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A Contemporary Assessment of the Bycatch of Regulated Species and the Nordmore Grate in the Northern Shrimp Fishery

Final Report

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Abstract

A data collection program was established using GMRI staff and NOAA observers to monitor and document the bycatch of regulated groundfish and non-regulated species during the 2008-2009 shrimp season. GMRI staff sampled the catch from 137 hauls (tows) over a period of 39 days (fishing trips). Initially four boats were used to collect data, one operating in the waters of northern Massachusetts, one near Boon Is., one in Saco Bay, and another in midcoast Maine. NOAA observers sampled the catch from 106 hauls over 25 fishing trips. The location of each fishing trip sampled by these observers was unknown.

GMRI and NOAA data indicated that the shrimp catch comprised almost 96% and 92% of total catch weight respectively. The proportion of regulated bycatch from both data sources was less than 2% of the total catch weight. In fifty-one percent of all fishing trips sampled by GMRI, regulated species bycatch averaged less than 1% of total catch weight, including all trips from midcoast Maine. In an additional thirty-three percent of fishing trips, regulated bycatch averaged between 1 – 2% of total catch weight. The bycatch of regulated species exceeded 5% of total catch weight in only 5% of hauls, and weighed no more than 55 lbs in any haul. All but one fishing trip sampled by GMRI staff had an average regulated species bycatch of less than 5% per haul. The boat operating in midcoast Maine consistently recorded the lowest proportion of regulated bycatch per haul, while the highest proportions were consistently recorded at Boon Is, particularly in January. Juvenile American plaice comprised almost 50% of regulated species bycatch sampled by GMRI staff. The effect of grate orientation was tested on one boat, but did not appear to alter grate performance.

The bycatch of regulated species did not exceed 5% of total catch weight in any haul sampled by NOAA observers. American plaice similarly dominated the bycatch of regulated species, but only represented 27% of the total catch of this bycatch. Grate orientation had little impact on the proportion or composition of shrimp and regulated bycatch in the total catch.

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Introduction

The Northern Shrimp fishery targets northern shrimp (*Pandalus borealis*) in the Gulf of Maine usually during winter and early spring. Since April 1992, fishermen engaged in this fishery have been required to install a finfish excluder device in their trawl net, known as the Nordmore grate. (Richards & Hendrickson, 2006). The Nordmore grate was introduced to the fishery in response to concerns over the impact of shrimp trawling on regulated groundfish [1], and to comply with the requirements of NOAA's small mesh fishery exemption program. This program exempts fishermen from a minimum codend mesh size requirement of 6.5″ square or diamond mesh, and requires the bycatch of regulated groundfish to be less than 5% of total catch weight[2] (50 CFR 648.80, 2009). Prior to the introduction of the Nordmore grate, regulated bycatch comprised almost two-thirds of total catch weight (Howell and Langan, 1992).

The Nordmore grate consists of a rigid or semi-rigid grate of parallel bars attached to a rigid frame, with a bar spacing not exceeding 1 inch (50 CFR 648.80, 2009). The grate must be inserted in the trawl net at angle of approximately 45 degrees. The grate is oriented to exclude bycatch through a triangular escape opening located either in the top or bottom of the codend. The base of the escape opening must measure at least 19 inches across and be located immediately ahead of the grate; the sides of the escape opening are cut on an all-bar taper to an apex. If desired, a second grate with a bar spacing not exceeding 7/16th of an inch can be located 6 to 10 feet behind the first grate. The second grate is designed to exclude small shrimp from the trawl net.

Since 1992, few studies have attempted to measure the efficacy of the approved Nordmore grate in the Northern Shrimp Fishery, with catch sampling often taking place in locations less frequently prosecuted by today's fishing fleet or outside of the peak fishing season. Fewer still have documented spatial or temporal changes in grate performance across the fishery, let alone demonstrate an ability to satisfy the 5% limit on regulated species bycatch. In a notable exception, Richards and Hendrickson (2006) evaluated grate performance by comparing catch data collected by observers during the two years prior to the introduction of the grate (1991 and 1992) with similar data collected during following the four years (1993 to 1996). In the years prior to the introduction of the grate, the bycatch of regulated roundfish and flatfish averaged 20% and 7% of total catch weight respectively. In the four years that followed, the grate reduced this bycatch to an average of 7% and 3% respectively. He and Balzano (2007a) also reported on the ability of the approved Nordmore grate to reduce bycatch, and found that in some hauls bycatch comprised up to 8% of total catch weight, although these catches were dominated by herring (*Clupea harengus*).

According to ASMFC (2007), during 1993 and 1996 fishing boats from Maine accounted for 70% to 88% of total shrimp landings, and 70% to 87% of total shrimp fishing effort. Since then, the dynamics of the fishery have changed significantly, and fishing effort has become more

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[1] Defined as the suite of NE multispecies that are regulated under the Magnuson-Stevens Act and the Northeast Multispecies Large-mesh Fishery Management Plan, and includes Atlantic cod (*Gadus morhua*), witch flounder (*Glyptocephalus cynoglossus*), American plaice (*Hippoglossoides platessoides*), yellowtail flounder (*Limanda ferruginea*), haddock (*Melanogrammus aeglefinus*) pollock (*Pollachius virens*), winter flounder (*Pseudopleuronectes americanus*), windowpane flounder (*Scophthalmus aquosus*), redfish (*Sebastes fasciatus*), and white hake (*Urophycis tenuis*).

[2] While not clearly stipulated, it is generally understood that this target refers to the proportion of regulated species bycatch per fishing trip.

heavily concentrated in the waters off midcoast Maine. Between 2002 and 2007, these waters accounted for 86% to 94% of total shrimp landings, and 80% to 90% of total shrimp fishing effort (ASMFC, 2007). Perkins et al. (2003) conducted extensive tests with the Nordmore grate during this period, in waters beyond the traditional fishing grounds between southern to midcoast Maine. This research was an effort to test the feasibility of extending the fishing season and alleviating fishing pressure on shrimp in heavily trawled inshore waters. In addition to testing the grate offshore, the tests were timed for May – a time when catch rates of shrimp are typically past their peak. The authors noted that shrimp catches were disappointingly low, although the mean bycatch of regulated species was 2.9% +/- 3.5 of catch weight. In an effort to further improve grate performance, Schick et al. (2006) tested a variety of grate configurations between 2003 and 2004 in Maine waters. Unfortunately the brevity of the fishing seasons during the study limited most testing to when the fishery was closed and shrimp catches were relatively poor. The standard Nordmore grate reportedly performed well but was unable to consistently reduce regulated species bycatch to below the 5% target, ranging from 0.6% to 7.3% of total catch weight. Additional efforts to test the grate in various configurations and improve catching performance included tests by Lee et al. (2005 & 2006). These studies described and compared spatial influences on grate performance, however, interpretation of these results at a species level was not possible because bycatch composition was reported only by broad catch categories.

Project goal and objectives

The primary goal of this project was to evaluate the bycatch of regulated groundfish species during the 2008-2009 northern shrimp season and assess the efficacy of the Nordmore grate in reducing the bycatch of regulated groundfish and non-regulated species. Specific project objectives were to:

1. Monitor and document the bycatch of regulated groundfish and non-regulated species during the 2008-2009 northern shrimp fishing season using GMRI samplers and NOAA observers.
2. Compare the bycatch of regulated species during the 2008-2009 fishing season across spatial and temporal scales.
3. Determine the ability of the Nordmore grate to reduce the bycatch of regulated species to 5% or less of total catch weight.
4. Identify factors affecting the operational performance of the Nordmore grate and compare the catching performance of both upward and downward excluding grates.

Methods

GMRI data collection

A data collection program using GMRI sea samplers was established to monitor and document the bycatch of regulated groundfish and non-regulated species during the 2008-2009 shrimp season. In addition to the 12 species included in the regulated groundfish category, we also included monkfish (*Lophius americanus*) due to their commercial importance in the groundfish and monkfish fisheries and red hake (*Urophycis chuss*). Red hake were included due to difficulties differentiating them from white hake[3]. Our plan was to sample approximately 5% of the fishing fleet by completing 64 days of observer coverage aboard four vessels over the course of four months (Table 1). Samplers were to spend four consecutive days per month (weather permitting) collecting haul-by-haul catch data for shrimp, and regulated and non-regulated bycatch during normal commercial fishing operations. We expected to collect catch data from 3-4 hauls per day, which is typical of normal industry practice (Schick et al., 2006).

All sea samplers received project-specific training from GMRI staff experienced in at-sea research and observer training. The sea samplers collected and recorded catch data following sampling protocols closely aligned with the NOAA observer program. This included length and weight of regulated bycatch species, and weight of shrimp and non-regulated species.

At the conclusion of each haul, all bycatch was separated from the shrimp catch and sorted by species. The catch of each regulated species was weighed to the nearest tenth of a pound and individual fish were measured to the nearest centimeter. For species caught in large numbers, only the first 100 individuals caught per day were measured due to limited time between hauls in which to collect data. Because of their prevalence in the catch, measurement of silver hake, red/white hake, and both Atlantic and river herring was recorded to the nearest centimeter. Shrimp weights were estimated by counting the number of trays filled with shrimp. Each full tray weighed an estimated 100 pounds, with partial tray weight estimated based upon the proportion filled. This method of estimation was consistent with practice by fishermen and NOAA observers. The sea samplers recorded fishing gear details and grate details including bar spacing, grate angle, and grate height, width, and orientation. Operational details concerning grate deployment, retrieval, deck handling, and maintenance was also recorded, along with location, direction, and duration of each haul. The original proposal called for one boat to regularly alter the orientation of the grate between an upward and downward excluder. Unfortunately, this practice proved unfeasible and was tested only on one boat over three days. All other boats in this study used an upward excluding grate.

Fishermen were selected for this study based upon i) their history of fishing throughout the entire shrimp season in the general vicinity of the majority of the fishing fleet, ii) history of landing shrimp at ports dominating shrimp landings, and iii) their willingness and preparedness to participate in this study. Our goal in using these criteria was to ensure that sampling reflected the overall distribution of fishing effort across the wider fishing fleet. Identifying fishermen that met these criteria were based largely on historical knowledge of the fishery by project staff. Because we wanted to compare bycatch across a spatial scale, we also strove to select fishermen from a variety of locations along the Gulf of Maine coast, from Northern Massachusetts to Port

[3] This process was similarly applied by NOAA observers.

Clyde, ME (Figure 1). Temporal comparison of bycatch was facilitated by sampling over the course of four different months at approximately the same time each month. Catch data was then compared between locations and time.

NOAA observer data collection

Catch data collected by NOAA observers during the 2008 – 09 shrimp fishing season, including shrimp, regulated bycatch, and non-regulated bycatch, was used to compare bycatch composition with data collected by GMRI sea samplers. The absence of haul information such as location, time, or duration, prevented spatial or temporal comparison with data collected by GMRI sea samplers. Likewise, an absence of grate dimensions and construction details did not permit comparison with GMRI data. Observer data did, however, permit an evaluation of the effect of grate orientation on catch composition.

Data analysis

The bycatch of regulated species was compared to that of other catch fractions, including shrimp and non-regulated bycatch, between locations and months. This allowed catches to be evaluated spatially and temporally and to identify potential bycatch hotspots or key species that may require further evaluation and/or grate modification.

A Chi-square test for independence was used to compare the proportion of shrimp, regulated bycatch, and non-regulated bycatch, in the total catch between locations for each month. This test enabled comparison of the proportion of these catches, and identify when and where these proportions may be substantially different from other sampling periods and locations. Prior to applying this test, the catch of shrimp, regulated bycatch, and non-regulated bycatch, from all hauls in a sampling location was pooled by month.

