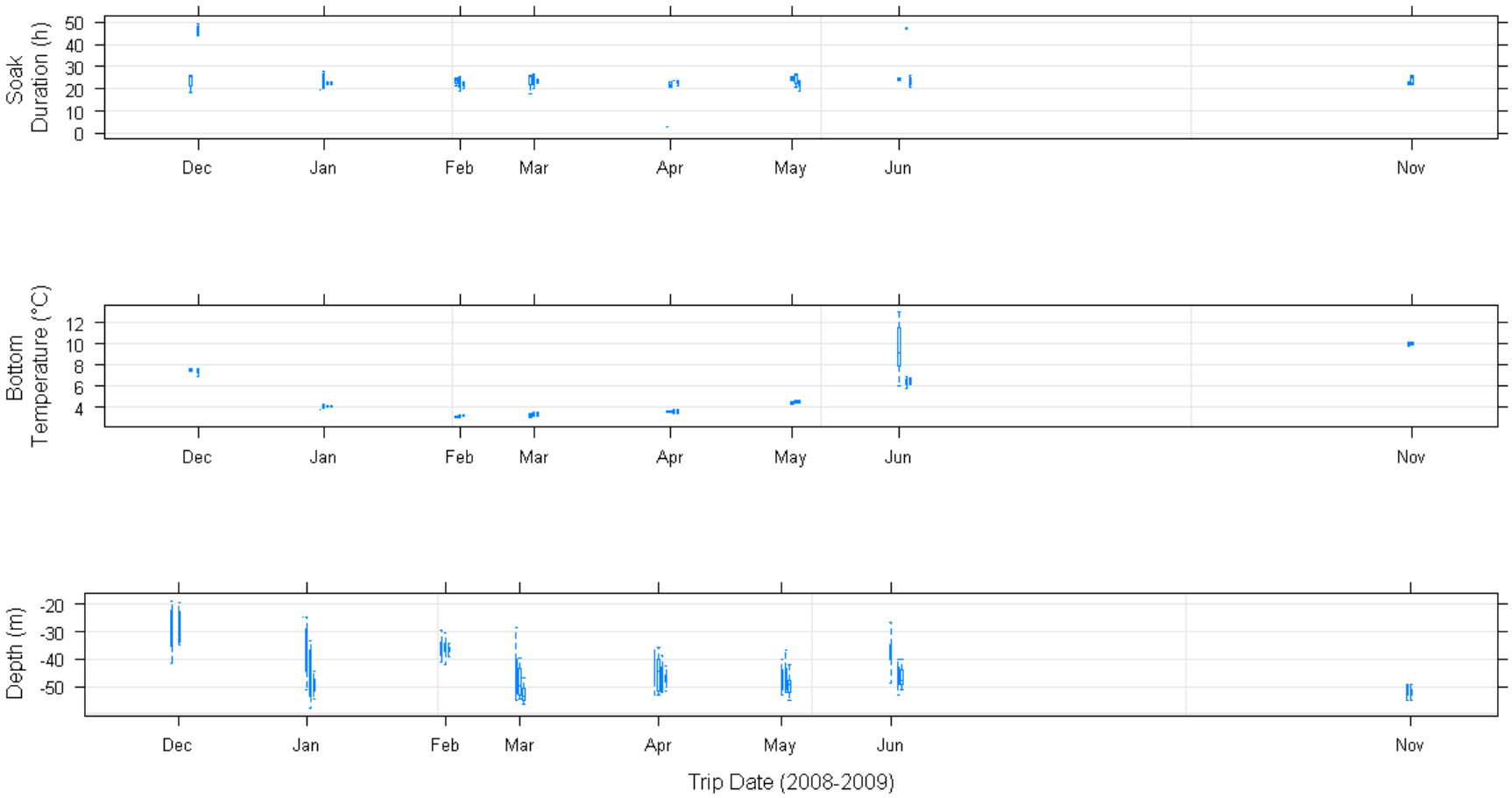

Figure 4: Boxplots of soak duration (h), bottom temperature (°C) and depth (m) for all pot-hauls by date.

