Testing the Effectiveness of Various Escape Panel Configurations on Sea Urchin Drags

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Abstract

Escape panels have been required on sea urchin drags in Maine since 2003, but there has never been any quantitative testing of their effectiveness in releasing small (sublegal) sea urchins. This project tested six different configurations of escape panels, and compared their performance with a control net with no escape panel.

Although panel effects varied greatly from place to place, two panel treatments consistently improved the mean size of urchins being retained, when used where urchins were generally small. However, the degree of improvement was variable, and relatively small. Further industry input is needed to determine whether the panels would be cost effective.

For draggers who fish on small urchins, escape panels in the bottom or entire back of the drag will provide a modest reduction in the number of smalls in the catch.

Introduction

In 1987, a market for the roe of the Maine green sea urchin (*Strongylocentrotus droebachiensis*) developed in Japan, and a valuable fishery rapidly grew (Andrew et al. 2001). By 1994 there were 2,725 licensed Maine sea urchin divers and draggers, who harvested 38 million pounds (17,000 mt) of urchins valued at $33 million that year. Since then, the fishery has declined to 3.5 million pounds (1,600 mt) valued at $5.1 million landed in 2005 by 556 license holders (Hunter et al. 2007). Preliminary landings data for 2006 are 3.4 million pounds (1,500 mt) valued at $4.6 million (Maine DMR, unpublished data). Most of the landings are now in eastern Maine (Hancock and Washington Counties), an area where the economy is struggling (Brookings Inst. 2006). About 41% of the landings are dragged; the rest are caught by divers (DMR, preliminary landings data for 2006-07 season, unpublished).

The decline in the fishery has been linked to a decline in stock abundance due to fishing (Harris and Tyrell 2001; Chen and Hunter, 2003; Steneck et al 2004, Grabowski et al. 2005).

Concern that the urchin resource was showing signs of overfishing prompted management actions by the Maine legislature and the Department of Marine Resources (DMR) to restrict fishing effort, beginning in 1993. One of the first actions taken was the establishment, in 1994, of a 2-inch (50.8 mm) minimum size (test diameter) limit, to protect small urchins. In 2001 the minimum size limit was increased to $2^{1}/_{16}$ inches (52.39 mm). The green sea urchin in Maine becomes sexually mature at about 45 mm diameter (Vadas and Beal, 1999). In 2000, a maximum size limit of 3½ inches (88.9 mm) was also implemented, and this was reduced to 3 inches (78.2 mm) in 2001.

Over-sized green sea urchins (> 3 inches) are relatively rare, about 0.5% of the total, while smalls ($<2^{1}/_{16}$ inches) are 77.7% and legals are 21.8% of the number of urchins at least 10 mm in diameter – as measured by the 2004 Maine sea urchin dive survey in depths of 15 m or less, after stratifying by depth and area (Hunter et al. 2005).

Despite the protection of small (and large) sea urchins, Maine's stock has continued to decline (Chen and Hunter 2003, Hunter et al. 2005). Consequently, managers have gradually shortened the fishing season. In 2004 the annual season was shortened from 94 days to just 10 days in management Zone 1 (Kittery to Rockland, see map above), and 45 days in Zone 2 (Rockland to Eastport, see map above), in a very painful and contentious process. Despite these drastic cuts, the stock has not recovered significantly, although the decline may have been halted (Hunter et al. 2007).

The size limits do not prevent the taking of small and over-sized urchins – harvesters are allowed to take an illegal animal as long as it is "culled on board immediately after harvesting and is liberated alive into the marine waters" (Maine Title 12, Ch. 623, §6749-A). The fate of the (mostly small) urchins that are culled (bycatch) from catches is not known. There is evidence that green sea urchins exposed to extremes of air temperature or rough handling may not survive (Robinson and MacIntyre, 1995). Temperature extremes are common during this fishery's season, conducted inshore between September and March. There is also evidence that dragged urchins can be critically damaged (punctured, crushed, spines broken) in the drag (Creaser and Weeks, 1998).

Beginning in October, 2003, at the suggestion of sea urchin fishermen, the State of Maine required that sea urchin drags be equipped with a large-mesh "escape panel" on the back of the drag, to reduce the harvesting and culling mortality of small sea urchins (less than the $2^1/_{16}$ inch diameter minimum legal size). Fishermen suggested that small urchins would be kicked up and out the panel. By regulation, this panel must consist of at least 2-inch square mesh. The 2-inch square mesh is generally achieved in the fishery by stretching a 4-inch diamond mesh with a tapered cut to be hung square, because of difficulty acquiring a mesh of 2-inch square. The regulation currently states that the culling panel must be at least two feet deep and extend across the full width of the drag, but there are no specific requirements for where this panel should be placed along the net. Most fishermen place this panel in the top of the drag (the end nearest the head bail). Until this project, there had been no thorough evaluation of the effectiveness of the panel or a determination of the best position for it.

Project Objectives and Scientific Hypotheses

The original objective of this project was to evaluate the size-selectivity of a standard urchin drag with no escape panel against:

a. A drag with the 2-inch, square-hung escape mesh along the entire drag,
b. A drag with the escape panel placed on the top half of the drag,
c. A drag with the escape panel placed on the bottom half of the drag.

However, since urchin drags are generally six feet long and the escape panels are only required by regulation to be two feet deep, it was decided to divide the drag into thirds rather than in half. Therefore, the primary objective of this project was changed to evaluate the selectivity of a standard urchin drag with no escape panel against:

a. A drag with 2-inch, square-hung escape mesh along the entire drag,
b. A drag with the escape panel placed on the top third of the drag,
c. A drag with the escape panel placed on the middle third of the drag,

d. A drag with the escape panel placed on the bottom third of the drag.

At the suggestion of Capt. Patryn, two other configurations were designed using a larger (2¼-inch, square hung) mesh for the escape panel:

e. A drag with the 2¼-inch, square-hung mesh escape panel placed on the top third of the drag,
f. A drag with the 2¼-inch, square-hung mesh escape panel placed on the bottom third of the drag.

It was determined that there was sufficient time during sea trials to test the two additional escape panel configurations, so they were added to the project. Therefore, the null hypothesis that this project was designed to test is that there is no difference in urchin catch efficiency and size-selectivity between a standard drag with no escape panel and a modified drag with one of the six escape panel configurations above.

The other main objective of this project was to identify any differences in escape panel performance between three Maine fishing areas, Jonesport, Cutler and Cobscook Bay.

Participants

Participants with key roles in project design and implementation are listed on the cover page. Other participants are listed under Partnerships, and Student Participation.

Methods

Constructing the drag

The first accomplishment of the project was the construction of the new drag from scratch (see photos). The drag constructed is (per Capt. Patryn) "a typical drag for the area". The head bail, from which the drag is towed, was made with steel weld construction. Running along the sides of the drag are double rows of ten double-linked 3¼-inch rings. One-inch by three-foot strips of rubber belting were woven through the rings in order to stiffen the drag, as well as close the openings of the rings themselves, typically done to reduce loss of urchins.

The bottom of the drag (the portion farthest from the head bail) is constructed of the 3¼-inch double-linked rings six deep and nineteen across. The two layers of rings compose a purse type cod-end with a chain catch.

The clubs, or part of the steel frame along the side, are in two parts, and hinged 18 inches from the bottom of the drag. The bottom steel rail is fixed to the 3¼-inch ring bag cod-end on either side with chain links. The rail on the front portion of the drag is fixed to a length of chain that feeds through a chain hole and track on the rail frame on the back portion of the bottom of the drag. The chain, when in place, is the catch for the drag.

The front of the drag, (the portion that comes in contact with the ocean floor), is constructed of chain squares which serve as "tickle chains" for collecting urchins. Each square is composed of columns of ⅜-inch chain, four links tall and two links of ½-inch chain between the adjacent column creating rows.

The attachment of the outer panels was done by using ½-inch hog rings. This was done for efficiency purposes and was found a successful means of complete panel occlusion proving just as effective as twine sewn. The panels are arranged so that the configurations tested could be exposed easily. The entire back of the urchin drag was outfitted with three two-foot panels of 4-inch diamond mesh hung square, to achieve 2-inch-square mesh. Three panels of standard ⅜-inch hex mesh were clipped over the square mesh in different positions (leaving the top, the middle, or the bottom section of the 2-inch mesh exposed) to simulate the various escape panel configurations. The smaller mesh covering the entire back of the drag served as the control (no escape panel). The 2-inch-square mesh was replaced with 2¼-inch-square mesh for the 2¼-inch-square mesh treatments.

Testing the escape panel treatments

All fishing trials were conducted aboard the F/V *Northern Eagle*, a 49-foot commercial fishing vessel owned and captained by Steve Patryn of Jonesboro, Maine, during April 2005. Captain Patryn is an experienced sea urchin dragger.

Four days were spent in the Jonesport area, four days off Cutler, and four days in the Lubec (Cobscook Bay) area (see charts, Figures 1-4). Eighteen to twenty-three tows were made each day, with an average tow time of 3-8 minutes depending on (inversely proportional to) the area's urchin density. (The average towing time during recent commercial seasons has been 7-8 minutes (Hunter et al, 2005, 2007) with a range of 4-12 minutes (unpublished, from port interviews).) Tow speed varied from 1.8 to 3.0 knots. Depths varied from 10 to 147 ft (3-45 meters). Wire out was 3 to 1 throughout. The bottom was hard, rocky substrate in areas commercially fished for sea urchins. Tows were made during daylight hours only.

Towing during the day was conducted in roughly the same spot, back and forth. For each day the vessel moved to a new spot within the same general area, so that there were four different places fished (four days) in each of the three main locations – see charts, Figures 2-4. The four places were chosen to be representative of the general area.