To compare the proportion of regulated species bycatch between sampling times and locations, evaluate the Nordmore grate's ability to satisfy the 5% regulated bycatch target, and identify regulated species 'hot spots', the data was assessed using box and whisker plots and a one-way unbalanced analysis of variance (ANOVA), with catch as the dependent variable and month or location as the independent variable. The box and whisker plots presented the mean, median, and range of regulated species bycatch as a proportion of total catch by fishing location and month. This also allowed an appraisal of the variation in regulated species bycatch between time and location. The unbalanced ANOVA model was used because it accommodates for an unequal number of sampling months between locations and hauls between months. Two null hypotheses were tested:

1. H_o: There was no significant difference in the mean proportion of regulated species bycatch between fishing *months*.

2. H_o: There was no significant difference in the mean proportion of regulated species bycatch between fishing *locations*.

A two-way unbalanced ANOVA was considered for this analysis, but the unbalanced model would not have permitted analysis of interactions between independent variables. Prior to applying ANOVA, the proportion of regulated species caught in each haul was pooled by month or location. Data was then arcsine-transformed to improve normality and stabilize the variance between months. This transformation is appropriate when variates are proportions with absolute limits between 0 and 1 (Fowler et al. 2005). A Bonferroni post hoc pairwise test was used to compare and identify significantly important fishing locations; this test often being more sensitive to a small number of sampling groups than other tests (Systat Software Inc., 2007).

Results

A variety of logistical problems during this project limited catch sampling to 137 hauls (tows) over a period of 39 days (fishing trips). Despite the fishery opening on December 1st, 2008, no project vessel commenced fishing until January (Table 2). Then, all project vessels severally curtailed fishing activity during the fishing season due to an oversupply of shrimp to existing processing facilities, and departed the fishery before the end of March. In April, we added a fifth vessel to obtain data from an additional month and add to the total number of sampling days and hauls. Poor weather and market conditions made it unfeasible to sample over the course of four consecutive days during any sampling location or month. Therefore, we made an effort to collect samples over four days as close together as possible during each month. If a four-day sampling period extended between months, the sample was grouped and denoted by the month when sampling commenced. The largest gap between sampling was 7 days and the largest gap between the first and last days of sampling was 15 days.

During the 2008 – 09 shrimp fishing season, NOAA observers sampled catches from 106 hauls during 25 fishing trips. Data pertaining to the timing and location of these fishing trips was unavailable, and it was not possible to compare these data spatially or temporally, nor compare against the data collected by GMRI samplers.

Shrimp catches and bycatch

Based on data collected by GMRI samplers, the average shrimp catch for each sampling location was over 2 300 lbs per fishing trip, with the exception of Sequin Island in April which averaged 1 220 lbs per trip (Table 3). Overall, shrimp comprised 95.8% ± 3.8 of total catch weight per trip. The average weight of regulated species bycatch ranged from 5.5 lbs to 64.2 lbs per trip. This was between 0.22% – 2.01% of total catch by weight, which is well below the 5% threshold. Across all sampling areas the bycatch of regulated species averaged a little over 1% of total catch weight per trip. The average weight of all bycatch, including non-regulated species, from all sampling areas ranged from 0.82% – 6.43% of total catch weight per trip, at an overall average of 4.2% of total catch weight. Only one haul (from Northern Massachusetts) did not retain any regulated species bycatch. Catch composition for all hauls is presented in Appendix 1.

Of the 39 fishing trips sampled, only one trip had an average bycatch of regulated species greater than 5% of total catch weight; at Boon Island on 1/9/2009 the proportion of regulated species bycatch reached 5.34%. In fifty-one percent of fishing trips the bycatch of regulated species averaged less than 1% of total catch weight, including all fishing trips from midcoast ME, and in an additional thirty-three fishing trips, the bycatch of regulated species averaged 1% – 2% of total catch weight.

The proportion of regulated species bycatch exceeded the 5% threshold in only 5% of hauls, while in 48% of hauls this bycatch was less than 1% of total catch weight (Table 4). The highest proportion of regulated bycatch species retained in a haul was 17.2%, although this occurred when total catch weight was only 113.6 lbs. Midcoast ME had the highest proportion of hauls in which regulated species bycatch was less than 1% of total catch weight, while Boon Island had the highest proportion of hauls with regulated species bycatch greater than 5% of total catch weight. In the hauls where regulated species bycatch was greater than 5% of total catch weight, the weight of regulated bycatch was between 5lbs to 55 lbs per haul (Table 5). The highest retained proportion of regulated species bycatch coincided with a shrimp catch of only 50 lbs.

The proportion of shrimp, regulated bycatch, and non-regulated bycatch in the total catch was dependent upon fishing location in all three months. In January, catches of regulated species bycatch and non-regulated bycatch at Boon Island were significantly higher compared to the other three study locations (χ^2 = 212.73, df = 6, p = 0.000). In February, catches of these bycatch fractions at Saco were significantly higher compared to the other sampling locations (χ^2 = 142.87, df = 4, p = 0.000), while in March catches of non-regulated bycatch was significantly lower in midcoast ME compared to Saco (χ^2 = 188.14, df = 2, p = 0.000).

Based on data from NOAA observers, total catch weight was 88 337 lbs and the shrimp catch comprised 79 984.1 lbs or 90.5% of total catch weight. The average shrimp catch was 720.9 lbs per haul. Overall, the bycatch of regulated species weighed 1 547.9 lbs, at an average of 61.9 lbs per trip or 14.6 lbs per haul. This bycatch comprised 1.8% of total catch weight, well below the 5% threshold, and did not exceed 5% of total catch weight in any haul. The non-regulated bycatch weighed 6 805 lbs, at an average of 272.2 lbs per trip or 64.2 lbs per haul. This bycatch comprised 7.7% of total catch weight.

Spatial comparison of bycatch

In January, the vessel fishing near Boon Island caught the highest proportion of regulated species bycatch, with a mean of 3.5% of total catch weight per trip (Figures 2 & 3). The Saco Bay vessel caught the next highest proportion of regulated species bycatch, with a mean just under 2%, while the northern Massachusetts and midcoast ME vessels both averaged less than 1%. The proportion of regulated species bycatch per haul was highly significant different between locations (F-ratio = 18.236, df = 3, p = 0.000), and all post hoc paired comparisons between locations were significant ($p<0.05$), with the exception of Boon Island and Saco, and Northern Massachusetts and midcoast ME (Table 6). Variation in the proportion of regulated bycatch per trip was greatest at Boon Island and Saco Bay. Relatively high proportions of non-regulated bycatch (8-14%) were also caught by the Boon Island and Saco Bay vessels in January.

Although the vessel in northern Massachusetts departed the shrimp fishery before February, we were able to collect and compare catch data from the three remaining vessels during this month (Figure 4). The Saco Bay vessel had the highest proportion of regulated species bycatch, with a mean of 1.4% of total catch weight per trip, followed by Boon Island (0.6%) and midcoast ME (0.08%) (Figure 5). These differences were highly significant (F-ratio = 23.104, df = 2, p = 0.000), as were all post hoc paired comparisons between locations ($p<0.05$)(Table 6). Variation in the proportion of regulated bycatch caught per fishing trip was again greatest at Boon Island and Saco Bay.

In March, only the Saco Bay and midcoast ME vessel continued fishing. As in January, non-regulated bycatch was relatively high (7% –10%) for 3 of the Saco Bay fishing trips (Figure 6). Catches of regulated species bycatch by the Saco Bay vessel averaged below 1.5% of total catch weight per trip, while the midcoast ME vessel averaged 0.07% per trip (Figure 7). The catch of regulated species bycatch was highly significantly different between these two locations (F-ratio = 23.848, df = 1, p = 0.000)(Table 6). Variation in the proportion of regulated bycatch per trip was greatest at Saco Bay. The Seguin Island vessel, which was added near the end of the project, was the only project vessel fishing for shrimp in April (Figure 8). The regulated and non-regulated bycatch was relatively low, with a mean bycatch of regulated species of 1.6% of total catch weight (Figure 9).

Temporal comparison of bycatch

Catch data was also compared temporally for each location where fishing occurred for more than one month. At the Boon Island site, the bycatch of regulated species declined from a mean of 3.4% of total catch weight in January to a mean of 0.6% in February (Figure 10). This was a highly significant difference between locations (F-ratio = 26.225, df = 1, p = 0.000), despite substantially greater variation in the proportion of regulated bycatch per trip in January.

At the Saco Bay site, regulated species bycatch remained relatively constant across months with a mean of 1.8% of total catch weight in January, 1.4% in February, and 1.5% in March (Figure 11). These differences were not significant (F-ratio = 0.735, df = 2, p = 0.485). In this location variation in the proportion of regulated bycatch caught per trip was relatively uniform between months.

Bycatch for midcoast ME was low throughout the study period, and declined from a mean of 0.5% of total catch weight in January to less than 0.1% in February and March (Figure 12). These differences were highly significant (F-ratio = 24.724, df = 3, p= 0.000), and post hoc comparison was very highly significant ($p \leq 0.001$) between the catch in January and the remaining months (Table 6). Similarly to Boon Island, variation in the proportion of regulated bycatch caught per trip was greatest in January and become more stable as the season progressed.

Composition of regulated species bycatch

Overall, the regulated species bycatch comprised of 9,955 individuals weighing a total of 1, 120 lbs (Table 7). The average weight per individual was 0.11 lbs or 1.8 ounces. American plaice (dabs) dominated this bycatch, accounting for 46.5% and 68.2% of individuals by weight and number respectively. The average weight per individual was 0.077 lbs or 1.23 ounces. Hake sp. (red and white) were the next dominant species, accounting for 26.8% and 16.6% of individuals by weight and number respectively. The average weight per individual was 0.18 lbs or 2.88 ounces. Flounder species accounted for 64% of all regulated species bycatch by weight and 77% by number.

By location, the proportion of American plaice in the regulated species bycatch was highest at Northern Massachusetts (76% and 88% by weight and number respectively) and lowest in midcoast ME (13% and 20% by weight and number respectively)(Figures 13 – 17). In all remaining locations, American plaice comprised at least 55% and 61% of the regulated bycatch by weight and number respectively. Overall, the largest number of American plaice was caught at Boon Island. The largest number of American plaice caught per haul was 28 ± 11 individuals at Boon Island, and the lowest number was only 3 ± 2 individuals per haul at midcoast ME. Hake sp. accounted for 59% and 56% of regulated by catch by weight and number respectively in midcoast ME (Figure 16), and was the dominant bycatch in that region. In contrast, the Hake catch in Northern Massachusetts was almost non-existent (Figure 13). The remaining regulated bycatch included various flounder species, redfish, monkfish, and cod. Flounder species collectively represented 63.7% of the bycatch of regulated species. Between January and March, average catches of the three most dominant regulated bycatch species decreased at Boon Island, Saco Bay, and ME, although slight increases in catches of these species was recorded in February at Saco Bay (Figure 18). Catches of these species each month was consistently lowest at midcoast ME.

The NOAA observer data indicated that American plaice similarly dominated the bycatch of regulated species, yet only accounted for 26.8% of this bycatch (Table 8). In descending order this was followed by Acadian redfish, Red/Hake, winter flounder, and witch flounder. Overall, the catch of flounders weighed 851.6 lbs or 55% of the total bycatch of regulated species.