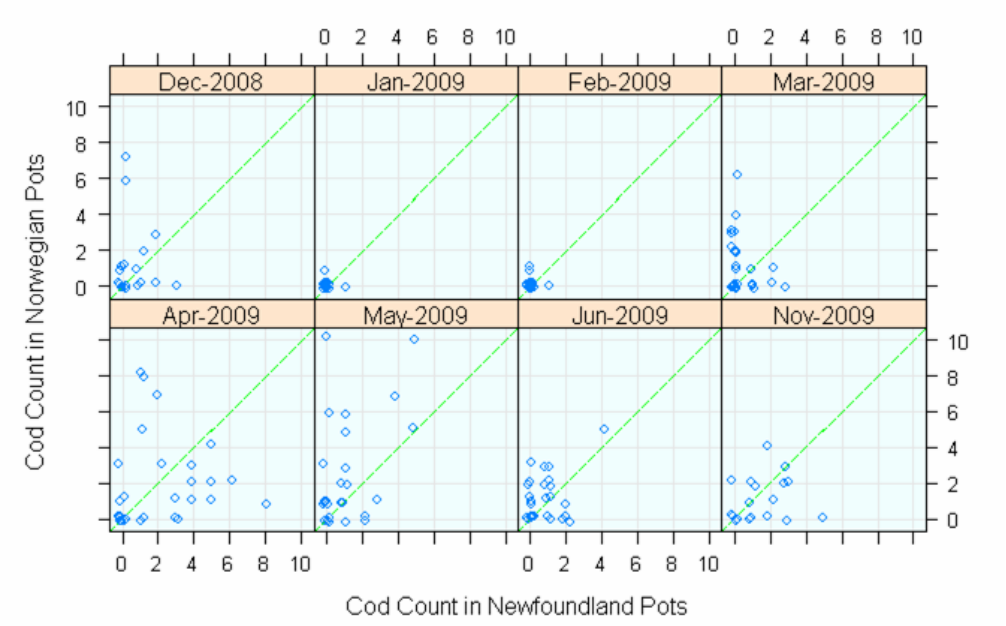

Figure 5: Equal catch plots of counts of Atlantic cod in paired pot-hauls of Newfoundland and Norwegian-style pots, by month. The green diagonal line is the line of equal catch.