On any given day, about four of the six escape panel configurations were tested against the control (no escape panel). Generally, each treatment was towed 3-4 times, and then switched for a different treatment. The control treatment was tested several different times throughout the day, every day. In addition, on six of the twelve days the escape panel configurations were outfitted with an outer bag made of ⅜-inch hex mesh and ½-inch plastic piping (see photos). This catch purse was designed to capture anything that escaped through the escape panel. Below is a list of the treatments and their abbreviations as used in the tables and figures:

Abbr	Escape Panel (Treatment) Types and Positions
C	**C**ontrol (no escape panel exposed)
T	2-inch mesh exposed in **T**op panel
M	2-inch mesh exposed in **M**iddle panel
B	2-inch mesh exposed in **B**ottom panel
E	2-inch mesh exposed in top, middle, and bottom panels (**E**ntire back of drag)
2¼T	2¼-inch mesh exposed in **T**op panel
2¼B	2¼-inch mesh exposed in **B**ottom panel
o (suffix)	with **o**uter catch bag over the escape panel

For each tow, the catch was sorted, bycatch species counted and released, and urchin volume estimated to the nearest tenth of a bushel. Urchin test diameter was measured using electronic calipers and recorded to a MS Excel™ workbook on an Allegro™ field computer, usually for all sea urchins caught. For tows with very high catch rates, a randomly picked sample of the urchins was measured. Tow information (start and end time, depth, loran coordinates, etc.) was recorded for each tow.

Photographs and short video clips were taken throughout the project and compiled to a CD.

Project materials such as the field computer, calipers and other hardware have been returned to the vessel captain in agreement with the NEC contract.

Data and Analyses

To evaluate the success of an escape panel treatment, we considered whether the mean diameter of urchins retained by the drag was significantly larger than those in the control catches. We also examined the percent of sublegal animals in the catches, and the catch rates of legal-sized urchins.

Catch rates for each tow were calculated as the number of urchins caught per minute of towing. The mean, standard deviation, median, minimum, and maximum sea urchin diameter, and the percentage that were sublegal-sized, were calculated for each tow. These calculations were made separately for urchins in the drag and those in the outer bag (when it was used). For tows that were subsampled, the total number of urchins caught was estimated by expanding the sampled number by the ratio of the total volume divided by the sample volume.

Data were pooled for each treatment and day. That is, the data for the four or so tows of the same treatment on a given day were added together to give a daily pooled estimate of catch rate, and mean diameter etc. for each treatment for each day.

Mean diameters for each day for the control tows were analyzed (one-way ANOVA and Tukey Test, (Zar, 1999)) for significant differences among days, keeping the three locations separate. Days that were not significantly different ($P > 0.05$) were pooled together for further analyses of treatment effects on mean diameter. Mean catch rates for the control tows were also analyzed for significant difference among days. Because of non-homogeneous variances in catch rates, the non-parametric Kruskal-Wallis, and Dunn's tests were used instead of the parametric

ANOVA and Tukey. Days that were not significantly different ($P > 0.05$) were pooled for further analyses of treatment effects on mean catch rate.

For each location, catch rates for similar days were pooled by treatment and day, and compared (paired t-test) to see whether the catch rates for the tows using the outer bag were significantly different ($P > 0.05$) from the tows that did not use it. This analysis was also conducted for all locations combined.

For each location, the data pooled for similar days were analyzed (one-way ANOVA and Dunnett Test (Zar, 1999)) to compare treatment mean diameters with control means, not including urchins in the outer bag catches.

For each location, the data pooled for similar days were analyzed (Kruskal-Wallis test (Zar, 1999)) for significant differences among treatment percent sublegal, not including urchins in the outer bag catches. This analysis was also performed as a one-way ANOVA on the arcsine-transformed percent sublegal.

Diameter data for each tow were standardized by tow duration and grouped by 0.5 mm interval, giving the number per tow for each size interval. These were then averaged for each treatment and day, to give a mean number per tow at size. These were plotted as size distributions for each treatment and day, keeping urchins in the drags and urchins in the outer bags separate.

For each tow that used the outer bag, the percentage of sublegal urchins that were retained in the drag, the percentage of sublegals that escaped into the outer bag, and the percentage of legals and oversized that escaped, were calculated. The mean diameter of those escaping, and the mean diameter of those that were sublegal-sized were also calculated.

The rate of escapement (%) vs. the median diameter of the sublegal sea urchins entering the drag, from tows using the outer bag, for all locations, were plotted for two of the treatments.

Selectivity curves were calculated for two of the treatments using data from tows with the outer catch bag from all locations (as described by DeAlteris (2000) for a covered cod end experiment). The 50% retention size (L_{50}), that is, the estimated diameter at which 50% of the urchins will be retained in the drag was estimated for the same two treatments.

For three of the treatments, pooled catch rates of just legal-sized urchins were compared (paired t-test) to pooled catch rates of legal-sized urchins for the control tows on the same day, to see whether the catch rates for the tows using the escape panel treatment were significantly different ($P > 0.05$) from the control tows.

Results

Two-hundred thirty-six (236) tows were completed. See Table 1 for a listing of the treatments applied, and tows accomplished each day at each of the three locations. A total of 59 control tows were made. Between 31 and 38 tows were made for each of the four 2-inch mesh escape panel treatments. Eighteen (18) tows were made for each of the two 2¼-inch escape panel treatments. Fifty-seven (57) of the tows used the outer catch bag. A total of 57,129 urchins were measured during the 12-day project. For seven tows in the Lubec area, subsamples of the catch were measured. For all the other tows, all urchins caught were measured.

Jonesport

Seventy-seven (77) tows were completed in the Jonesport/Jonesboro area (Figure 2). See Table 2 for a listing of catch rates, mean, standard deviation, median, minimum, and maximum sea urchin diameter, and the percentage that were sublegal-sized, for each tow. Table 3 lists the data for each treatment, pooled by day.

Table 8 displays the mean diameters of sea urchins caught by each treatment and day. For the control tows, day was a very highly significant factor ($P < 0.001$), with different mean diameters on different days. Further testing revealed that day 1 and day 4 diameters were both significantly different from all the other days in the control tows. Days 2 and 3 were significantly different (larger) from the others but not from each other. Catch rates were also significantly different in the control tows depending on day, with days 1 and 4 significantly different (higher) from the others, but not each other. Days 2-3 were not significantly different from each other. Urchins were generally larger but less abundant on days 2 and 3, and smaller and more abundant on days 1 and 4. Size and abundance of urchins varied by day, because the vessel moved to a new location each day (Figure 2).

We expect a higher rate of escapement from the panels if the urchins are smaller, but we encountered different sized urchins on different days. Since not all treatments were tested every day, tows performed for a treatment on different days could not be pooled or compared with other treatments because of size differences, except days 2-3. However, we were able to compare the treatment mean diameters, pooled by day, with the control means for the same day (Table 8).

The mean urchin diameter for treatment T (2-inch mesh escape panel in Top) was never significantly different from the control mean on that day. The mean urchin diameter for treatment M (2-inch mesh escape panel in Middle) was significantly larger than the control on day 4 only. The mean urchin diameter for treatment B (2-inch mesh escape panel in Bottom) was significantly larger than the control on day 4, and was larger than the controls on the two other days, though not significantly so. The mean urchin diameter for treatment E (2-inch mesh escape panel in Entire) was significantly larger than the control on day 2, the only day it was tested. However, on day 3, in a location with urchins of similar size to day 2, there were only 2 urchins in the outer bag for treatment Eo, so it is doubtful if the difference is real unless the outer bag adversely affected the performance of the escape panel (see discussion below). The two urchins in the bag were the two smallest, but there were too few small urchins at that location that day to make a difference in mean size retained.

The mean diameter for panel treatment 2¼B (2¼-inch mesh escape panel in Bottom) was higher than the control but not significantly so. Treatment 2¼T (2¼-inch mesh escape panel in Top) did not exhibit any improvement in mean diameter.

There were very few (5 total in 15 tows) urchins caught by the outer bag when it was deployed on day 3. On day 4 there were a total of 30 in 6 tows in the bag (Tables 2-3 and Figure 17). On day 3, only 7.7% of the urchins in the control catches were sublegals. On day 4, 56.9% were sublegal (Table 3).

None of the escape panel treatments significantly reduced the percent of sublegal urchins in the catches, compared with the control tows for the same day (Table 10). It is possible however, that this is due in part to the relatively few numbers of tows for each treatment each day, resulting in a low number of degrees of freedom (df) and low power for statistical testing.

When comparing the catch rates of the tows without the outer catch bags with tows that used it, pooled for days with similar catch rates, and by treatment (Table 3), we found that the tows using the catch bag had significantly lower catch rates than tows without it ($P=0.049$), in Jonesport. It is possible that the outer bag negatively affected the drag's performance. For this reason, we kept these tows separate, as though they were different treatments, throughout the experiment.

The mean urchin diameter in the control tows was less than the legal minimum size (52.39 mm) only on day 4 (Table 8). The percentage of sublegal urchins in the control catches was never more than 25% until day 4, when it varied from 29-71% (Table 2 and size distributions in Figures 5-8). For this reason, it seems unlikely that escape panels would perform well, except on day 4. Unfortunately, not all treatments were tested on day 4.

Summary of results for Jonesport

1) The mean urchin sizes for days 1 and 4 were significantly different (smaller) from all other days in the control tows. Days 2 and 3 are not significantly different from each other. Therefore, days 2-3 can be pooled in any analysis of size.
2) The control tow catch rates were significantly different for certain days: Days 4 and 1 were significantly different (higher) from days 2 and 3, but not from each other. Therefore, day 4 can be pooled with day 1, and day 2 can be pooled with day 3, for any analyses of catch rates.
3) From the analysis of catch rates, the outer bag adversely affected the performance of the drag.
4) The small number of urchins in the outer bags on day 3, and the lack of consistent differences between treatment and control mean sizes on days 1-3, and the relatively large urchin sizes on days 1-3 lead us to conclude there were no treatment effects on those days (except possibly treatment E).
5) The mean urchin size in the control tows was the smallest on day 4. This is the day when the treatments could be expected to be most successful, that is, with mean urchin sizes in the escape panel treatments most likely to be larger than the controls. On all other days the mean diameter in the control tows was well above the legal minimum.
6) On day 4, the only day with a mean diameter less than 52 mm in the controls, treatments B and M performed significantly better than the controls (but 2¼B did not!). E was not tested on this day.
7) None of the treatments significantly reduced the percent of sublegals, on any day.

<u>Cutler</u>

Seventy-seven (77) tows were completed in the Cutler area. See Table 4 for a listing of catch rates, mean, standard deviation, median, minimum, and maximum sea urchin diameter, and the percentage that were sublegal-sized, for each tow. Table 5 lists the data for each treatment, pooled by day.