American plaice (dabs) by size
For all locations, individuals measuring 11 – 16 cm typically comprised the largest proportion of the American plaice catch, although at the Seguin Island site there was also large numbers measuring 20 – 28 cm. The average length of American plaice was smallest at Saco Bay (13.2 cm ± 2.8) and largest at Sequin Is. (17.8 cm ± 5.0). All measured American plaice were below the legal landing size of 35.6 cm.

NOAA observers measured only 606 American plaice, and it is not known what proportion this represents of the total observer-reported catch (415.2 lbs) of this species. The average length of these individuals was 18.9 cm ± 6.3. All measured American plaice were similarly below the legal landing size of 35.6 cm.

Grate orientation
The effect of grate orientation on catch rates was tested by a GMRI sampler on only one vessel. Initially the grate was oriented to exclude downwards but after three trips was reoriented to exclude upwards (Table 9). The grate remained in this orientation for the remainder of the project. The results indicated that a downward excluding grate retained a higher proportion of regulated species bycatch and a lower proportion of shrimp compared to an upward excluding grate. Between vessels, all grates were similar in design and size (Table 10).

According to data collected by NOAA observers, an upward excluding grate was used in 69% of fishing trips. A downward excluding grate was used in 19% of reported trips, and grate orientation was not reported in 12% of trips. The shrimp catch represented 94% of total catch weight when both grate orientations were used (Table 11). There was no difference in the proportion of American plaice in the catch (0.4%), irrespective of grate orientation. When the downward and upward grates were used, the catch of dominant regulated species represented 1.3% and 1.2% of total catch weight respectively.

Net geometry
In two locations Net mind acoustic sensors were attached to the wingends and headline of the shrimp trawl. At Boon Island these sensors were used during four hauls. Wingend spread ranged between 9.4 m ± 4.1 to 10.75 m ± 0.9 per haul. At midcoast ME, these sensors were used during two hauls and wingend spread ranged from 9.0 m ± 3.57 to 9.7 m ± 1.4. Useful headline height data was collected only at midcoast ME, and ranged from 3.2 m ± 0.6 to 4.5 m ± 0.4 (Figure 19). Acoustic sensors were not used by NOAA observers.

Discussion

This project provided an invaluable opportunity to evaluate the operation and performance of the Nordmore grate under typical commercial fishing conditions. Unfortunately sampling by GMRI staff was not as extensive as originally anticipated due to i) fishermen involved in the project postponing fishing activity by one month, thus shortening the available fishing season, ii) limitations placed on fishing activity by processing facilities due to oversupply and inability to cope with large landings of shrimp, and iii) several fishermen prematurely terminating shrimp fishing due to the aforementioned processing limitations and low shrimp landing price. Consideration was given to sourcing additional fishermen to increase the number of hauls and sampling locations, however, by the time problems ii) and iii) became acute the number of remaining fishermen available for project participation was severely limited. Some fishermen were simply not interested or unable to commit to this project as they were unsure of their extent of involvement during the remaining fishing season. Adding additional fishermen would also have not overcome our limited ability to evaluate catches temporally, although we did add another fisherman in April (when all other project boats had departed the fishery) to gain a limited insight into catch rates and composition in that month and location.

Despite less than anticipated field sampling during this project, GMRI samplers collected bycatch data from 39 fishing trips and 137 hauls. In contrast, the NOAA observer program sampled 25 fishing trips and 106 hauls during the fishing season. Care is therefore required interpreting project data and extrapolating findings across the entire shrimp fishery; the overall number of fishing trips sampled in this project represents just over 10% of the average number of commercial fishing trips completed across the entire fishery during the past 5 years. However, despite this cautionary note, this project still provides a major step forward with regard to describing the efficacy of the Nordmore grate performance on catches of shrimp, regulated bycatch, and non-regulated bycatch.

Bycatch reduction

We found that the Nordmore grate effectively reduced catches of regulated species to less than 5% of total catch volume per fishing trip. Moreover, based on data collected by GMRI samplers, only 5% of hauls exceeded the 5% threshold, and the bycatch of regulated species did not exceed 55 lbs per haul. All but one of these hauls occurred in January. As catches of regulated species bycatch was reduced in the following months, we surmise that fishermen were better able to target aggregations of shrimp (having identified their location and movements in January) with less bycatch, and that the abundance of bycatch was less strongly associated with shrimp abundance. While the NOAA observer data lacked spatial and temporal information, these data similarly demonstrate that the grate reduced the bycatch of regulated species to less than 5% of total catch weight for all fishing trips. It is therefore not unreasonable to suspect that similar performance is achieved across the entire fishery.

The lowest proportion of regulated species bycatch was consistently recorded at midcoast ME. In almost 93% of hauls at this location, the bycatch of regulated species was less than 1% of total catch volume and this proportion did not exceed 3% in any haul. In contrast, catches of regulated species bycatch exceeded the 5% threshold in 5 of 29 hauls at Boon Island, although these hauls occurred in January when shrimp catches were low and catches of regulated species bycatch was relatively high. As the season progressed less bycatch was retained at Boon Island and by the completion of this study the average proportion of regulated species bycatch in this region was just over 2%.

In three locations (Boon Island, Saco Bay, and midcoast ME), sampling took place over two or three months. At Saco Bay the proportion of regulated species bycatch in the total catch was relatively consistent over the three month period. In contrast, there was a relatively greater reduction in catches of these species at the two other locations over the sampling periods. This may also reflect an improved ability of fishermen to target large aggregations of shrimp as the season progress and reduced association between shrimp and bycatch.

A key reason for the impressive bycatch reduction performance at midcoast ME may have been the addition of a 50-mesh long cylinder of 50 mm (2″) square-mesh netting between the grate and codend. This panel would have provided an additional opportunity for small, fusiform fish to escape because the mesh openings in square-mesh netting remain open independently of haul duration and catch volume. Diamond mesh netting, on the other hand, tends to close with increased catch volume, thus limiting fish escape. It was not possible to evaluate the impact of square-mesh netting on catches of regulated species bycatch in this project, although intuitively this mesh was probably too small to allow the escape of American plaice and other flounder species. It is possible, however, that this netting allowed large numbers of small hake and other fish to escape from the trawl, and it may have been responsible for low catches of non-regulated bycatch in this location compared to other sampling locations. Future research will be necessary to evaluate the efficacy of this netting on catches of both regulated and non-regulated bycatch.

Flounder bycatch

Flounder species accounted for at least 55% of all regulated species bycatch, and was dominated by American plaice. The dominance of flounder in the bycatch of regulated species is somewhat surprising given their bodies are dorso-ventrally compressed and wider than the space between the bars in the grate. American plaice, for example, typically have a length to width ratio of approximately 2.5 to 1 (Bigelow and Shroeder, 1953), meaning that individuals longer than 75 mm should theoretically be unable to pass through the grate while swimming flat with their longitudinal axis (length) parallel to the seabed. The passage of these individuals through the grate may therefore have occurred while swimming ‘on edge’, with their lateral axis (width) parallel to the bars in the grate. In this orientation, the thickness of individual fish is the important dimension influencing their passage through the grate. This posture is atypical to observed normal swimming behavior by flounder, although as a change in body orientation in response to ground cable and sweep contact is not unusual, a similar escape response to contact with the grate is not surprising.

According to Clarke et al. (2000), this fishery has a long history of juvenile finfish capture, notably juvenile flatfish and whiting. Perkins et al. (2001) reported that American plaice and grey sole were the dominant flounder bycatch species in their study, and that these species dominated the total bycatch of regulated species by weight. Many other studies have also commented on the prevalence of flounders in the bycatch, including He & Balzano (2007a & 2007b), He et al. (2008), He et al. (2007), Lee et al. (2006), Schick et al. (2006) and Richards and Hendrickson (2006), and clearly the capture of these species is widespread across the fishery.

While the proportion of flounders in the trawl net that ultimately pass through the grate and are captured is unknown, this proportion could potentially be very high, and the grate largely ineffective in preventing their capture. Given the importance of flounders to the groundfish fishery, these catches are a source of concern and should be addressed by future research. This could include evaluating gear modifications that exploit behavioral, size, or morphological differences between flounder and shrimp. Flounders are typically located on or very close to the seabed. Shrimp are also on or close to the seabed but they often have a greater vertical distribution when aggregated. Flounders can be herded towards the trawl mouth by ground cables and sweep - although interestingly, He et al. (2006) were unable to reduce the capture of flounders during tests of a semi-pelagic shrimp trawl, with ground cables rigged above the seabed - but the herding response of shrimp is weak or non-existent. These differences can potentially be exploited to separate these species and reduce flounder bycatch, and modifications to that allow flounders to escape below the sweep and trawl net may be a useful starting point. Underwater cameras could perhaps be used to estimate the number of flounders that escape as a proportion that pass through the grate, and to confirm the response of flounders to grate contact. Depending on the field of view, this approach could go a long way to providing a first order estimate of the catching efficiency of flounder (or other species) when a grate is used. Video footage could also be used to assist the identification of behavioral differences between species and the efficacy of gear modifications to exploit these differences.

Grate orientation and performance

With grate orientation tested by GMRI samplers during a limited number of fishing trips, and only at Boon Island, interpreting the effect of grate orientation on regulated species bycatch is difficult. Early in the fishing season, when grate orientation was downwards, the proportion of regulated species bycatch in the total catch was relatively high compared to later in the season when the grate was orientated upwards. While this result could imply that an upward excluding grate improved bycatch reduction performance, it may also be linked to changes in shrimp abundance as the fishing season progressed. Supporting this claim is a reduction in the proportion of regulated species bycatch at other sampling locations, where grate orientation remained unchanged for the entire fishing season, while the proportion of shrimp in the total catch increased. In contrast to this result, the data collected by NOAA observers indicated little difference in bycatch reduction performance between grate orientations. This result is based on a comparison using a greater number of fishing trips than that by GMRI samplers, however, the location and timing of the observer fishing trips is unknown. Richards and Hendrickson (2006) reported that a downward excluding grate significantly reduced the catch of regulated roundfish without impacting on catches of regulated flatfish or shrimp, while He and Balzano (2007a) reported that a downward excluding grate caught more flounder than an upward excluding grate. It therefore appears that certainty regarding the impact of grate orientation on bycatch in the shrimp fishery is still lacking, although these results imply that bycatch reduction performance is influenced by variability in catch composition both spatially and temporally.

With the exception of the grate used at midcoast ME, all grates were reasonably similar in design. At midcoast ME the grate was designed with two distinct bar spacings. The upper three-quarters of the grate was similar in design to those used in other locations; a plastic grate with a 25 mm (1″) bar spacing and approximately 13 mm (1/2″) bar width. The lower quarter of the grate was constructed from metal bars each 10 mm (3/8″) wide and 13 mm (1/2″) apart. The grate was inserted into the extension piece of the trawl in such a way that anterior netting was attached to the circumference of the entire grate while posterior netting was attached only to the circumference of the upper three-quarters of the grate. In this way small fish and shrimp that passed through the lower quarter of the grate were no longer retained in the trawl and escaped capture. This modification was initially designed to reduce the capture of small shrimp and its affect on small bycatch species is not well understood. Whether or not this modification contributed to low catches of regulated and non-regulated bycatch at midcoast ME is unclear, or if this simply reflects a relatively low abundance of these animals at this location.

Trawl geometry

The use of acoustic sensors to measure headline height and wingend spread was limited to a small number of hauls at two locations. Unfortunately problems with sensor performance resulted in usable data from only four hauls at one location.