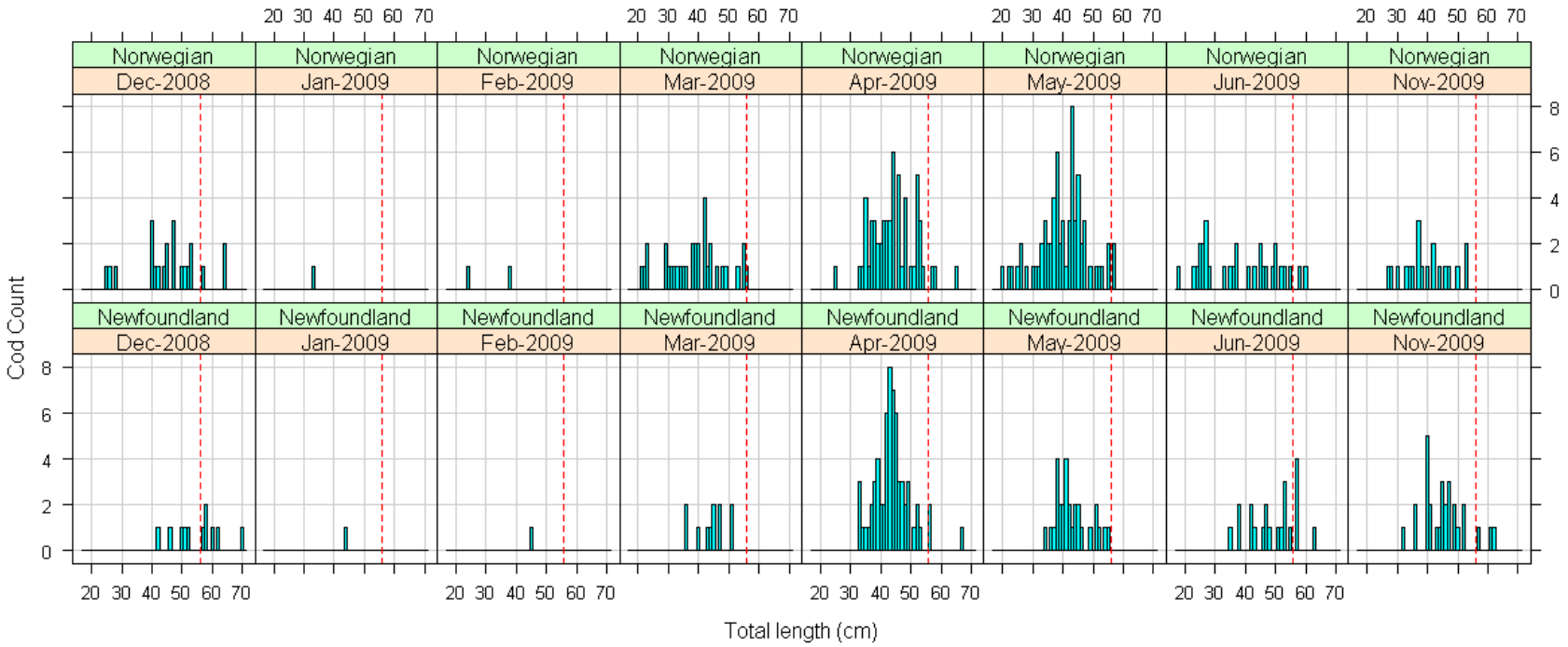

Figure 6: Length frequencies of counts of Atlantic cod lengths captured in two pot designs (Norwegian: top row; Newfoundland: bottom row), and by month (columns). The red dashed line indicated minimum landing size in the region (55.9 cm).

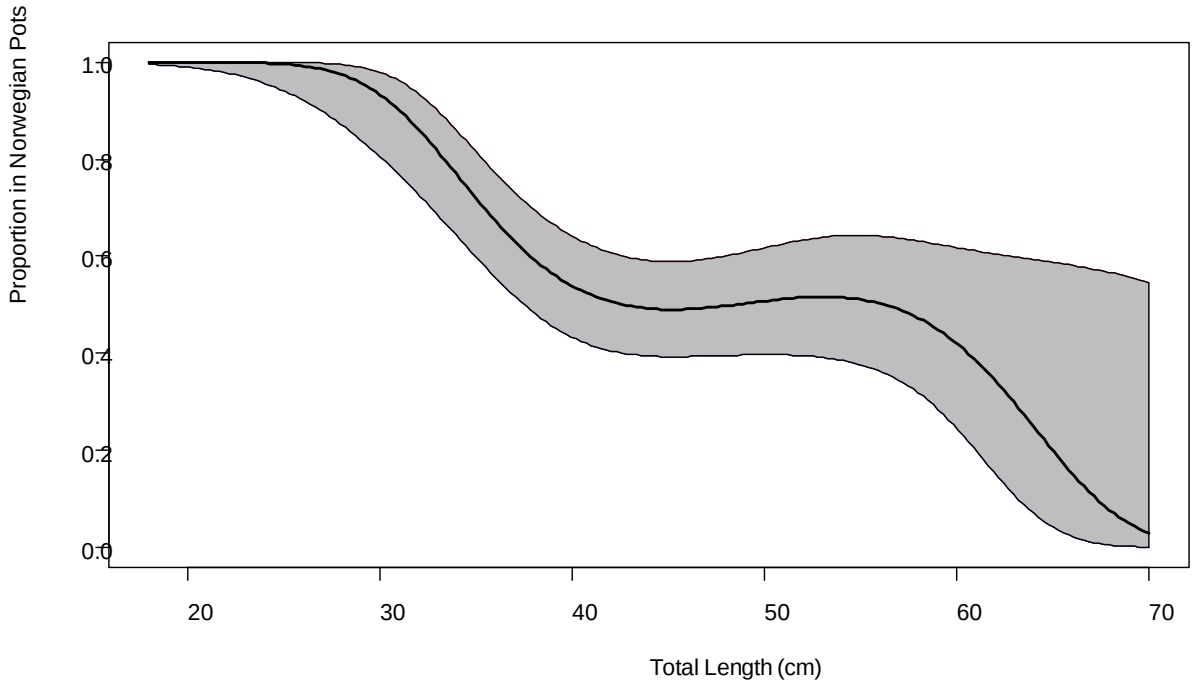

Figure 7: Generalized linear mixed model (GLMM) mean curve fit to the proportion of cod in Norwegian pots over the total count for each length caught in both designs. The horizontal dashed line at 0.5 defines equal performance of both designs. The shaded areas around the mean curve are 95% confidence regions. Non-overlap of the 0.5 line by the confidence regions indicated significant differences. The red dashed line indicated minimum landing size in the region (55.9 cm).