Table 8 displays the mean diameters of sea urchins caught by each treatment and day. For the control tows, day was a very highly significant factor ($P < 0.001$), with different mean diameters on different days. Further testing revealed that day 6 diameters were significantly different (larger) from the other three days in the control tows. Days 5, 7, and 8 were not significantly different from each other. Catch rates were also significantly different in the control tows depending on day, with day 6 significantly different (lower) from days 5 and 8. Catch rates for days 5, 7, and 8 were not significantly different from each other. Urchins were generally smaller and more abundant on days 5, 7, and 8, and larger and less abundant on day 6. Size and abundance of urchins varied by day, because the vessel moved to a new location each day (Figure 3).

We expect a higher rate of escapement from the panels if the urchins are smaller, but we encountered different sized urchins on different days. Tows performed for a treatment on day 6 could not be pooled with other days or compared with other treatments because of the size differences. However, we were able to compare the treatment mean diameters, pooled by day, with the control means for the same day, and we were able to repeat the analyses for days 5, 7, and 8 combined (Table 8).

None of the escape panel treatments had significantly different mean diameters from the control mean on that day. The same was true when days 5, 7, and 8 were pooled – none of the escape panel treatments had significantly larger mean urchin diameters when compared with the controls (Table 8).

There were also relatively few (27 total in 18 tows) escaping urchins caught by the outer bag when it was deployed (days 7 and 8, Table 4).

None of the escape panel treatments significantly reduced the percent of sublegal urchins in the catches, compared with the control tows for the same day (Table 10).

When comparing the catch rates of the tows without the outer catch bags with tows that used it, with days 7 and 8 pooled, and by treatment (Table 5), we found that the tows using the catch bag had lower catch rates for 4 out of 5 treatments. Although this was not statistically significant ($P=0.12$) in Cutler, it is possible that the outer bag negatively affected the drag's performance. For this reason, we kept these tows separate, as though they were different treatments.

The mean urchin diameter in the control tows was above or close to the legal minimum (52.39 mm) on all days (Table 8). The daily pooled percentage of urchins in the control catches that were sublegal ranged from 14.7% to 52.7% (Table 5).

Summary of results for Cutler

1) The mean urchin sizes on day 6 were significantly larger than on the other three days in the control tows. Days 5, 7, and 8 were not significantly different from each other. Therefore, day 6 must be kept separate in any analysis of size.
2) The catch rate for day 6 was significantly lower than days 5 and 8 in the control tows: Days 5, 7, and 8 were not significantly different from each other. Therefore, day 6 must be kept separate and cannot be pooled for any analysis of catch rates.
3) From the analysis of catch rates, it is inconclusive whether the outer bag adversely affected the performance of the drag.
4) The small number of urchins in the outer bags, and the lack of differences between treatment and control mean sizes on any days, indicate no escape panel treatment effects.
5) The mean urchin size in the control tows on all days was near or above 52.39 mm.
6) None of the treatments significantly reduced the % smalls, on any day.

<u>Lubec (Cobscook Bay)</u>

Eighty-two (82) tows were completed in the Lubec/Eastport (Cobscook Bay) area. See Table 6 for a listing of catch rates, mean, standard deviation, median, minimum, and maximum sea urchin diameter, and the percentage that were sublegal-sized, for each tow. Table 7 lists the data for each treatment, pooled by day.

Table 8 displays the mean diameters of sea urchins caught by each treatment and day. For the control tows, day was a very highly significant factor ($P < 0.001$), with different mean diameters on different days. Further testing revealed that day 11 diameters were significantly different (smaller) from the other three days in the control tows, and day 12 diameters were significantly larger than the other 3 days. Days 9 and 10 were not significantly different from each other. Catch rates were not significantly different in the control tows from day to day. The size of urchins varied by location, and the vessel moved to a new location each day (Figure 4). On day 9 and 10 urchins were small, on day 11 they were even smaller, and on day 12 they were largest. They were relatively abundant on all days, compared with Jonesport and Cutler.

Since the size of urchins varied by day, and because not all treatments were tested every day, treatment tows performed on different days could not be pooled together or compared with other treatments, except days 9-10. However, we were able to compare the treatment mean diameters, pooled by day, with the control mean for the same day, and with days 9-10 combined (Table 8).

The mean urchin diameter for treatment T (2-inch mesh escape panel in Top) was never significantly different from the corresponding control means. The mean urchin diameter for treatment M (2-inch mesh escape panel in Middle) was significantly larger than the control on days 9 and 11 but not day 10. The mean urchin diameter for treatment B (2-inch mesh escape panel in Bottom) was significantly larger than the control on days 9 and 10 but not day 12. The mean urchin diameter for treatment E (2-inch mesh escape panel in Entire) was significantly larger than the control on day 9, larger but not significantly so on day 10, and smaller on day 12. Neither of the two 2¼-inch escape panel treatments showed a significantly larger mean urchin diameter than the controls.

There were 636 urchins (in 18 tows) caught by the outer bag when it was deployed, vastly more than in Jonesport or Cutler. The daily pooled percentage of urchins in the control catches that were sublegal ranged from 44.0% to 73.8% (Table 7).

None of the escape panel treatments significantly reduced the percent of sublegal urchins in the catches, compared with the control tows for the same day (Table 10). It is possible however, that this is due in part to the relatively few numbers of tows for each treatment each day, resulting in a low number of degrees of freedom (df) and low power for statistical testing.

When comparing the catch rates of the tows without the outer catch bags with tows that used it, by day and treatment (Table 7), we found that the tows using the catch bag had lower catch rates for 3 out of 5 treatments. Although this was not statistically significant (P=0.49) in Lubec, it is possible that the outer bag negatively affected the drag's performance. For this reason, we kept these tows separate, as though they were different treatments.

The mean urchin diameter in the control tows was less than the legal minimum size (52.39 mm) on days 9 and 10, and was particularly low on day 11 (46.27mm) (Table 8). Days 9, 10, and 11 had the smallest urchins of the entire experiment. For this reason, one would expect the escape panels to perform well on those days, especially on day 11. Unfortunately, not all treatments were tested on day 11.

Since 73.8% of the urchins caught in the control tows on day 11 were sublegal, we wonder whether harvesters would actually bother to fish in this area. This is a point we hope to clear up when we discuss this report with the industry.

Summary of results for Lubec

1) On day 11, the mean urchin size in the control tows was significantly smaller than on the other three days, and on day 12 it was significantly larger. Days 9 and 10 were not different from each other. Tows on days 9-11 encountered the smallest urchins in the experiment.
2) The control tow catch rates for days 9, 10, 11 and 12 were not significantly different from one another.
3) From the analysis of catch rates, the outer bag did not appear to adversely affect the performance of the drag.
4) Treatment B performed significantly better than the control on days 9-10.
5) Treatments E and M performed significantly better than the control on day 11 (when control mean was smallest, 46.27 mm). Treatment M also performed well on day 9, but not day 10.
6) Treatment E always performed better than the control on days 9-11, though not always significantly so.
7) None of the treatments did better than the control on day 12, when mean urchin size was largest (52.69mm).
8) None of the treatments significantly reduced the % smalls, on any day.

Overall

In reviewing the mean diameter data for the various escape panel treatments, as summarized in Table 8, it appears that none of the treatments consistently resulted in improvements in the size of the urchins retained in the drag. However, if one looks only at the days on which the mean diameter in the control tows was small, less than 52.39 mm, which corresponds to more than 50% sublegal, as displayed in Table 9 (days 4, 7, 8, 9, 10, and 11), **two of the treatments, B and E, seem to have been consistently effective when the urchins encountered were small.**

- Treatment T (2-inch mesh escape panel in Top) improved the size on day 9 but not significantly so, and did not improve the size on day 10. The Top position is that currently used by most of the industry.
- Treatment M (2-inch mesh escape panel in Middle) significantly improved the size on three days but not on three others.
- Treatment B (2-inch mesh escape panel in Bottom) improved the size on all four days, significantly so on three.
- Treatment E (2-inch mesh escape panel in Entire) improved the size on the two days it was tested, significantly so on one.
- Treatment 2¼T did not improve the size on the two days it was tested.
- Treatment 2¼B improved the size on both days it was tested, but not significantly so.

The catch rates for the tows that used the outer bag were smaller than the catch rates for tows that did not use it, in 11 out of 16 day-treatment combinations. This indicated that the outer bag might affect the performance of the drag in some way. Although this was not statistically significant, we did not combine the tows for a treatment that used the bag with tows of the same treatment that did not use it.

However, the outer bag tows provide some useful information. Figures 17-19 and Tables 12-14 present data on the size of the urchins that escaped from the drags, including the percent of the sublegals entering the drag that escaped. This percentage has been plotted against the median size of the sublegals that entered the drag, in Figure 20, for treatments B and E. There is clearly a significant negative linear relationship (R^2=0.94 for treatment E and R^2=0.78 for treatment B) between the size of the small urchins that enter the drag and the number that escape, that is, the smaller they are, the more likely they are to escape.

This is also confirmed by the selectivity curves plotted in Figure 21, in which the percentage of urchins retained in the drag at size is plotted against size. In general, for urchins greater than 50 mm, 100% were retained in the drag. For urchins less than 20 mm, usually none were retained in the drag.

How many sea urchins could be released by using escape panels B or E?

Although escape panels B and E significantly improved the mean size of the urchins that were being retained in some cases (Table 9), the improvements were measured as only a millimeter or two difference in the mean diameter. Would this difference be noticeable in commercial catches?

Clearly, the value of using an escape panel depends on where it is being fished. If it is fished in areas where the urchins are, on average, larger than the legal minimum size (most Jonesport and Cutler locations tested here), a panel seems to offer little improvement in size, with little or no improvement in the number of sublegal urchins retained in the drag (Tables 8 and 10). However, if the urchins are small (most Cobscook Bay locations tested here) (Tables 9 and 11), the escape panels (B and E) provide some improvement, with an improvement (reduction) in the percentage of sublegals in the catch ranging from less than 1% to about 9%, with an average improvement of about 5% for panel B and 3% for panel E (Table 11).

Here is an example of how this might translate into the number of small urchins released: The average control tow on day 10 caught an average of 75.28 urchins per minute, of which 59% were sublegal (Table 7). This would result in 602 urchins caught in a normal 8-minute tow, of which 355 would be sublegal. If an escape panel reduced the number of sublegals by 5% (to 54% sublegal), that would result in 65 sublegal urchins escaping. Since draggers make, on average, about 40 tows/day for a day's catch (from DMR 2005-06 port sampling data, unpublished), about 2,600 small urchins would escape per day's catch. A 3% improvement would result in about 1,625 sublegal urchins escaping per day's catch.