The distance between the wingends of a trawl net is usually measured by attaching acoustic sensors to the upper wingends of the net. The master wingend sensor receives an acoustic signal from the slave sensor and transmits this signal to a towed hydrophone. In this study though, we were unable to attach the sensors to the wingends because the boats used a one-legged trawl design where the top and bottom panels of the net are tapered to a single wingend (or point). Each wingend is attached directly to a ground cable, and sensors attached to these locations would risk damage due to seabed contact. Wingend sensors were therefore placed approximately one meter back from the wingend towards the center of the headline. The headline sensor was attached near the middle of the headline, a few meshes aft of the headline.

We found that wingend spread measurements were characterized by high variation but headline height measurements were not. This could be due to signal alignment problems between the wingend sensors (during several hauls the sensors provided not data at all) and is not thought to be due to a variable trawl opening, which in any case would normally be accompanied by a variable headline height. Reasons for these problems could be due to poor sensor attachment technique, or misalignment between master sensor and hydrophone or between wingend sensors.

Fishing industry involvement

Noteworthy in this project was the quality of involvement and support by all fishing industry participants. Despite aforementioned problems with boat access and sampling time, all captains and crew were very accommodating and helpful, even to the extent of assisting with catch sorting and the collection of bycatch data. We are very grateful for their participation and contribution to this project.

Presentations

At the 2009 Annual NEC meeting in Portsmouth, NH, a summary of preliminary study findings was presented by the PI. The title of the presentation was, ‘A contemporary assessment of the bycatch of regulated species and the Nordmore grate in the Northern Shrimp Fishery.’ A copy of this presentation is provided in Appendix 2.

Data
An electronic copy of fieldwork data has been provided to the Northeast Consortium.

Published reports and papers
No reports or papers have been published at this time.

Conclusion

Despite fewer sampling opportunities than initially projected this project achieved almost all stated objectives. We were able to document the bycatch of regulated species both spatially and temporally and determine if the Nordmore grate was achieving the required bycatch reduction target. Factors affecting the performance of the grate were not identified – in part because their high performance resulted in few modifications during this study – and while attempts were made at one location to compare grate orientation, few hauls made it difficult to determine the effect of orientation of catches of shrimp and bycatch. NOAA observer data, however, indicated that grate orientation had little effect on catch composition or the ability of the grate to reduce regulated species bycatch. In context, however, this sampling project represents a relatively extensive and contemporary assessment of Nordmore grate performance. Our results indicate that the grate is successfully reducing catches of regulated species bycatch to less than 5% of total catch volume per fishing trip, both spatially and temporally across the fishery.

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Table 1. Planned observer data collection program.

Boat #	Days per month			
	Dec	Jan	Feb	Mar
1	4	4	4	4
2	4	4	4	4
3	4	4	4	4
4	4	4	4	4

Table 2. Total number of sampling days (trips) sorted by sampling location.

Sampling location	Sampling Days Per Month			
	Jan	Feb	Mar	Apr
Northern Massachusetts	4	0	0	0
Boon Island, ME	4	4	0	0
Saco Bay, ME	4	4	5	0
Seguin Island, ME	0	0	0	3
Midcoast ME	4	4	3	0

Table 3. Average shrimp catch & bycatch (regulated species and non-regulated bycatch species) per trip for each fishing location. Catch proportions are based on total catch per trip.

Location	Trip	Shrimp	Bycatch			
			Reg. Species	Non-reg. Species	Avg. Reg. Spp.	Avg. All Spp.
	#	(lbs ± SD)	(lbs ± SD)		(% ± SD)	
North. Mass.	4	2737.5 ± 1229.8	23.2 ± 12.7	45.4 ± 21.0	0.85 ± 1.01	2.67 ± 1.01
Boon Is. ME	8	3777.5 ± 1986.4	64.2 ± 55.7	126.0 ± 109.6	2.01 ± 1.83	5.63 ± 4.74
Saco Bay, ME	13	2318.8 ± 1141.1	34.6 ± 17.0	110.5 ± 78.2	1.55 ± 0.53	6.43 ± 3.17
Seguin Is. ME	3	1220.0 ± 281.2	21.9 ± 16.3	45.9 ± 70.5	1.59 ± 0.77	4.46 ± 4.93
Midcoast ME	11	2571.4 ± 749.2	5.5 ± 6.5	13.0 ± 13.9	0.22 ± 0.24	0.82 ± 0.93
All Vessels	39	2647.7 ± 1370.6	30.3 ± 33.7	74.5 ± 82.1	1.21 ± 1.10	4.19 ± 3.78

Table 4. Regulated bycatch proportions by fishing location. For each location proportions may not equal 100 due to rounding in each category.

Location	Hauls	Regulated bycatch (%)					
	#	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5+
North. Mass.	16	62.5	25.0	6.3	0.0	0.0	6.3
Boon Is. ME	29	34.5	27.6	6.9	6.9	3.4	17.2
Saco Bay, ME	57	29.8	42.1	17.5	5.2	3.5	1.8
Seguin Is. ME	8	25.0	62.5	12.5	0.0	0.0	0.0
Midcoast ME	27	92.6	3.7	3.7	0.0	0.0	0.0
All Vessels	137	48.2	30.7	9.5	4.4	2.2	5.1

Table 5. Catch weight and proportion in hauls when regulated bycatch exceeded 5% of total catch weight.

Location	Date	Haul	Shrimp		Bycatch			
					Regulated		Non-regulated	
		#	lbs	%	lbs	%	lbs	%
North. Mass.	1/21/09	1	200	79.2	17.2	6.8	35.5	14.0
Boon Is.	1/9/09	1	600	83.4	54.7	7.6	65.1	9.0
Boon Is.	1/9/09	2	50	44.0	19.6	17.3	44.0	38.7
Boon Is.	1/10/09	1	325	82.1	30.3	7.7	40.6	10.3
Boon Is.	1/12/09	2	725	86.3	50.2	6.0	64.7	7.0
Boon Is.	1/13/09	3	100	81.2	9.4	7.6	13.7	11.1
Saco Bay	3/13/09	1	80	91.3	5.0	5.7	2.6	3.0

Table 6. ANOVA and Bonferroni post hoc test output comparing proportions of regulated species bycatch per haul. Significant figures ($p<0.05$) are in bold type.

Variable	df	F-ratio	p-value	Bonferroni post hoc	p-value
Month					
January	3	18.236	**0.000**	N. Mass v Boon Is.	**0.000**
				N. Mass v Saco Bay	**0.028**
				N. Mass v Midcoast ME	1.000
				Boon Is. v Saco Bay	0.065
				Boon Is. v Midcoast ME	**0.000**
				Saco Bay v Midcoast ME	**0.001**
February	2	23.104	**0.000**	Boon Is. v Saco Bay	**0.001**
				Boon Is. v Midcoast ME	**0.019**
				Saco Bay v Midcoast ME	**0.000**
March	1	23.848	**0.000**	Saco Bay v Midcoast ME	**0.000**
Location					
Boon Is	1	26.225	**0.000**	Jan v Feb	**0.000**
Saco Bay	2	0.735	0.485	Jan v Feb	1.000
				Jan v Mar	0.694
				Feb v Mar	1.000
Midcoast ME	2	24.724	**0.000**	Jan v Feb	**0.000**
				Jan v Mar	**0.000**
				Feb v Mar	1.000

Table 7. Composition of regulated species bycatch (all locations and hauls combined) from 137 hauls over 39 fishing trips.

Common name	Scientific name	Weight		Number	
		lbs	%	No.	%
American plaice	*Hippoglossoides platessoides*	520.8	46.52	6788	68.19
Red/white hake	Order: Gadiforme	299.5	26.75	1652	16.59
Winter flounder	*Pseudopleuronectes Americanus*	108.8	9.71	506	5.08
Yellowtail flounder	*Limanda ferruginea*	60.6	5.41	191	1.92
Acadian redfish	*Sebastes fasciatus*	39.3	3.51	244	2.45
Monkfish	*Lophius Americanus*	32.5	2.90	159	1.60
Windowpane flounder	*Scophthalmus aquosus*	23.1	2.06	217	2.18
Atlantic cod	*Gadus morhua*	11.5	1.03	70	0.70
other		23.6	2.11	128	1.29
Total		*1119.6*	*100.00*	*9955*	*100.00*

Table 8. Composition of regulated species bycatch (all locations and hauls combined) collected by NOAA observers from 106 hauls and 25 fishing trips. Due to rounding errors catch proportions do not equal 100%.

Common name	Scientific name	Weight	
		lbs	%
American plaice	*Hippoglossoides platessoides*	415.2	26.82
Acadian redfish	*Sebastes fasciatus*	340.6	22.00
Red/white hake	Order: Gadiforme	281.9	18.21
Winter flounder	*Pseudopleuronectes Americanus*	211.9	13.69
Witch flounder	*Glyptocephalus cynoglossus*	134.1	8.66
Windowpane flounder	*Scophthalmus aquosus*	65.3	4.22
Monkfish	*Lophius Americanus*	48.6	3.14
Yellowtail flounder	*Limanda ferruginea*	25.1	1.62
Atlantic cod	*Gadus morhua*	6.9	0.44
Other		18.3	1.18
Total		*1547.9*	*100.00*

Table 9. Shrimp and bycatch proportion by fishing trip. The first three fishing trips were completed with a downward excluding grate (↓) and an upward excluding grate (↑).

Trip date	Grate orientation	Shrimp (%)	Bycatch (%)	
			Regulated	Non-reg.
1/09/2009	↓	86.31	5.34	8.35
1/10/2009	↓	91.88	2.32	5.80
1/12/2009	↓	89.73	4.04	6.23
Average all trips		*89.31*	*3.90*	*6.79*
1/13/2009	↑	93.73	1.94	4.34
2/11/2009	↑	99.38	0.26	0.37
2/12/2009	↑	98.06	0.52	1.42
2/14/2009	↑	97.85	1.08	1.08
2/15/2009	↑	98.03	0.57	1.40
Average all trips		*97.41*	*0.87*	*1.72*

Table 10. Weights of shrimp and dominant regulated bycatch species by grate orientation, based on observer data.

Grate orient.	Catch statistic	Total catch	Species						
			Shrimp	Monkfish	Am. plaice	Redfish	Hake mix	Winter fl.	Witch fl.
↓	Wt. (lbs)	23277.0	21951.0	10.0	92.0	31.0	59.0	91.0	13.0
	Av. (n = 5)	4655.4	4390.2	5.0	18.4	6.2	11.8	18.2	2.6
	SD	2323.5	2261.5	1.4	11.2	4.4	10.7	15.1	2.9
↑	Wt. (lbs)	57275.4	53841.0	38.5	221.9	155.6	96.9	104.9	48.1
	Av. (n = 18)	3182.0	2991.2	2.1	12.3	8.6	5.4	5.8	2.7
	SD	2676.7	2674.0	4.2	18.5	23.1	12.2	5.3	6.3

Table 11. Nordmore grate dimensions and construction details for each sampling locations.