Which escape panel performed better, B or E?

Intuitively, one would expect a panel that covers the entire back of the drag to perform better, or at least as well, as one that only covers the bottom third. However, looking at days 9-10 on Tables 9 and 11, the only days with small urchins on which both treatments were used, treatment B (bottom) seemed to do better than E (entire). This may just be the result of inadequate numbers of samples – panel B was tested six times, and E eight times on days 9-10. On the other hand, looking at tows that used the outer bag, panel E appeared to be more effective. In the plots of escapement rates vs. size of urchins entering the drag – admittedly based on just a few points – the predicted escapement rate for panel E is better than that for B, at the same size (Figure 20). For instance, at, say, 44 mm size, about 10% would escape through panel B, while about 25% would escape through panel E. This trend is confirmed by the selectivity plots in Figure 21, which show that the predicted L_{50}, the size at which there would be 50% escapement, is higher for panel E (25.6 mm) than for panel B (23.1 mm).

A few legal-sized urchins escaped from the drag and were counted in the outer bag catches, for panel treatments Bo, Eo, and 2¼Bo (Tables 12-14 and Figures 17-19 and 21). However, the catch rates for urchins greater than 52.39mm (legals and oversized) for escape panels B, E, and 2¼B (derived from the data on Tables 3, 5, and 7) were not significantly different than the controls (P=0.17, P=0.30, and P=0.33 respectively), indicating that the panels did not significantly hinder the drag's ability to catch and retain legal-sized urchins.

Conclusions

For draggers who fish on small urchins, escape panels in the bottom or entire back of the drag will provide a modest reduction in the number of smalls in the catch.

The performance of the escape panels varied from day to day and place to place, making it difficult to evaluate their overall effectiveness. However, two of the panel treatments, 2-inch mesh in the Bottom of the back of the drag, and 2-inch mesh in the Entire back of the drag, showed consistent improvements in mean urchin size and percent sublegal, compared with control tows, when towed in places where the urchins present were small (mean less than 52.39 mm and percent sublegal greater than 50%). The degree of improvement was relatively small, varying from a reduction of about one to nine percentage points in the percentage of sublegals retained in the catch. The treatment with 2¼-inch mesh in the Bottom may also have been effective, but was not tested enough times to show a significant effect.

It will be important to obtain industry input on whether the panels are cost-effective. It is possible that a modest reduction in the number of small urchins in some catches is not worth the effort. It is also possible the panels are only useful on populations of urchins with individuals so small they are not usually fished, and a small improvement in catch size-distribution in those places might not be important. Conversely, a small improvement in catch size-distributions might turn an unexploitable (because of small urchin size) or marginally exploitable area into a more exploitable one.

Since the industry is now accustomed to using 2-inch mesh escape panels, that did not seem to cause any significant loss of legal-sized urchins in this project, we recommend their continued use, in either the bottom, or, preferably, the entire back of the drag. The utilization of 2¼-inch mesh is promising but needs further study.

Partnerships

This project would not have been possible without the cooperation of people from many different vocations. Fisherman Steve Patryn was involved in project design, from conceiving the original project idea, to design and construction of the drag, picking tow sites, and captaining the vessel during sea trials. Leigh Feeny, an urchin dragger from Jonesboro, assisted in vessel operation by serving as crew member and offering local knowledge in identifying tow sites and hazard areas. Lee Gardner also assisted as crew member. Local fishing gear-builder and welder Everett Roberts, Jr. assisted in the construction of the drag. Leo Murray of Lubec, and other sea urchin draggers offered advice about the drag design. Dana Morse, University of Maine Sea Grant and Cooperative Extension, helped with the computer configuration, and the University of Maine at Machias loaned a computer for downloading the data each night. Three University of Maine at Machias students, as well as Allie Rohrer, and Rachel Gallant of NEC also assisted on board for a day. Consultant scientist Drew Gowen did the lion's share of the logistical preparation, the onboard sampling, data entry, and the preliminary analyses, and was the main liaison for communication between the scientists and harvesters. DMR staff scientists Keri Stepanek and Margaret Hunter developed the statistical design, evaluated the data, and produced the figures for this report.

Impacts and Applications

This project provides some useful information for urchin fishermen, scientists and managers regarding the effectiveness of current drag escape panels and their placement. In addition, it provides preliminary data on the use of a larger escape mesh to cull undersized urchins.

Related Projects

There are no projects associated with this investigation.

Presentations

Steve Patryn spoke at a Cobscook Bay Fishermen's Association meeting in January 2005, and a Sea Urchin Zone Council meeting in March 2005 to inform local fishermen about the project. Steve also discussed the project and cooperative research in general at the Maine Sea Grant sea urchin workshop in Ellsworth in April 2005. In addition, a brief presentation was given by Drew Gowen to a Marine Biology class at the University of Maine at Machias to describe the project and background of urchin fishing. Formal presentations of these results will be made to the Maine Sea Urchin Zone Council in the fall of 2007, and at the sea urchin session of the 2008 Maine Fishermen's Forum, if there is one.

Student Participation

Three undergraduates from the University of Maine at Machias participated in this project, serving as on-board crew for a day: Mike Peck, Angela Mills, and Sara Bigley. All three were students in the Marine Biology program.

Published Reports and Papers

No reports or papers have been published. This report will be made available on DMR's web site at http://www.maine.gov/dmr/rm/seaurchin/research.htm.

Future Research

The escape panels only seemed to be effective under certain conditions - when encountering populations of urchins that were more than 50% sublegal. In this experiment, the number of tows made for each treatment under these conditions was relatively small (about half of the total testing). Further testing needs to be done with the two or three most promising panels, using an experimental design which minimizes the location effects that complicated this experiment. Since sea urchins exhibit great spatial variations in population densities and size distributions (reviewed by Scheibling and Hatcher, 2001), a much greater number of tows may be necessary. A more powerful statistical approach, perhaps using urchin diameters in control tows as a covariate, might also be useful.

There should be further work on comparing 2-inch vs. 2¼-inch mesh, both for escapement of sublegal urchins, and the undesirable escapement of legal ones.

Input from industry members also needs to be gathered, to determine whether the panels would be cost effective. It is possible they are only useful on populations of urchins that are so small they are not usually fished, and a small improvement in catch size-distribution might not be enough to change that. Conversely, a small improvement in catch size-distributions might turn an unexploitable (because of small urchin size) or marginally exploitable area into a more exploitable one.

It is difficult to evaluate any biological benefit that might be derived from escape panels when the mortality rate of culled urchins is not known. If these urchins survive undamaged, then there would be little or no biological benefit. Research into the fate of culled urchins is needed.

Even if there were no biological benefit, the economic benefit of reduced sorting times could be important. Industry input, and/or a cost/benefit study on reduced sorting times would be helpful.

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Table 1. List of tows completed each day, with tow number and treatment type (top); summed by treatment type (middle); with treatment type legend (bottom).

Date	9-Apr	10-Apr	11-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	19-Apr	20-Apr	21-Apr	22-Apr
Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Tow	**Jonesport**				**Cutler**				**Lubec**			
1	C	B	Eo	B	C	B	Eo	B	C	B	Eo	C
2	C	B	Eo	B	C	B	Eo	B	C	B	Eo	C
3	T	C	Eo	2¼B	T	C	Eo	2¼B	T	C	Eo	C
4	T	C	Eo	2¼B	T	C	Eo	2¼B	T	C	Eo	B
5	T	E	C	2¼B	T	E	C	2¼B	T	E	C	B
6	T	E	C	2¼Bo	T	E	C	2¼Bo	T	E	C	B
7	C	E	To	2¼Bo	C	E	To	2¼Bo	C	E	To	B
8	C	E	To	2¼Bo	C	E	To	2¼Bo	C	E	To	E
9	M	C	To	C	E	C	To	C	E	C	To	E
10	M	C	To	C	E	C	To	C	E	C	To	E
11	M	T	C	M	E	T	C	M	E	T	C	E
12	M	T	C	M	E	T	C	M	E	T	C	2¼B
13	C	T	Bo	M	C	T	Bo	M	C	T	Bo	2¼B
14	C	T	Bo	2¼T	C	T	Bo	2¼T	C	T	Bo	2¼B
15	B	C	Bo	2¼T	B	C	Bo	2¼T	B	C	Bo	2¼Bo
16	B	C	Bo	2¼T	B	C	Bo	2¼T	B	C	Bo	2¼Bo
17	B	M	Mo	2¼To	B	M	M	2¼To	B	M	M	2¼Bo
18	B	M	Mo	2¼To	B	M	M	2¼To	B	M	M	2¼T
19		M	Mo	2¼To		M	M	2¼To	M	M	M	2¼T
20				C				C	M			2¼T
21				C				C	M			2¼To
22												2¼To
23												2¼To

Type	Number of Tows Each Day by Escape Panel (Treatment) Type												Totals
C	6	6	4	4	6	6	4	4	6	6	4	3	59
T	4	4	0	0	4	4	0	0	4	4	0	0	24
To	0	0	4	0	0	0	4	0	0	0	4	0	12
M	4	3	0	3	0	3	3	3	3	3	3	0	28
Mo	0	0	3	0	0	0	0	0	0	0	0	0	3
B	4	2	0	2	4	2	0	2	4	2	0	4	26
Bo	0	0	4	0	0	0	4	0	0	0	4	0	12
E	0	4	0	0	4	4	0	0	4	4	0	4	24
Eo	0	0	4	0	0	0	4	0	0	0	4	0	12
2¼T	0	0	0	3	0	0	0	3	0	0	0	3	9
2¼To	0	0	0	3	0	0	0	3	0	0	0	3	9
2¼B	0	0	0	3	0	0	0	3	0	0	0	3	9
2¼Bo	0	0	0	3	0	0	0	3	0	0	0	3	9
Totals	18	19	19	21	18	19	19	21	21	19	19	23	236

Escape Panel (Treatment) Types			
C	Control (none)	**E**	2-inch, Entire
T	2-inch, Top	**2¼T**	2¼-inch, Top
M	2-inch, Middle	**2¼B**	2¼-inch, Bottom
B	2-inch, Bottom	**o**	with outer catch bag

Table 2. Jonesport area tow data (days 1-4). Catch rate is in urchins per minute. “drag” and “bag” indicate catches in the drag or in the outer bag respectively, when the outer bag was used. “Urchins Caught” and “Catch Rate” include all sizes.

Day	Tow Number	Treatment Type	Minutes Towed	Outer Bag?	Urchins Caught	Catch Rate	Sea Urchin Diameter (mm)					Percent Sublegal
							Mean	Median	Std Dev	Min	Max	
1	1	C	7		243	34.7	58.3	58.7	6.3	36.8	71.5	17.3
1	2	C	8		313	39.1	57.2	57.2	5.8	40.4	75.4	17.6
1	3	T	8		304	38.0	57.0	57.3	5.5	28.5	70.2	13.5
1	4	T	8		296	37.0	57.8	58.0	6.4	36.9	84.0	18.2
1	5	T	8		202	25.3	57.8	58.7	6.6	36.7	72.4	16.8
1	6	T	8		263	32.9	56.2	56.5	6.7	31.3	73.6	21.7
1	7	C	8		204	25.5	56.6	56.6	6.6	32.7	76.4	21.1
1	8	C	7		501	71.6	56.6	56.6	6.1	36.9	74.0	22.4
1	9	M	8		222	27.8	57.8	58.5	6.9	35.3	76.4	18.0
1	10	M	8		390	48.8	55.8	55.9	6.1	31.0	72.7	23.6
1	11	M	8		162	20.3	58.5	58.7	6.7	37.7	77.9	12.3
1	12	M	7		159	22.7	57.7	58.5	7.3	37.5	78.7	20.1
1	13	C	9		146	16.2	58.2	59.0	7.2	39.4	78.4	19.2
1	14	C	8		247	30.9	56.6	57.2	7.2	33.8	77.3	23.9
1	15	B	8		155	19.4	57.0	58.5	7.1	34.6	75.9	21.3
1	16	B	8		142	17.8	59.1	59.6	5.4	43.3	75.9	9.9
1	17	B	8		146	18.3	58.9	59.7	6.3	41.2	74.3	17.1
1	18	B	8		256	32.0	56.6	56.9	7.7	34.5	87.1	24.6
2	1	B	6		111	18.5	60.8	61.2	6.6	42.9	77.3	11.7
2	2	B	7		92	13.1	62.6	62.5	5.2	48.8	75.4	3.3
2	3	C	6		68	11.3	60.6	61.7	7.1	42.8	75.9	14.7
2	4	C	8		14	1.8	63.2	61.6	7.4	52.7	76.6	0.0
2	5	E	7		165	23.6	63.6	63.6	6.7	46.6	83.3	5.5
2	6	E	7		107	15.3	62.0	62.3	7.1	42.8	80.7	8.4
2	7	E	8		25	3.1	65.8	64.8	6.6	54.6	79.8	0.0
2	8	E	7		69	9.9	61.4	62.9	7.1	42.5	74.1	11.6
2	9	C	7		15	2.1	59.2	59.1	7.5	44.4	69.8	20.0
2	10	C	7		13	1.9	64.5	64.6	5.8	52.9	71.4	0.0
2	11	T	9		6	0.7	67.0	67.7	10.6	48.7	79.8	16.7
2	12	T	8		17	2.1	57.0	57.7	5.3	47.0	66.6	23.5
2	13	T	7		52	7.4	59.6	58.6	7.9	36.1	82.9	11.5
2	14	T	7		50	7.1	59.1	58.3	7.5	40.8	74.1	18.0
2	15	C	8		26	3.3	61.1	61.4	9.7	42.9	74.9	19.2
2	16	C	8		58	7.3	62.0	62.6	5.8	48.6	81.0	1.7
2	17	M	8		72	9.0	60.5	61.7	7.3	42.3	74.8	13.9
2	18	M	6		18	3.0	60.7	60.4	5.6	51.8	74.7	5.6
2	19	M	7		90	12.9	60.3	60.9	8.5	19.6	79.5	13.3

Table 2 continued.

	Tow	Treatment	Minutes	Outer	Urchins	Catch	Sea Urchin Diameter (mm)					Percent
Day	Number	Type	Towed	Bag?	Caught	Rate	Mean	Median	Std Dev	Min	Max	Sublegal
3	1	Eo	8	drag	78	9.8	60.1	60.3	5.7	44.8	73.9	7.7
				bag	1	0.1	13.3	13.3		13.3	13.3	100.0
3	2	Eo	8	drag	39	4.9	59.5	59.6	7.0	41.4	79.8	10.3
				bag	0	0.0						
3	3	Eo	7	drag	62	8.9	60.6	60.8	5.8	47.7	72.7	8.1
				bag	1	0.1	11.0	11.0		11.0	11.0	100.0
3	4	Eo	8	drag	32	4.0	59.7	60.1	8.9	23.5	72.7	12.5
				bag	0	0.0						
3	5	C	8		25	3.1	59.2	58.9	7.1	38.9	69.7	8.0
3	6	C	8		64	8.0	57.5	57.0	5.3	44.8	71.3	12.5
3	7	To	7	drag	58	8.3	59.6	60.0	5.7	48.1	72.9	12.1
				bag	0	0.0						
3	8	To	8	drag	18	2.3	60.4	58.6	8.3	47.1	80.0	22.2
				bag	0	0.0						
3	9	To	8	drag	59	7.4	60.4	59.9	5.2	45.4	73.8	5.1
				bag	0	0.0						
3	10	To	7	drag	26	3.7	59.9	59.0	6.4	44.3	74.5	7.7
				bag	0	0.0						
3	11	C	8		51	6.4	61.3	60.2	7.2	47.0	76.0	7.8
3	12	C	8		41	5.1	61.2	60.0	4.8	53.7	71.0	0.0
3	13	Bo	9	drag	43	4.8	57.1	57.9	6.4	41.9	73.7	23.3
				bag	1	0.1	14.5	14.5		14.5	14.5	100.0
3	14	Bo	8	drag	57	7.1	60.3	60.6	6.0	46.0	74.7	12.3
				bag	1	0.1	18.9	18.9		18.9	18.9	100.0
3	15	Bo	7	drag	63	9.0	59.9	59.9	6.5	38.7	75.2	7.9
				bag	1	0.1	15.7	15.7		15.7	15.7	100.0
3	16	Bo	7	drag	8	1.1	65.5	65.5	5.5	57.6	73.1	0.0
				bag	0	0.0						
3	17	Mo	8	drag	32	4.0	57.7	57.5	6.1	41.6	76.4	12.5
				bag	0	0.0						
3	18	Mo	8	drag	36	4.5	59.8	59.0	5.9	45.4	73.5	8.3
				bag	0	0.0						
3	19	Mo	7	drag	53	7.6	60.9	60.5	6.1	43.3	74.4	5.7
				bag	0	0.0						
4	1	B	8		362	45.3	52.2	52.1	6.6	31.4	71.6	51.4
4	2	B	8		260	32.5	52.1	52.9	5.9	26.9	71.1	46.9
4	3	2¼ B	8		276	34.5	51.1	51.2	6.9	22.5	67.7	58.0
4	4	2¼ B	8		256	32.0	51.5	51.7	7.7	22.1	71.5	54.3
4	5	2¼ B	9		433	48.1	50.9	50.9	6.9	11.8	73.7	56.8
4	6	2¼Bo	8	drag	308	38.5	49.7	50.0	6.5	24.0	68.8	67.5
				bag	2	0.3	48.2	48.2	3.1	46.1	50.4	100.0
4	7	2¼Bo	7	drag	159	22.7	53.2	53.1	6.0	40.6	80.5	45.3
				bag	8	1.1	48.9	48.4	4.6	43.5	56.2	75.0
4	8	2¼Bo	8	drag	284	35.5	52.2	52.1	6.7	27.8	77.5	53.2
				bag	6	0.8	40.1	39.6	12.9	22.6	62.0	83.3
4	9	C	8		77	9.6	56.1	55.9	6.6	42.9	75.1	28.6
4	10	C	7		313	44.7	53.2	53.4	7.3	28.8	73.4	39.6
4	11	M	7		131	18.7	51.5	52.0	6.2	35.0	64.8	52.7
4	12	M	8		397	49.6	51.1	50.9	6.5	25.0	72.5	59.9
4	13	M	8		209	26.1	52.7	53.0	6.3	25.8	72.6	44.5
4	14	2¼ T	7		273	39.0	50.8	51.5	5.8	28.8	72.5	56.8
4	15	2¼ T	8		346	43.3	49.2	49.8	6.4	27.7	68.8	70.5
4	16	2¼ T	7		319	45.6	51.5	51.7	5.9	33.6	65.8	53.9
4	17	2¼ To	8	drag	404	50.5	50.9	50.9	6.8	22.9	75.9	59.4
				bag	3	0.4	43.0	43.4	5.8	37.0	48.5	100.0
4	18	2¼ To	7	drag	233	33.3	49.9	50.5	6.8	26.6	70.1	62.2
				bag	2	0.3	46.5	46.5	6.3	42.1	51.0	100.0
4	19	2¼ To	8	drag	377	47.1	49.4	48.8	7.1	25.2	72.7	70.6
				bag	9	1.1	39.6	41.8	12.1	12.5	50.9	100.0
4	20	C	7		263	37.6	48.7	49.1	6.9	28.5	72.5	71.1
4	21	C	8		379	47.4	49.3	49.8	7.0	25.0	80.5	67.0

Totals 77 tows 12,358 urchins caught and measured

Table 3. Jonesport area tow data pooled by treatment and day. Urchins caught are the same as urchins sampled (no subsampling).