Parameter	Location				
	N. Mass	Boon Is.	Saco Bay	Midcoast ME	Seguin Is.
Extension mesh size[1] (mm)	57	51	51	51	51
Grate height (mm)	1 524	1 524	1 524	1 397	1524
Grate width (mm)	1 168	914	965	965	914
Grate angle (degrees)	47	45	52	45	55
Grate orientation	↑	↓/↑	↑	↑	↑
Bar spacing (mm)	25	25	25	25/13	19
Bar width (mm)	-	13	-	10/13	13
Grate material	S/steel	Plastic	Plastic	Plastic/ metal	Plastic
Escape outlet width (mm)	1 219	n/a	660	1 397	914
Escape outlet length (mm)	1 016	n/a	762	965	914

1. Stretched mesh center to center of opposing knots.

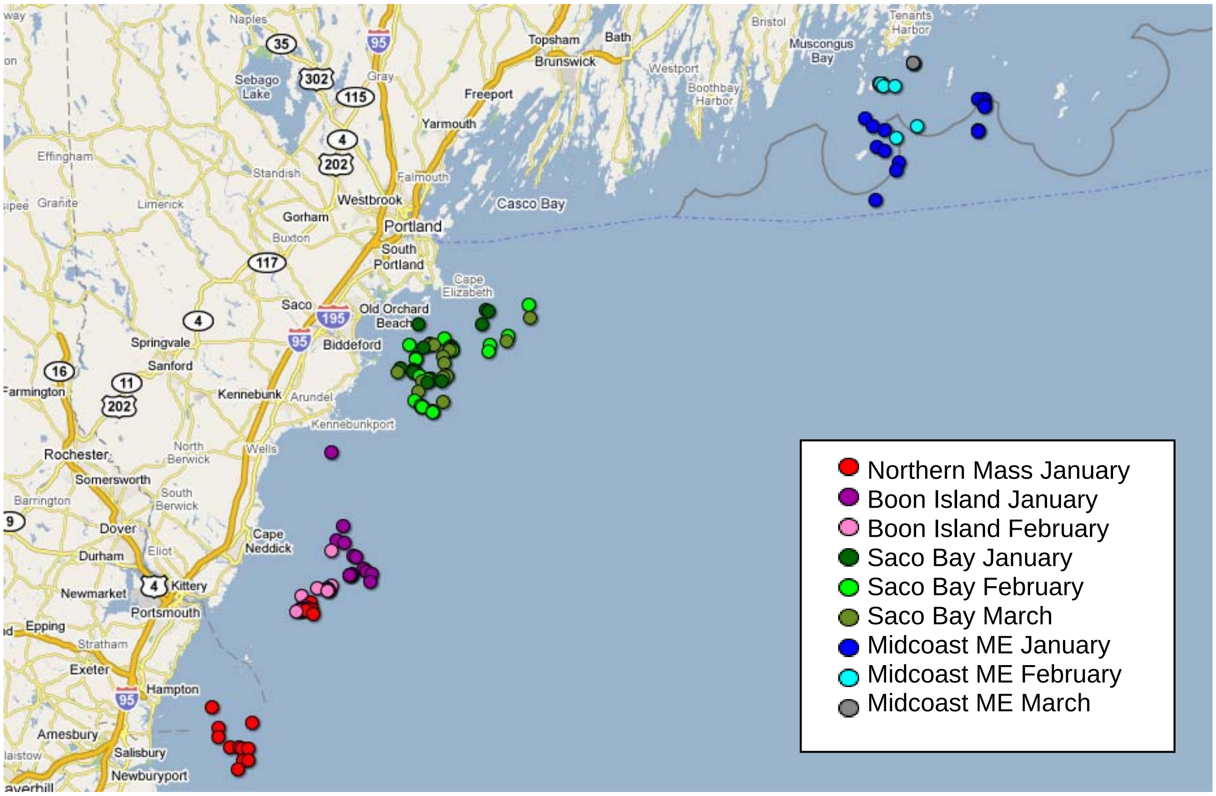


Figure 1: The four locations sampled, Northern Massachusetts, Boon Is, Saco Bay, and midcoast ME.

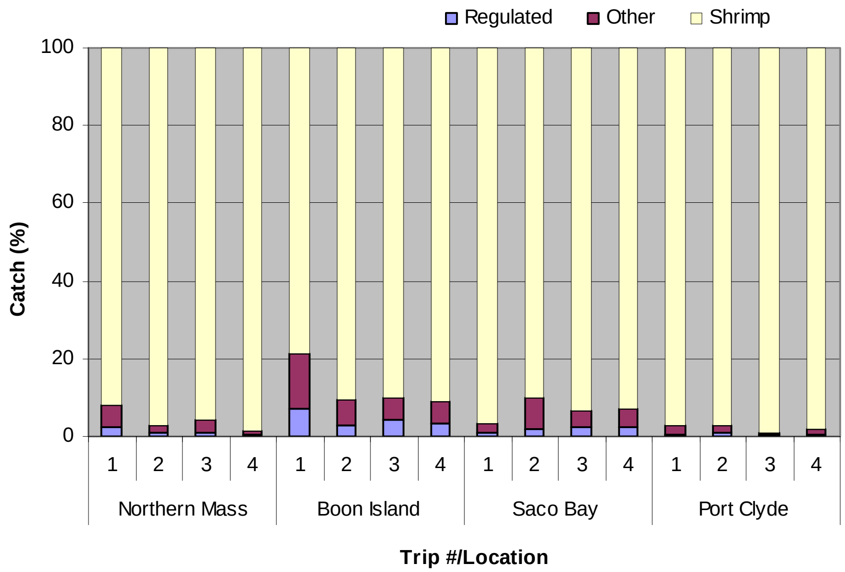


Figure 2. Catch composition by trip and location in January

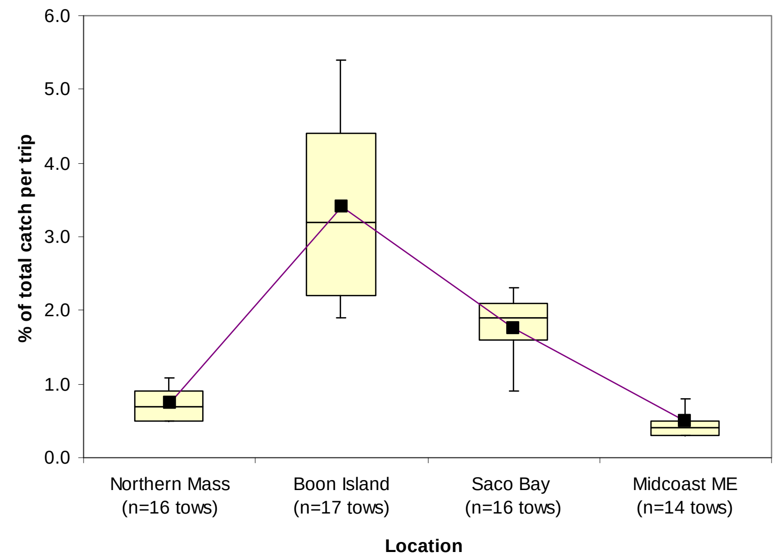


Figure 3. Mean (black square), median (horizontal line), upper and lower quartiles (areas enclosed by box), and maximum and minimum values (vertical lines) of regulated species bycatch per trip as % of total catch in January.

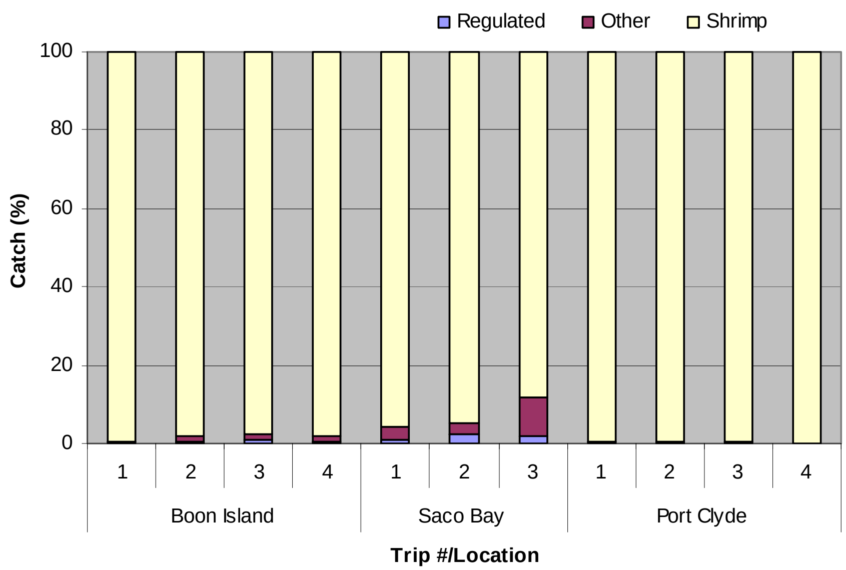


Figure 4. Catch composition by trip and location in February

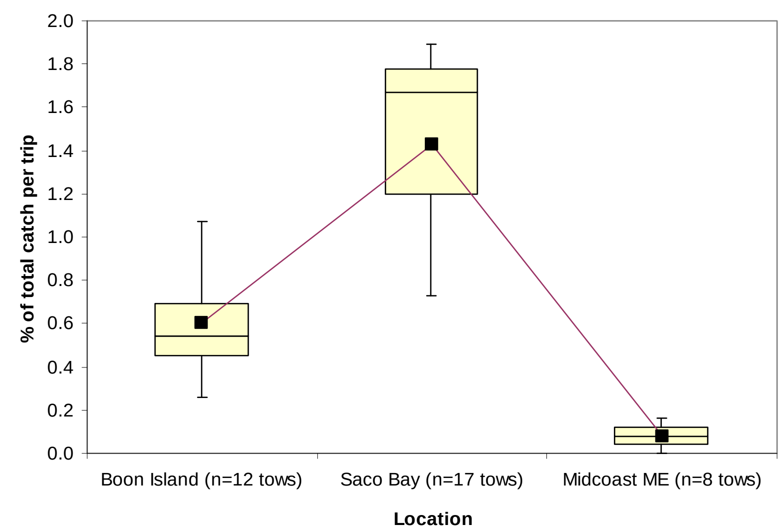


Figure 5. Mean (black square), median (horizontal line), upper and lower quartiles (areas enclosed by box), and maximum and minimum values (vertical lines) of regulated species bycatch per trip as % of total catch in February.

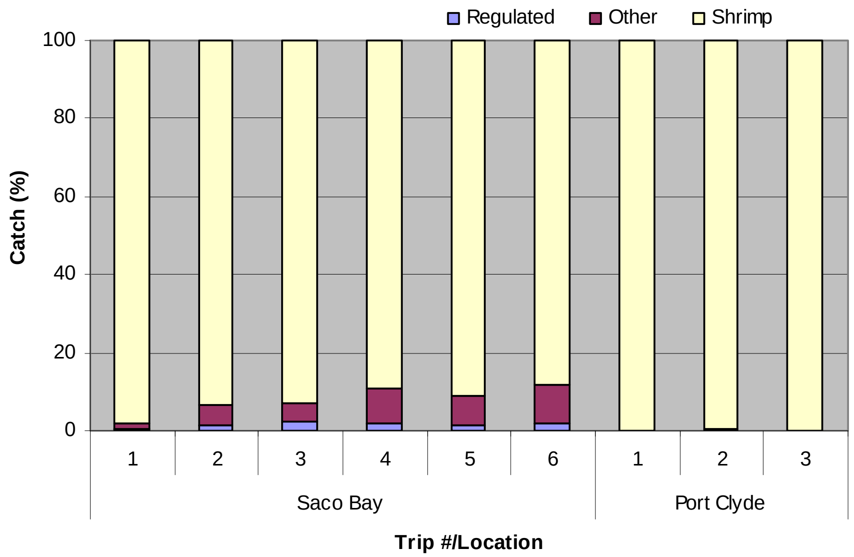


Figure 6. Catch composition by trip and location in March

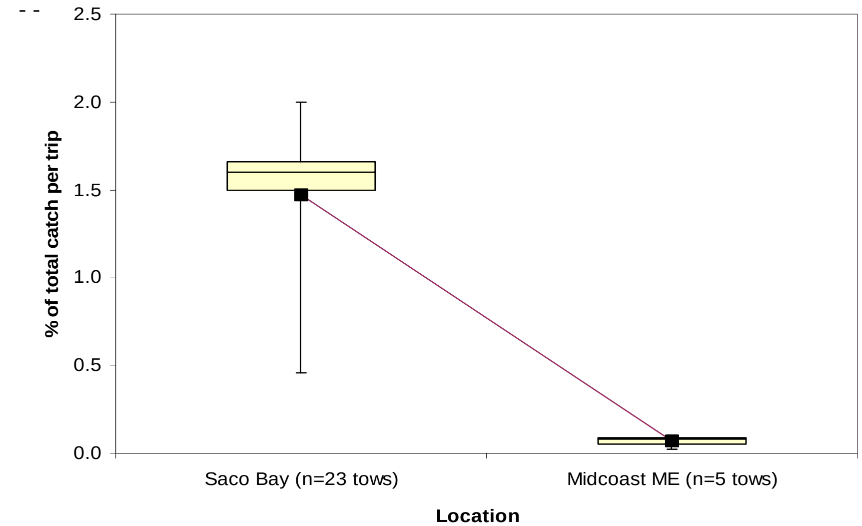


Figure 7. Mean (black square), median (horizontal line), upper and lower quartiles (areas enclosed by box), and maximum and minimum values (vertical lines) of regulated species bycatch per trip as % of total catch in March.