Treatment Type	Day	Number of Tows	With Outer Bag?	Total Urchins Caught	Pooled Catch Rate (num/min)	Pooled Sea Urchin Diameter (mm) Mean	Median	Std Dev	Min	Max	Pooled Percent Sublegal
C	1	6		1,654	35.2	57.09	57.35	6.5	32.7	78.4	20.5
C	2	6		194	4.4	61.42	61.99	7.1	42.8	81.0	9.8
C	3	4		181	5.7	59.63	58.97	6.3	38.9	76.0	7.7
C	4	4		1,032	34.4	50.85	51.18	7.4	25.0	80.5	56.9
T	1	4		1,065	33.3	57.15	57.52	6.3	28.5	84.0	17.5
T	2	4		125	4.0	59.38	58.68	7.7	36.1	82.9	16.0
To	3	4	drag	161	5.4	60.06	59.47	6.0	44.3	80.0	9.9
			bag	0	0.0						
M	1	4		933	30.1	57.07	57.23	6.7	31.0	78.7	19.7
M	2	3		180	8.6	60.41	61.30	7.8	19.6	79.5	12.8
M	4	3		737	32.0	51.66	51.72	6.4	25.0	72.6	54.3
Mo	3	3	drag	121	5.3	59.74	59.79	6.1	41.6	76.4	8.3
			bag	0	0.0						
B	1	4		699	21.8	57.70	58.31	6.9	34.5	87.1	19.3
B	2	2		203	15.6	61.64	61.60	6.0	42.9	77.3	7.9
B	4	2		622	38.9	52.17	52.59	6.4	26.9	71.6	49.5
Bo	3	4	drag	171	5.5	59.60	59.70	6.5	38.7	75.2	12.9
			bag	3	0.1	16.36	15.66	2.3	14.5	18.9	100.0
E	2	4		366	12.6	62.85	63.22	7.0	42.5	83.3	7.1
Eo	3	4	drag	211	6.8	60.07	60.37	6.5	23.5	79.8	9.0
			bag	2	0.1	12.15	12.15	1.7	11.0	13.3	100.0
2¼ T	4	3		938	42.6	50.42	51.04	6.1	27.7	72.5	60.9
2¼ To	4	3	drag	1,014	44.1	50.15	50.17	6.9	22.9	75.9	64.2
			bag	14	0.6	41.29	42.77	10.2	12.5	51.0	100.0
2¼ B	4	3		965	38.6	51.09	51.21	7.1	11.8	73.7	56.5
2¼ Bo	4	3	drag	751	32.7	51.38	51.41	6.6	24.0	80.5	57.4
			bag	16	0.7	45.51	46.10	9.2	22.6	62.0	81.3
Totals				12,358							

Table 4. Cutler area tow data (days 5-8). Catch rate is in urchins per minute. "drag" and "bag" indicate catches in the drag or in the outer bag respectively, when the outer bag was used. "Urchins Caught" and "Catch Rate" include all sizes.

Day	Tow Number	Treatment Type	Minutes Towed	Outer Bag?	Urchins Caught	Catch Rate	Sea Urchin Diameter (mm) Mean	Median	Std Dev	Min	Max	Percent Sublegal
5	1	C	5		584	116.8	52.7	53.0	5.6	28.3	68.3	45.0
5	2	C	5		482	96.4	53.5	53.7	6.8	28.8	74.9	41.5
5	3	T	5		369	73.8	53.0	53.8	6.8	29.0	68.1	42.0
5	4	T	5		602	120.4	52.7	53.2	6.5	24.8	77.6	43.4
5	5	T	5		408	81.6	52.9	53.4	6.8	23.5	73.4	45.1
5	6	T	5		341	68.2	50.9	51.2	7.1	28.9	71.4	54.3
5	7	C	5		322	64.4	52.1	52.8	5.9	30.4	68.0	48.1
5	8	C	5		338	67.6	50.4	51.4	7.1	26.1	72.6	56.5
5	9	E	5		432	86.4	51.6	51.9	6.7	25.9	69.7	51.9
5	10	E	5		398	79.6	53.1	53.5	5.6	32.5	70.1	41.2
5	11	E	4		360	90.0	52.0	52.2	6.2	30.8	71.8	52.5
5	12	E	5		242	48.4	52.7	52.6	5.7	31.7	68.1	47.5
5	13	C	5		323	64.6	52.7	53.4	6.5	29.4	69.3	42.4
5	14	C	5		175	35.0	53.8	54.2	6.0	32.8	70.3	37.1
5	15	B	5		292	58.4	51.3	52.0	6.8	27.3	74.7	53.8
5	16	B	5		408	81.6	51.6	52.2	7.1	30.8	71.5	51.0
5	17	B	5		291	58.2	53.8	54.0	7.4	25.4	81.1	36.4
5	18	B	5		356	71.2	51.5	52.8	7.8	23.4	74.2	46.6
6	1	B	6		52	8.7	59.5	59.0	9.7	24.8	78.0	15.4
6	2	B	7		88	12.6	57.4	58.4	9.1	22.0	76.4	26.1
6	3	C	6		106	17.7	58.9	59.1	6.4	38.0	74.1	10.4
6	4	C	7		53	7.6	60.9	61.0	7.2	41.4	74.0	11.3
6	5	E	6		91	15.2	58.2	59.6	7.4	28.8	75.1	22.0
6	6	E	6		52	8.7	61.7	61.6	8.0	39.1	77.1	9.6
6	7	E	6		113	18.8	58.6	58.2	8.3	30.5	80.4	15.9
6	8	E	6		29	4.8	56.8	58.3	10.1	20.8	70.1	20.7
6	9	C	7		91	13.0	58.6	59.6	6.0	34.5	70.0	12.1
6	10	C	7		91	13.0	58.4	59.6	7.5	35.5	77.3	20.9
6	11	T	7		84	12.0	58.7	59.6	8.1	29.5	74.0	16.7
6	12	T	7		60	8.6	59.7	60.3	7.7	40.3	74.1	16.7
6	13	T	7		79	11.3	58.4	59.0	6.8	38.9	72.5	17.7
6	14	T	7		30	4.3	58.6	58.3	4.8	51.1	66.9	6.7
6	15	C	7		84	12.0	59.2	60.4	7.6	27.1	72.6	14.3
6	16	C	7		45	6.4	58.5	59.5	8.3	38.3	74.6	22.2
6	17	M	7		76	10.9	58.7	58.8	6.2	43.8	76.1	17.1
6	18	M	7		23	3.3	59.6	60.0	7.2	45.0	77.5	17.4
6	19	M	7		124	17.7	60.4	60.7	6.7	40.1	75.8	9.7

Table 4 continued.

Day	Tow Number	Treatment Type	Minutes Towed	Outer Bag?	Urchins Caught	Catch Rate	Sea Urchin Diameter (mm)					Percent Sublegal
							Mean	Median	Std Dev	Min	Max	
7	1	Eo	5	drag	501	100.2	52.6	52.1	7.8	31.3	86.3	51.1
				bag	2	0.4	34.9	34.9	6.4	30.4	39.4	100.0
7	2	Eo	5	drag	320	64.0	50.2	50.7	7.3	26.5	68.6	58.4
				bag	2	0.4	42.6	42.6	3.4	40.2	45.0	100.0
7	3	Eo	5	drag	440	88.0	53.0	53.3	7.2	21.4	72.5	44.3
				bag	2	0.4	42.4	42.4	6.0	38.1	46.6	100.0
7	4	Eo	5	drag	194	38.8	52.0	51.3	8.1	31.7	74.2	54.6
				bag	4	0.8	missing					
7	5	C	5		296	59.2	51.6	51.0	7.5	33.1	74.9	56.1
7	6	C	5		202	40.4	54.3	55.1	6.9	35.4	77.0	38.1
7	7	To	5	drag	345	69.0	49.5	49.1	7.4	28.1	72.8	64.9
				bag	0	0.0						
7	8	To	5	drag	190	38.0	54.7	54.4	7.6	35.7	87.3	36.3
				bag	1	0.2	42.8	42.8		42.8	42.8	100.0
7	9	To	5	drag	264	52.8	50.4	50.3	7.3	24.6	72.5	64.0
				bag	0	0.0						
7	10	To	5	drag	156	31.2	53.4	53.6	7.0	35.5	78.7	40.4
				bag	2	0.4	40.5	40.5	10.0	33.4	47.6	100.0
7	11	C	5		256	51.2	51.5	51.4	7.2	31.6	70.3	54.7
7	12	C	5		178	35.6	51.4	51.9	7.6	32.0	72.9	53.9
7	13	Bo	5	drag	308	61.6	50.5	50.4	7.5	34.1	80.8	61.4
				bag	2	0.4	44.1	44.1	6.9	39.2	48.9	100.0
7	14	Bo	5	drag	437	87.4	50.1	50.1	7.4	22.5	85.1	62.2
				bag	3	0.6	34.2	29.5	9.2	28.4	44.8	100.0
7	15	Bo	5	drag	263	52.6	49.3	50.3	7.7	30.0	69.5	63.9
				bag	4	0.8	36.9	34.2	6.8	32.2	47.0	100.0
7	16	Bo	5	drag	326	65.2	52.5	52.8	8.2	32.1	75.6	47.2
				bag	2	0.4	43.0	43.0	1.4	42.0	44.0	100.0
7	17	M	5		193	38.6	50.3	50.2	7.8	33.0	77.9	59.6
7	18	M	5		206	41.2	50.1	50.1	7.4	34.3	68.8	61.7
7	19	M	5		286	57.2	47.9	48.1	7.4	27.7	71.7	71.0
8	1	B	4		327	81.8	51.6	51.1	6.4	12.3	70.8	59.0
8	2	B	3		167	55.7	54.2	54.8	6.4	32.9	67.9	34.1
8	3	2¼ B	3		164	54.7	52.8	52.9	7.4	28.2	72.5	47.6
8	4	2¼ B	3		471	157.0	52.0	52.3	5.6	32.1	78.7	50.3
8	5	2¼ B	3		437	145.7	51.6	51.7	5.9	30.7	68.8	56.8
8	6	2¼Bo	3	drag	532	177.3	51.7	51.9	5.0	30.5	67.6	54.1
				bag	1	0.3	41.8	41.8		41.8	41.8	100.0
8	7	2¼Bo	3	drag	335	111.7	51.9	51.9	5.5	38.8	65.8	52.5
				bag	1	0.3	54.7	54.7		54.7	54.7	0.0
8	8	2¼Bo	3	drag	255	85.0	52.8	52.7	5.7	35.7	69.1	47.5
				bag	1	0.3	56.2	56.2		56.2	56.2	0.0
8	9	C	2		166	83.0	51.4	51.5	6.9	32.0	79.1	55.4
8	10	C	3		430	143.3	51.6	51.6	5.7	37.0	72.5	58.4
8	11	M	3		442	147.3	51.9	51.8	5.9	30.3	68.8	54.5
8	12	M	3		197	65.7	53.0	52.5	5.9	30.9	68.4	49.2
8	13	M	3		220	73.3	50.9	51.4	6.4	27.7	69.2	59.1
8	14	2¼ T	3		556	185.3	51.8	52.0	6.2	33.5	70.2	53.1
8	15	2¼ T	3		244	81.3	50.5	51.4	6.2	28.3	66.3	58.2
8	16	2¼ T	3		260	86.7	52.0	52.2	6.3	32.8	70.1	51.9
8	17	2¼To	3	drag	402	134.0	50.4	50.2	6.2	31.5	70.7	63.7
				bag	0	0.0						
8	18	2¼To	3	drag	158	52.7	51.5	51.7	6.0	34.6	65.0	54.4
				bag	0	0.0						
8	19	2¼To	3	drag	340	113.3	52.7	53.3	6.1	31.3	70.2	43.8
				bag	0	0.0						
8	20	C	3		156	52.0	52.4	53.1	6.8	31.8	67.8	46.2
8	21	C	3		185	61.7	52.8	54.2	6.8	29.6	67.6	42.7

Totals 77 tows 19,926 urchins caught and measured

Table 5. Cutler area tow data pooled by treatment and day. Urchins caught are the same as urchins sampled (no subsampling).

Treatment Type	Day	Number of Tows	With Outer Bag?	Total Urchins Caught	Pooled Catch Rate (num/min)	Pooled Sea Urchin Diameter (mm)					Pooled Percent Sublegal
						Mean	Median	Std Dev	Min	Max	
C	5	6		2,224	74.1	52.51	53.01	6.4	26.1	74.9	45.5
C	6	6		470	11.5	58.99	59.93	7.1	27.1	77.3	14.7
C	7	4		932	46.6	52.12	52.16	7.4	31.6	77.0	51.4
C	8	4		937	85.2	51.96	52.08	6.3	29.6	79.1	52.7
T	5	4		1,720	86.0	52.46	53.06	6.8	23.5	77.6	45.6
T	6	4		253	9.0	58.81	59.23	7.3	29.5	74.1	15.8
To	7	4	drag	955	47.8	51.42	51.40	7.6	24.6	87.3	55.0
			bag	3	0.2	41.29	42.81	7.2	33.4	47.6	100.0
M	6	3		223	10.6	59.73	59.80	6.6	40.1	77.5	13.0
M	7	3		685	45.7	49.24	49.23	7.5	27.7	77.9	65.0
M	8	3		859	95.4	51.87	51.96	6.1	27.7	69.2	54.5
B	5	4		1,347	67.4	51.97	52.72	7.4	23.4	81.1	47.3
B	6	2		140	10.8	58.16	58.91	9.4	22.0	78.0	22.1
B	8	2		494	70.6	52.46	52.32	6.5	12.3	70.8	50.6
Bo	7	4	drag	1,334	66.7	50.59	50.64	7.8	22.5	85.1	58.7
			bag	11	0.6	38.57	39.20	7.2	28.4	48.9	100.0
E	5	4		1,432	75.4	52.32	52.64	6.1	25.9	71.8	48.3
E	6	4		285	11.9	58.83	59.37	8.3	20.8	80.4	17.2
Eo	7	4	drag	1,455	72.8	52.10	52.14	7.6	21.4	86.3	51.1
			bag	10	0.5	39.94	39.81	5.8	30.4	46.6	60-100
2¼ T	8	3		1,060	117.8	51.55	51.89	6.3	28.3	70.2	54.0
2¼ To	8	3	drag	900	100.0	51.48	51.76	6.2	31.3	70.7	54.6
			bag	0	0.0						
2¼ B	8	3		1,072	119.1	51.98	52.10	6.0	28.2	78.7	52.5
2¼ Bo	8	3	drag	1,122	124.7	52.02	52.11	5.3	30.5	69.1	52.1
			bag	3	0.3	50.87	54.67	7.9	41.8	56.2	33.3
Totals				19,926							

Table 6. Lubec area tow data (days 9-12). Catch rate is in urchins per minute. “drag” and “bag” indicate catches in the drag or the outer bag respectively, when the outer bag was used. “Urchins Sampled,” “Caught” and “Catch Rate” include all sizes.

	Tow	Treatment	Minutes	Outer	Urchins	Subsample	Urchins	Catch	Sea Urchin Diameter (mm)					Sublegals	
Day	Number	Type	Towed	Bag?	Sampled	Expansion	Caught	Rate	Mean	Median	Std Dev	Min	Max	Sampled	%
9	1	C	3		387	2.6	1,006	335.4	49.7	51.6	9.3	13.2	66.9	219	56.6
9	2	C	3		636	1	636	212.0	49.1	50.4	9.4	14.9	69.9	396	62.3
9	3	T	3		47	1	47	15.7	53.7	54.0	7.9	34.3	72.3	18	38.3
9	4	T	3		246	1	246	82.0	51.4	52.2	9.0	20.2	74.9	124	50.4
9	5	T	3		242	1	242	80.7	51.7	52.3	7.3	24.2	69.7	124	51.2
9	6	T	3		407	2.0	814	271.3	49.2	50.5	10.4	12.9	76.1	232	57.0
9	7	C	3		276	1	276	92.0	49.6	51.1	9.4	16.9	70.0	160	58.0
9	8	C	3		290	1	290	96.7	51.2	51.9	8.7	16.7	68.8	155	53.4
9	9	E	3		236	1	236	78.7	52.7	53.8	9.2	13.3	71.0	95	40.3
9	10	E	3		366	2.0	732	244.0	50.4	51.9	9.5	15.1	69.7	192	52.5
9	11	E	3		152	1	152	50.7	50.3	51.7	9.0	14.0	68.8	81	53.3
9	12	E	3		605	1	605	201.7	50.2	51.3	8.8	19.4	72.4	331	54.7
9	13	C	3		230	1	230	76.7	50.9	51.9	8.5	13.4	67.8	119	51.7
9	14	C	3		212	1	212	70.7	51.0	51.5	7.8	18.3	71.9	115	54.2
9	15	B	3		234	1	234	78.0	52.2	53.1	7.5	26.9	66.9	102	43.6
9	16	B	3		258	1	258	86.0	50.7	51.4	7.6	23.3	71.1	148	57.4
9	17	B	3		195	1	195	65.0	52.0	53.0	8.2	15.9	68.7	92	47.2
9	18	B	3		194	1	194	64.7	52.6	53.4	6.9	15.8	69.1	82	42.3
9	19	M	4		209	1	209	52.3	51.5	52.3	8.0	21.3	70.2	106	50.7
9	20	M	3		150	1	150	50.0	52.9	53.1	7.6	28.0	75.9	69	46.0
9	21	M	3		103	1	103	34.3	51.3	52.3	8.7	20.4	71.9	53	51.5
10	1	B	4		495	1	495	123.8	49.7	50.5	6.5	25.7	67.3	313	63.2
10	2	B	4		315	1	315	78.8	51.7	52.8	7.4	21.1	71.5	147	46.7
10	3	C	4		351	1	351	87.8	50.4	51.1	7.1	21.4	68.4	201	57.3
10	4	C	5		519	1	519	103.8	49.9	51.2	8.0	22.2	69.4	291	56.1
10	5	E	5		276	1	276	55.2	52.0	52.6	6.7	30.6	73.0	134	48.6
10	6	E	5		239	1	239	47.8	50.5	51.5	7.2	22.4	63.5	138	57.7
10	7	E	5		304	1	304	60.8	48.9	50.6	7.8	26.1	64.5	187	61.5
10	8	E	5		295	1	295	59.0	48.8	49.4	8.3	15.2	68.8	191	64.7
10	9	C	5		304	1	304	60.8	50.0	51.1	7.0	25.0	67.5	180	59.2
10	10	C	5		233	1	233	46.6	48.2	49.7	8.3	22.1	65.0	151	64.8
10	11	T	5		933	1	933	186.6	47.8	49.2	8.6	17.2	66.1	618	66.2
10	12	T	5		471	2.3	1,083	216.7	49.8	51.0	8.7	14.2	69.6	264	56.1
10	13	T	5		565	1	565	113.0	48.2	49.5	8.5	14.1	68.7	372	65.8
10	14	T	5		354	1	354	70.8	49.4	50.5	8.1	10.6	69.0	219	61.9
10	15	C	5		395	1	395	79.0	49.3	50.5	7.4	23.7	68.0	252	63.8
10	16	C	5		381	1	381	76.2	49.8	51.2	8.3	20.2	71.4	214	56.2
10	17	M	5		340	1	340	68.0	48.3	49.1	7.5	19.4	66.8	235	69.1
10	18	M	5		221	1	221	44.2	51.6	52.1	6.2	31.8	65.5	115	52.0
10	19	M	5		145	1	145	29.0	49.0	51.5	8.6	24.9	66.4	78	53.8

Table 6 continued.