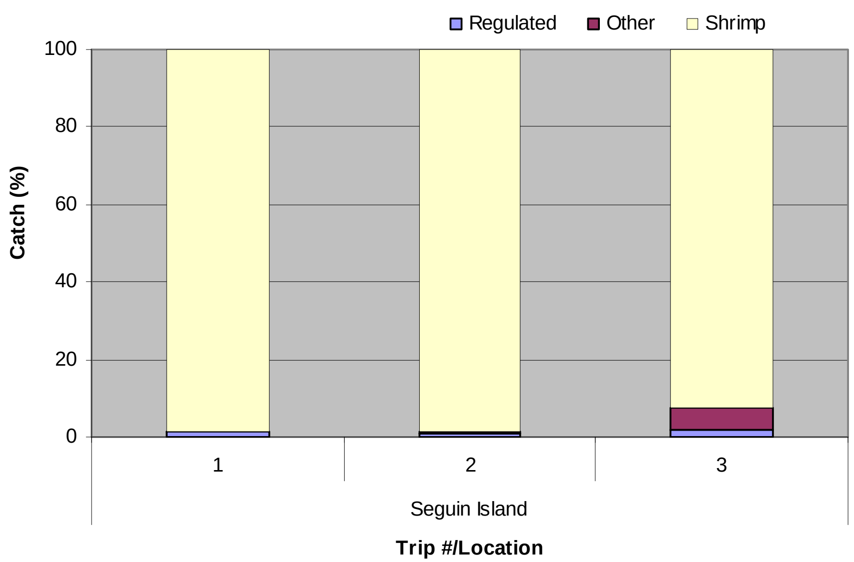


Figure 8. Catch composition by trip and location in April

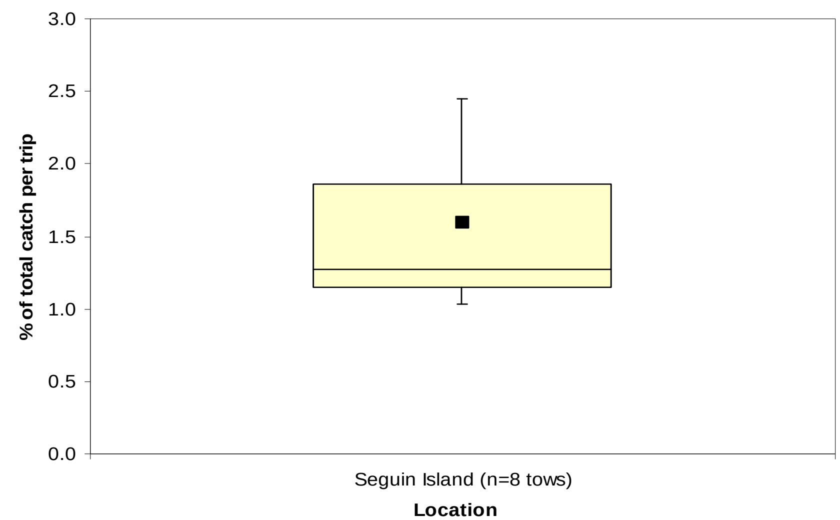


Figure 9. Mean (black square), median (horizontal line), upper and lower quartiles (areas enclosed by box), and maximum and minimum values (vertical lines) of regulated species bycatch as % of total catch in April.

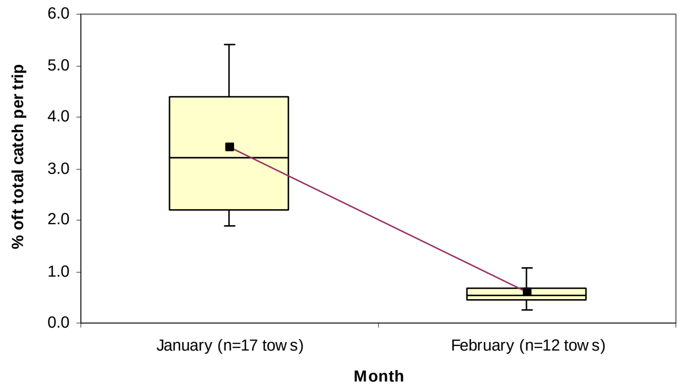


Figure 10. Mean (black square), median (horizontal line), upper and lower quartiles (areas enclosed by box), and maximum and minimum values (vertical lines) of regulated species bycatch as a % of total catch per trip for Boon Island by month.

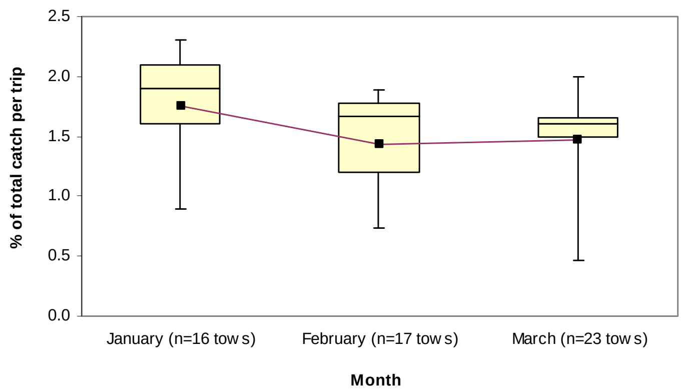


Figure 11. Mean (black square), median (horizontal line), upper and lower quartiles (areas enclosed by box), and maximum and minimum values (vertical lines) of regulated species bycatch as a % of total catch per trip for Saco Bay by month.

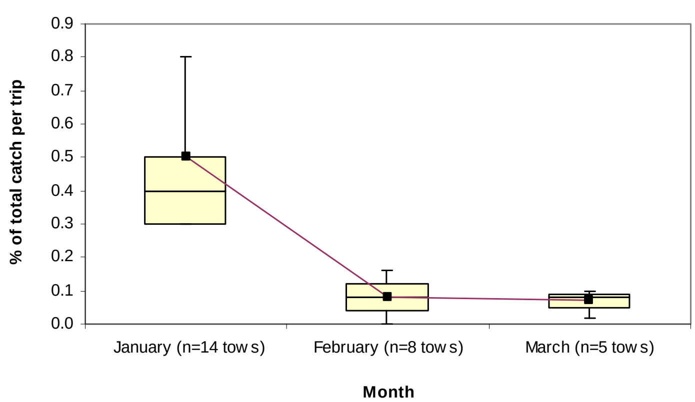
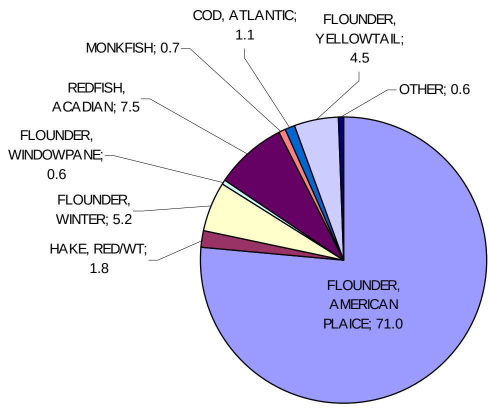


Figure 12. Mean (black square), median (horizontal line), upper and lower quartiles (areas enclosed by box), and maximum and minimum values (vertical lines) of regulated species bycatch as a % of total catch per trip for Midcoast ME by month.



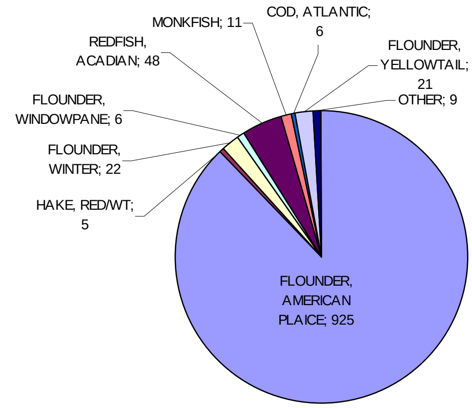
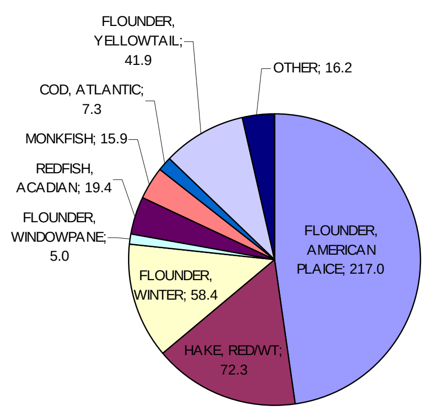


Figure 13. Regulated species bycatch for Northern Massachusetts by weight (lbs., left) and number (right).



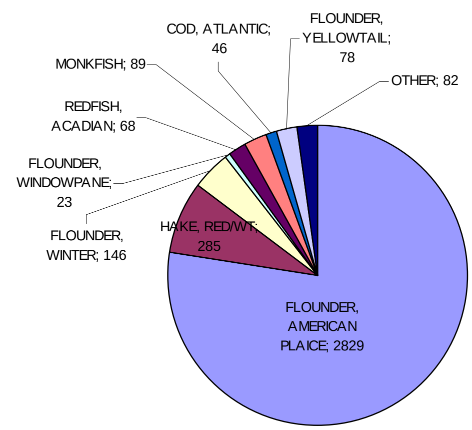
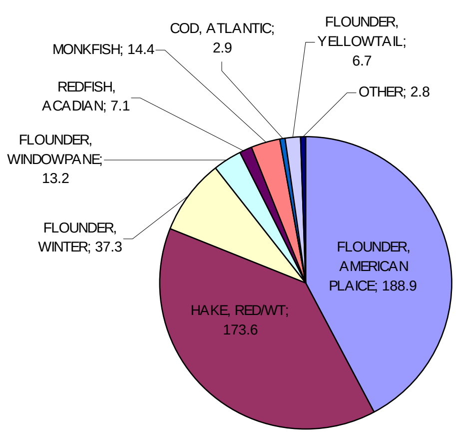


Figure 14. Regulated species bycatch for Boon Island by weight (lbs., left) and number (right).



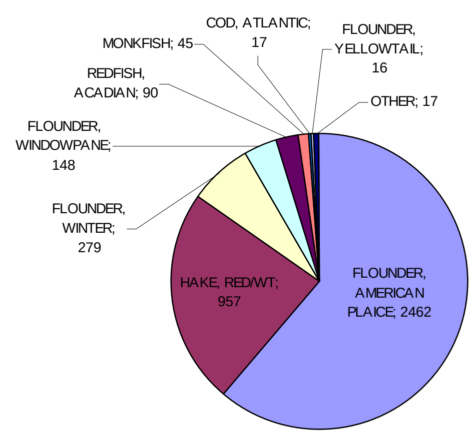


Figure 15. Regulated species bycatch for Saco Bay by weight (lbs., left) and number (right).

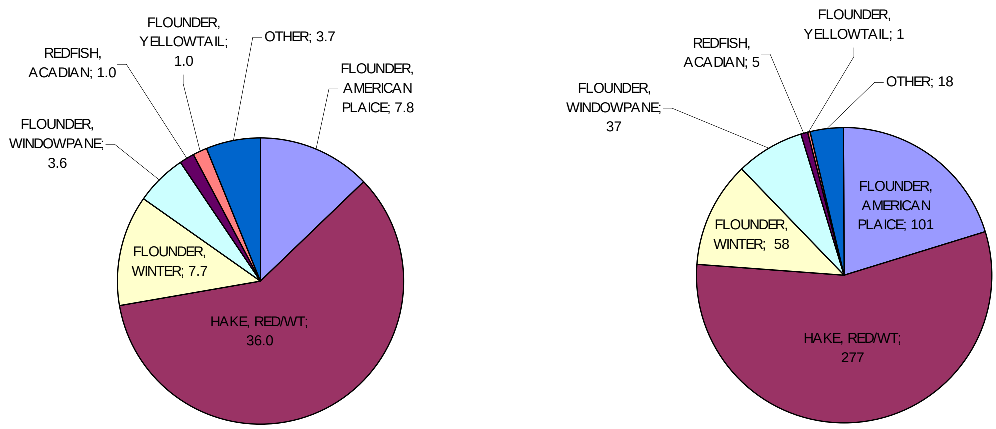


Figure 16. Regulated species bycatch for midcoast ME by weight (lbs., left) and number (right).

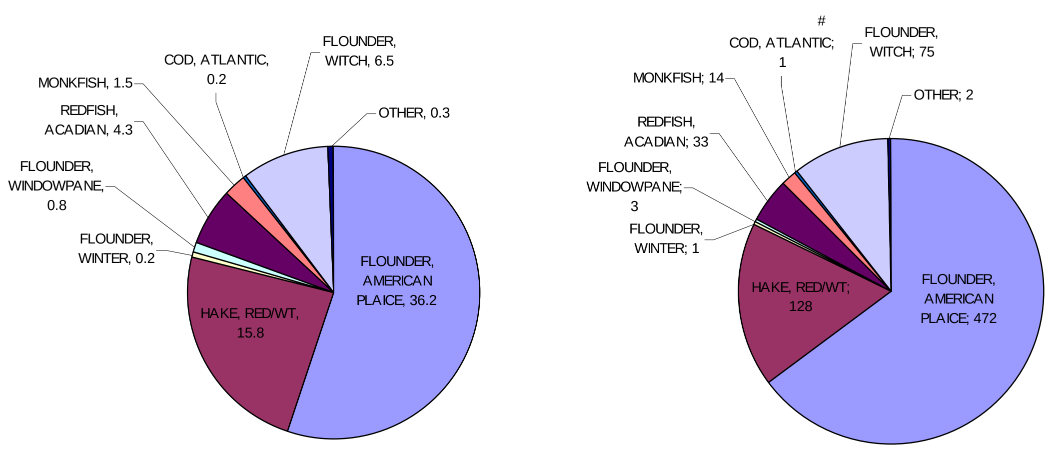


Figure 17. Regulated species bycatch for Seguin Island by weight (lbs., left) and number (right).

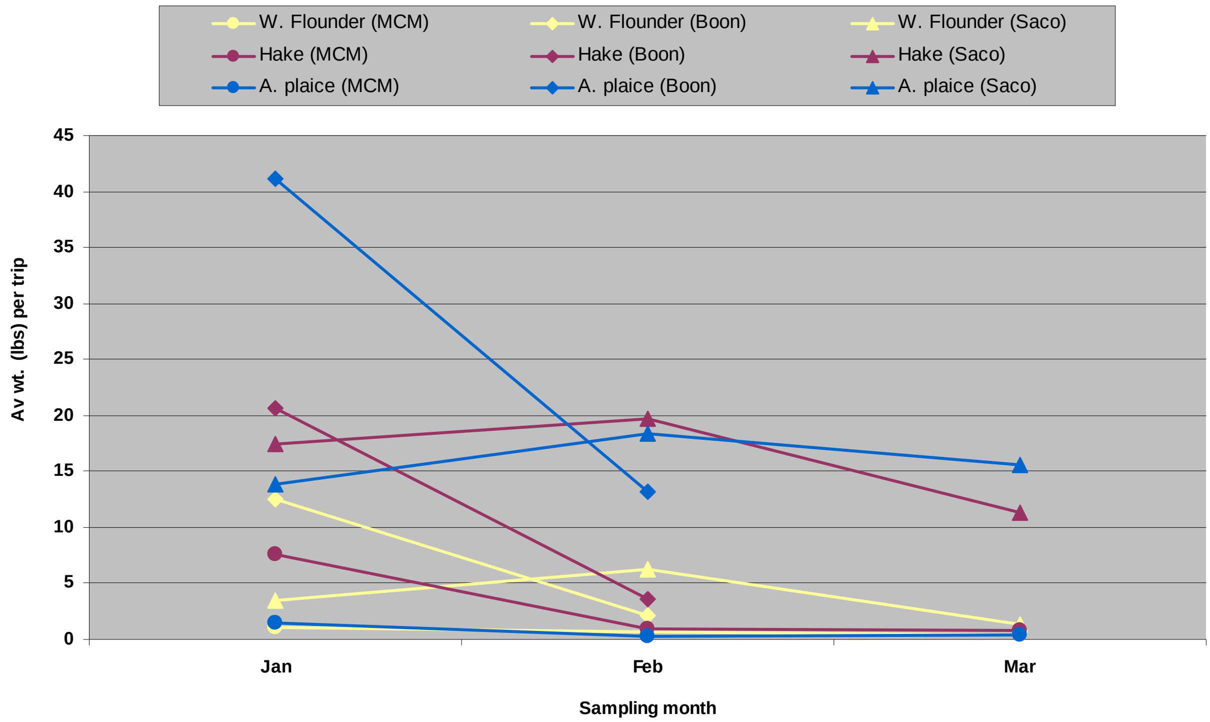


Figure 18. Average weight of dominant regulated bycatch per trip by month. Only regions sampled over two or more months are presented.

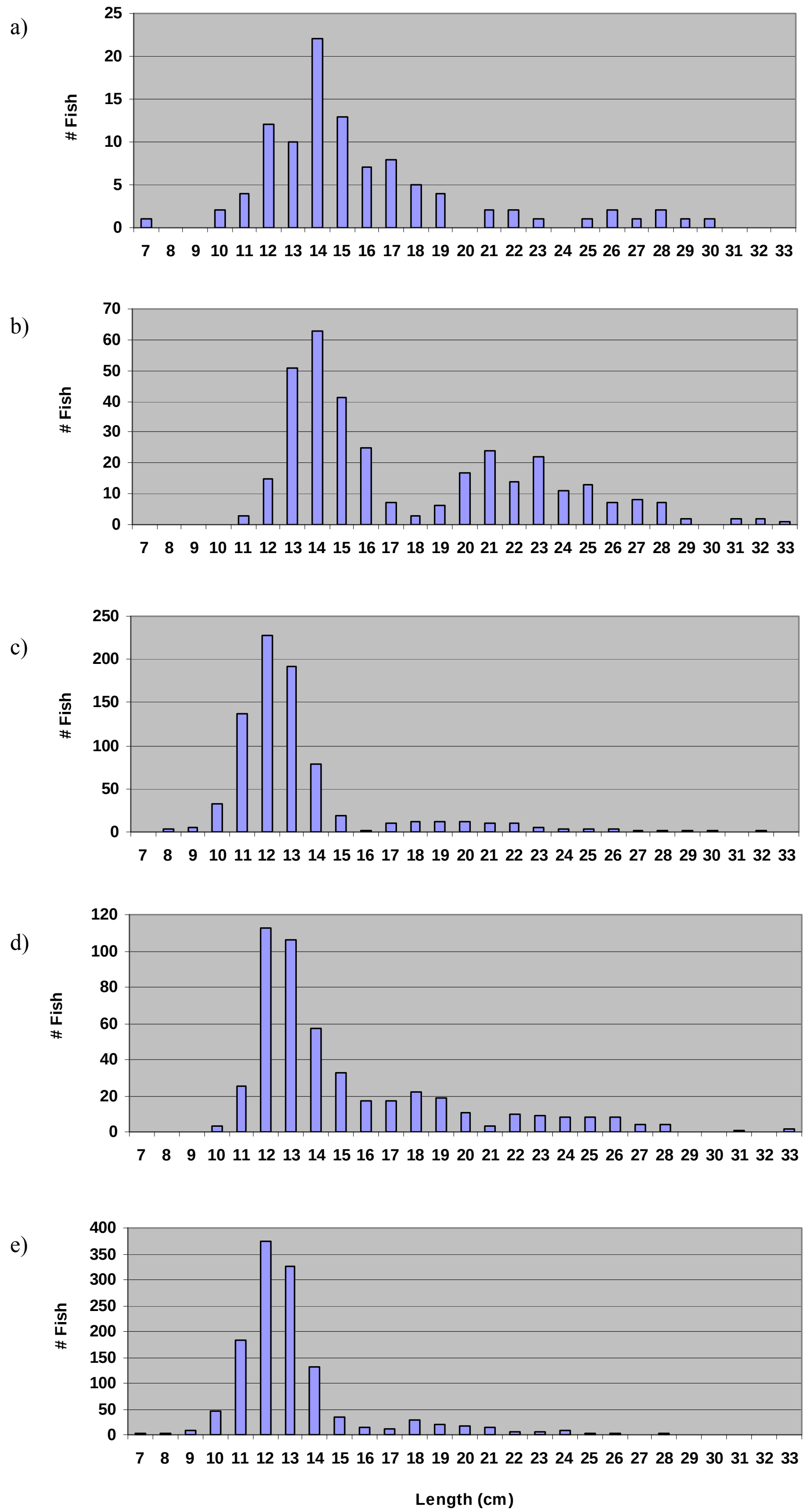


Figure 19. Length frequency distribution for dabs caught in a) midcoast ME, b) Sequin island, c) Boon island, d) Northern Massachusetts, and e) Saco Bay. The minimum legal landing size for dabs is 35.6 cm (14 inches).

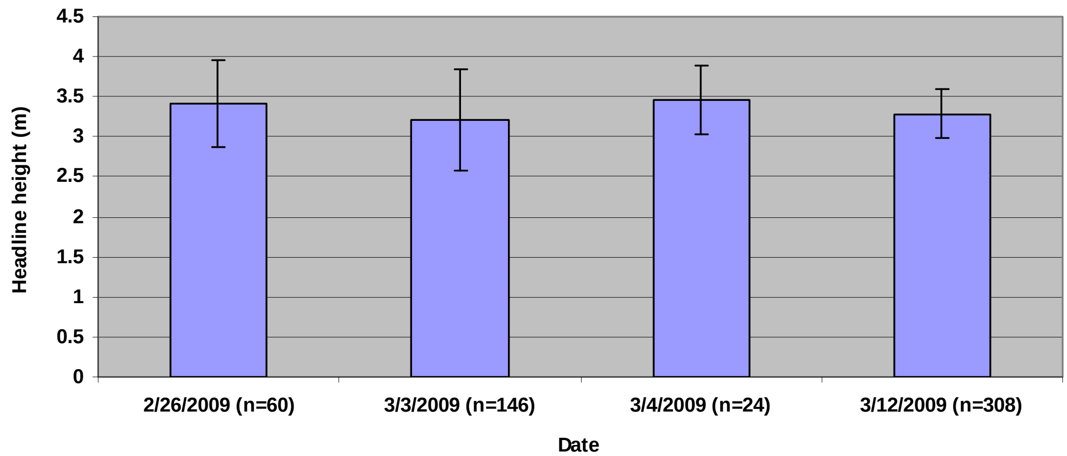


Figure 20. Average headline height ± standard deviation of the shrimp trawl used at midcoast ME.

Appendix 1. Composition of catches (lbs) by trip, month, and location.

Location	Month	Trip #	Haul #	Reg.	Non-reg.	Shrimp	Total
N. Massachusetts	January	1	1	17.2	35.5	200.0	252.7
			2	2.1	7.3	100.0	109.4
			3	7.8	9.0	1400.0	1416.8
			4	14.0	14.4	1900.0	1928.4
			Total	**41.05**	**66.05**	**3600.0**	**3707.1**
		2	1	3.9	8.9	300.0	312.8
			2	7.15	19.1	900.0	926.3
			Total	**11.05**	**28.0**	**1200.0**	**1239.1**
		3	1	0.0	16.0	200.0	216.0
			2	5.2	8.5	200.0	213.7
			3	7	11.0	500.0	518
			4	4.3	12.0	700.0	716.3
			5	4.3	13.5	700.0	717.8
			Total	**20.8**	**61**	**2300.0**	**2381.8**
		4	1	6.3	6.0	750.0	762.3
			2	3.1	12.6	800.0	815.7
			3	3.5	4.1	1100.0	1107.6
			4	2.6	2.0	900.0	904.6
			5	4.5	1.9	300.0	306.4
			Total	**20.0**	**26.6**	**3850**	**3896.6**
Boon Is	January	1	1	54.7	65.1	600.0	719.8
			2	19.6	44.0	50.0	113.6
			3	2.4	16.2	325.0	343.6
			4	17.6	22.3	550.0	589.9
			Total	**94.3**	**147.6**	**1525.0**	**1766.9**
		2	1	30.3	40.6	325.0	395.9
			2	14.0	78.9	1000.0	1092.9
			3	16.4	71.3	1100.0	1187.7
			4	19.6	75.6	1400.0	1495.2
			5	51.6	63.3	1400.0	1514.9
			Total	**131.9**	**329.7**	**5225.0**	**5686.6**
		3	1	49.3	69.9	1225.0	1344.2
			2	50.2	64.7	725.0	839.9
			3	37.6	93.2	800.0	930.8
			4	18.4	11.6	700.0	730.0
			Total	**155.5**	**239.4**	**3450.0**	**3844.9**
		4	1	8.5	55.1	620.0	683.6
			2	15.2	15.3	800.0	830.5
			3	9.4	13.7	100.0	123.1
			4	12.8	18.6	700.0	731.4
			Total	**45.9**	**102.7**	**2220.0**	**2368.6**
	February	1	1	7.3	15.6	2500.0	2522.9
			2	8.2	6.6	3500.0	3514.8
			Total	**15.5**	**22.2**	**6000.0**	**6037.7**
		2	1	6.7	22.5	1800.0	1829.2
			2	9.4	23.7	1900.0	1933.1
			3	4.9	22.6	1000.0	1027.5
			4	7.4	9.4	700.0	716.8
			Total	**28.4**	**78.2**	**5400.0**	**5506.6**
		3	1	11.0	11.0	1000.0	1022.0
			Total	**11.0**	**1000.0**	**1022.0**	**11.0**

Appendix 1 continued.

Location	Month	Trip #	Haul #	Reg.	Non-reg.	Shrimp	Total
Boon Is	February	4	1	10.6	30.3	1800.0	1840.9
			2	9.9	24.8	1700.0	1734.7
			3	5.2	12.2	700.0	717.4
			4	2.7	7.3	850.0	860.0
			5	3.0	2.4	350.0	355.4
			Total	**31.4**	**77.0**	**5400.0**	**5508.4**
Saco Bay	January	1	1	7.9	28.8	550.0	586.7
			2	7.3	14.6	600.0	621.9
			3	8.1	9.7	650.0	667.8
			4	7.1	9.0	1400	1416.1
			Total	**30.4**	**62.1**	**3200.0**	**3292.5**
		2	1	11.8	37.4	550.0	599.2
			2	12.8	33.8	450.0	496.6
			3	12.0	58.6	375.0	445.6
			4	6.0	41.1	600.0	647.1
			5	9.4	56.7	625.0	691.1
			Total	**52.0**	**227.6**	**2600.0**	**2879.6**
		3	1	10.0	6.1	500.0	516.1
			2	4.4	4.2	200.0	208.6
			3	2.7	5.6	50.0	58.3
			4	1.5	6.0	150.0	157.5
			Total	**18.6**	**21.9**	**900.0.0**	**940.5**
		4	1	11.6	24.0	620.0	655.6
			2	6.2	11.55	250.0	267.75
			3	13.6	23.9	400.0	437.5
			Total	**31.4**	**59.5**	**1270.0**	**1360.9**
	February	1	1	6.8	45.4	600.0	652.2
			2	3.7	32.6	1200.0	1236.3
			3	7.2	23.2	1000.0	1030.4
			4	9.2	32.6	900.0	941.8
			5	7.2	10.8	750.0	768.0
			Total	**34.1**	**144.6**	**4450.0**	**4628.7**
		2	1	17.2	18.2	400.0	435.4
			2	14.0	16.6	620.0	650.6
			3	15.2	30.4	625.0	670.6
			4	18.0	15.8	450.0	483.8
			5	4.0	4.6	300.0	308.6
			6	8.4	15.4	1500.0	1523.8
			Total	**76.8**	**101**	**3895.0**	**4072.8**
		3	1	9.4	9.9	750.0	769.3
			2	6.6	7.6	400.0	414.2
			3	5.2	6.5	300.0	311.7
			4	12.4	36.0	200.0	248.4
			5	8.8	23.1	450.0	481.9
			6	3.6	21.4	500.0	525.0
			Total	**46.0**	**104.5**	**2600.0**	**2750.5**

Appendix 1 continued.

Location	Month	Trip #	Haul #	Reg.	Non-reg.	Shrimp	Total
Saco Bay	February	4	1	4.6	10.1	600.0	614.7
			2	3.6	4.3	900.0	907.9
			3	2.1	5.8	550.0	557.9
			4	2.3	7.6	800.0	809.9
			5	2.0	5.3	250.0	257.3
			Total	**14.6**	**33.1**	**3100.0**	**3147.7**
	March	1	1	10.2	23.8	550.0	584.0
			2	13.8	43.	600.0	656.8
			3	3.3	19.9	450.0	473.2
			Total	**27.3**	**86.7**	**1600.0**	**1713.9**
		2	1	5.0	2.6	80.0	87.6
			2	5.9	21.3	325.0	352.2
			3	5.0	29.6	325.0	359.6
			4	3.9	4.6	400.0	408.5
			5	7.7	24.3	400.0	432.0
			Total	**27.5**	**82.4**	**1530.0**	**1639.9**
		3	1	6.9	18.4	400.0	425.2
			2	8.7	45.8	300.0	354.6
			Total	**15.6**	**64.2**	**700.0**	**779.8**
		4	1	10.2	28.0	400.0	438.2
			2	8.6	44.9	600.0	653.5
			3	6.6	43.0	500.0	549.6
			4	5.3	37.4	400.0	442.7
			Total	**30.7**	**153.3**	**1900.0**	**2084.0**
		5	1	19.7	50.5	600.0	670.2
			2	5.9	54.5	600.0	660.4
			3	9.8	37.5	500.0	547.3
			4	9.1	153.0	700.0	862.1
			Total	**44.5**	**295.5**	**2400.0**	**2740.0**
Midcoast ME	January	1	1	2.8	29.4	950.0	982.2
			2	2.0	12.5	550.0	564.4
			Total	**4.8**	**41.8**	**1500.0**	**1546.6**
		2	1	9.4	16.0	330.0	355.4
			2	3.4	4.1	520.0	527.5
			3	3.8	3.3	1380.0	1387.1
			4	6.4	2.6	600.0	609.0
			Total	**23.0**	**26.0**	**2830.0**	**2879.0**
		3	1	3.8	2.9	530.0	536.7
			2	3.3	3.6	720.0	726.8
			3	1.7	0.6	650.0	652.3
			4	1.0	1.0	200.0	202.0
			Total	**9.8**	**7.9**	**2100.0**	**2117.7**
		4	1	3.3	6.1	620.0	629.4
			2	1.4	5.5	600.0	606.9
			3	2.6	6.5	650.0	659.1
			4	1.3	13.4	480.0	494.7
			Total	**8.5**	**31.4**	**2350.0**	**2389.9**
	February	1	1	1.8	6.0	2200.0	2207.8
			2	2.6	3.3	1400.0	1405.9
			Total	**4.4**	**9.3**	**3600.0**	**3613.7**

Appendix 1 continued.

Location	Month	Trip #	Haul #	Reg.	Non-reg.	Shrimp	Total
Midcoast ME	February	2	1	0.6	3.7	1650.0	1654.3
			2	0.3	9.6	1150.0	1159.9
			Total	**0.9**	**13.2**	**2800.0**	**2814.1**
			1	2.4	4.4	1550.0	1556.8
			2	0.8	1.9	730.0	732.6
		3	3	0.7	1.1	600.0	601.8
			Total	**3.9**	**7.3**	**2880.0**	**2891.2**
		4	1	0.9	1.5	2250.0	2252.4
			Total	**0.9**	**1.5**	**2250.0**	**2252.4**
	March	1	1	0.9	0.3	3650.0	3651.2
			Total	**0.9**	**0.3**	**3650.0**	**3651.2**
		2	1	0.3	0.7	625.0	626.0
			2	1.7	2.2	900.0	903.9
			3	0.4	1.4	1450.0	1451.8
			Total	**2.4**	**4.3**	**2975.0**	**2981.7**
		3	1	1.3	0.5	1350.0	1351.8
			Total	**1.3**	**0.5**	**1350.0**	**1351.8**
Seguin	April	1	1	8.2	2.8	525.0	536.0
			2	3.8	0.8	400.0	404.6
			Total	**12.0**	**3.6**	**925.0**	**940.6**
		2	1	8.1	1.9	650.0	660.0
			2	5.0	4.9	600.0	609.9
			Total	**13.1**	**6.8**	**1250.0**	**1269.9**
		3	1	13.0	6.1	410.0	429.1
			2	14.4	33.7	725.0	773.1
			3	6.1	72.1	500.0	578.2
			4	7.2	15.3	350.0	372.5
			Total	**40.7**	**127.2**	**1985.0**	**2152.9**

Appendix 2: Copy of presentation presented at the 2009 annual NEC meeting