Day	Tow Number	Treatment Type	Minutes Towed	Outer Bag?	Urchins Sampled	Subsample Expansion	Urchins Caught	Catch Rate	Sea Urchin Diameter (mm) Mean	Median	Std Dev	Min	Max	Sublegals Sampled	%
11	1	Eo	4	drag	365	1	365	91.3	47.3	48.0	7.8	21.3	63.5	279	76.4
				bag	50	1	50	12.5	38.2	38.9	10.2	13.3	56.5	45	90.0
11	2	Eo	4	drag	189	1	189	47.3	46.9	48.0	8.5	22.2	66.4	133	70.4
				bag	49	1	49	12.3	37.1	37.8	10.2	12.0	55.0	47	95.9
11	3	Eo	4	drag	198	1	198	49.5	47.1	48.6	9.0	15.8	65.8	135	68.2
				bag	69	1	69	17.3	35.0	36.7	11.6	9.8	58.8	65	94.2
11	4	Eo	4	drag	555	1	555	138.8	47.8	48.6	7.8	19.3	67.7	395	71.2
				bag	82	1	82	20.5	31.5	31.8	12.6	8.9	53.7	81	98.8
11	5	C	4		259	1	259	64.8	45.4	46.8	9.1	18.5	62.5	203	78.4
11	6	C	4		406	1	406	101.5	46.8	48.5	9.0	18.5	73.8	283	69.7
11	7	To	4	drag	305	3.33	1,017	254.2	44.7	47.0	9.8	18.2	64.4	231	75.7
				bag	16	1	16	4.0	24.7	24.7	8.6	10.5	39.5	16	100.0
11	8	To	4	drag	268	1	268	67.0	49.2	49.8	8.1	21.2	63.6	163	60.8
				bag	18	1	18	4.5	20.1	19.4	5.8	11.7	32.6	18	100.0
11	9	To	4	drag	220	1	220	55.0	46.9	48.8	8.2	21.0	61.1	159	72.3
				bag	2	1	2	0.5	37.3	37.3	9.8	30.3	44.2	2	100.0
11	10	To	4	drag	249	1	249	62.3	47.1	48.2	9.3	19.4	66.2	172	69.1
				bag	4	1	4	1.0	36.6	38.2	13.6	20.5	49.6	4	100.0
11	11	C	4		374	1	374	93.5	46.3	47.3	8.5	14.9	63.5	274	73.3
11	12	C	4		181	1	181	45.3	46.2	47.9	8.5	17.4	66.3	140	77.3
11	13	Bo	4	drag	218	1	218	54.5	44.8	46.3	8.7	9.2	66.1	186	85.3
				bag	53	1	53	13.3	28.8	28.6	10.7	11.3	49.1	53	100.0
11	14	Bo	4	drag	298	1	298	74.5	46.6	47.7	8.7	12.4	71.1	217	72.8
				bag	23	1	23	5.8	29.2	28.3	11.0	15.7	54.5	21	91.3
11	15	Bo	4	drag	414	1	414	103.5	44.9	45.7	8.2	23.5	67.3	337	81.4
				bag	55	1	55	13.8	28.8	30.5	10.7	10.5	52.5	54	98.2
11	16	Bo	3	drag	297	1	297	99.0	46.6	47.9	7.6	19.2	65.8	232	78.1
				bag	22	1	22	7.3	29.2	30.7	12.3	10.7	49.6	22	100.0
11	17	M	4		425	1	425	106.3	47.4	48.8	8.7	22.4	67.6	293	68.9
11	18	M	4		203	1	203	50.8	48.8	49.2	7.9	23.9	66.8	135	66.5
11	19	M	4		385	1	385	96.3	47.6	48.2	7.9	16.5	69.1	280	72.7
12	1	C	4		372	2.25	837	209.3	52.8	53.9	8.7	19.3	71.3	157	42.2
12	2	C	5		202	1	202	40.4	52.5	52.8	8.2	12.6	70.5	94	46.5
12	3	C	4		417	1	417	104.3	52.6	53.5	8.4	19.5	74.8	185	44.4
12	4	B	4		60	1	60	15.0	51.4	51.1	6.1	35.6	68.0	35	58.3
12	5	B	4		540	1	540	135.0	53.4	54.3	8.3	23.4	73.0	209	38.7
12	6	B	4		373	2.0	746	186.5	51.2	52.6	8.7	16.8	70.8	182	48.8
12	7	B	4		229	1	229	57.3	53.7	53.7	7.9	33.7	71.2	95	41.5
12	8	E	5		235	1	235	47.0	50.8	52.2	9.5	21.7	72.2	119	50.6
12	9	E	4		242	1	242	60.5	52.5	53.3	7.8	23.4	68.9	109	45.0
12	10	E	4		798	1	798	199.5	51.6	52.8	9.1	10.2	71.5	386	48.4
12	11	E	4		206	1	206	51.5	52.5	53.6	8.6	17.5	71.5	97	47.1
12	12	2¼ B	4		45	1	45	11.3	53.8	54.4	10.3	13.0	72.6	15	33.3
12	13	2¼ B	4		264	1	264	66.0	50.4	51.7	9.0	19.0	72.0	146	55.3
12	14	2¼ B	4		50	1	50	12.5	55.8	56.2	7.2	38.5	68.8	16	32.0
12	15	2¼Bo	4	drag	404	1	404	101.0	50.0	51.8	10.4	13.6	71.9	214	53.0
				bag	49	1	49	12.3	32.0	33.3	12.8	9.2	57.0	48	98.0
12	16	2¼Bo	4	drag	38	1	38	9.5	53.6	54.4	8.8	26.1	69.3	14	36.8
				bag	36	1	36	9.0	38.1	44.6	15.4	11.3	56.7	31	86.1
12	17	2¼Bo	5	drag	546	1	546	109.2	52.0	53.4	9.8	14.6	73.6	248	45.4
				bag	63	1	63	12.6	37.3	36.8	11.1	15.7	60.9	56	88.9
12	18	2¼ T	4		164	1	164	41.0	53.2	54.5	9.5	18.5	71.3	70	42.7
12	19	2¼ T	4		101	1	101	25.3	52.3	51.3	7.3	28.8	72.1	55	54.5
12	20	2¼ T	4		118	1	118	29.5	52.4	53.7	9.6	22.6	70.8	50	42.4
12	21	2¼ To	4	drag	56	1	56	14.0	51.9	52.6	7.1	29.5	67.9	28	50.0
				bag	20	1	20	5.0	18.3	14.0	10.9	9.1	49.7	20	100.0
12	22	2¼ To	4	drag	50	1	50	12.5	52.0	53.2	7.1	31.0	67.9	22	44.0
				bag	10	1	10	2.5	16.6	15.9	2.3	13.0	20.4	10	100.0
12	23	2¼ To	5	drag	79	1	79	15.8	51.9	53.5	9.9	9.2	70.8	34	43.0
				bag	15	1	15	3.0	17.2	12.8	9.3	10.6	43.7	15	100.0
Totals	82 tows				24,845	measured,	28,399	caught						14,748	

Table 7. Lubec area tow data pooled by treatment and day.

Treatment Type	Day	Total Minutes Towed	Number of Tows	with Outer Bag?	Total Urchins Sampled	Total Urchins Caught	Pooled Catch Rate (num/min)	Pooled Sea Urchin Diameter (mm) Mean	Median	Std Dev	Min	Max	Pooled Sublegals Sampled	%
C	9	18	6		2,031	2,650	147.2	49.99	51.12	9.1	13.2	71.9	1,164	57.3
C	10	29	6		2,183	2,183	75.3	49.69	50.95	7.7	20.2	71.4	1,289	59.0
C	11	16	4		1,220	1,220	76.3	46.27	47.51	8.8	14.9	73.8	900	73.8
C	12	13	3		991	1,456	112.0	52.69	53.55	8.5	12.6	74.8	436	44.0
T	9	12	4		942	1,349	112.4	50.67	51.79	9.3	12.9	76.1	498	52.9
T	10	20	4		2,323	2,935	146.8	48.55	49.86	8.6	10.6	69.6	1,473	63.4
To	11	16	4	drag	1,042	1,754	109.6	46.90	48.65	9.1	18.2	66.2	725	69.6
				bag	40	40	2.5	24.44	22.62	9.6	10.5	49.6	40	100.0
M	9	10	3		462	462	46.2	51.95	52.46	8.0	20.4	75.9	228	49.4
M	10	15	3		706	706	47.1	49.46	50.73	7.5	19.4	66.8	428	60.6
M	11	12	3		1,013	1,013	84.4	47.75	48.77	8.2	16.5	69.1	708	69.9
B	9	12	4		881	881	73.4	51.82	52.72	7.6	15.8	71.1	424	48.1
B	10	8	2		810	810	101.3	50.50	51.50	6.9	21.1	71.5	460	56.8
B	12	16	4		1,202	1,575	98.4	52.68	53.43	8.3	16.8	73.0	521	43.3
Bo	11	15	4	drag	1,227	1,227	81.8	45.72	46.82	8.3	9.2	71.1	972	79.2
				bag	153	153	10.2	28.91	29.31	10.9	10.5	54.5	150	98.0
E	9	12	4		1,359	1,725	143.8	50.70	52.00	9.1	13.3	72.4	699	51.4
E	10	20	4		1,114	1,114	55.7	49.97	51.11	7.7	15.2	73.0	650	58.3
E	12	17	4		1,481	1,481	87.1	51.74	52.79	8.9	10.2	72.2	711	48.0
Eo	11	16	4	drag	1,307	1,307	81.7	47.43	48.36	8.1	15.8	67.7	942	72.1
				bag	250	250	15.6	34.90	36.27	11.7	8.9	58.8	238	95.2
2¼ T	12	12	3		383	383	31.9	52.71	53.63	9.0	18.5	72.1	175	45.7
2¼ To	12	13	3	drag	185	185	14.2	51.95	53.24	8.3	9.2	70.8	84	45.4
				bag	45	45	3.5	17.56	14.77	9.0	9.1	49.7	45	100.0
2¼ B	12	12	3		359	359	29.9	51.57	52.66	9.2	13.0	72.6	177	49.3
2¼ Bo	12	13	3	drag	988	988	76.0	51.25	52.78	10.0	13.6	73.6	476	48.2
				bag	148	148	11.4	35.73	37.97	13.0	9.2	60.9	135	91.2
Totals			82		24,845	28,399							14,748	

Table 8. Mean sea urchin diameters (mm), from data pooled by treatment and day (above), and pooled by treatment with similar days (similar mean diameters in the control tows) combined (below). Means for tows with the outer bag (**o** suffix) are for the contents of the drag only.

Day	1	2	3	4	5	6	7	8	9	10	11	12
Treatment	**Jonesport**				**Cutler**				**Lubec**			
C	**57.09**	**61.42**	**59.63**	**50.85**	**52.51**	**58.99**	**52.12**	**51.96**	**49.99**	**49.69**	**46.27**	**52.69**
T	57.15	59.38	-	-	52.46	58.81	-	-	50.67	48.55	-	-
To	-	-	60.06	-	-	-	51.42	-	-	-	46.90	-
M	57.07	60.41		***51.66**	-	59.73	49.24	51.87	****51.95**	49.46	****47.45**	-
Mo	-	-	59.74	-	-	-	-	-	-	-	-	-
B	57.70	61.64	-	****52.17**	51.97	58.16	-	52.46	****51.82**	***50.50**	-	52.68
Bo	-	-	59.60	-	-	-	50.59	-	-	-	45.72	-
E	-	***62.85**	-	-	52.32	58.83	-	-	***50.70**	49.97	-	51.74
Eo	-	-	60.07	-	-	-	52.10	-	-	-	****47.43**	-
2¼T	-	-	-	50.42	-	-	-	51.55	-	-	-	52.71
2¼To	-	-	-	50.15	-	-	-	51.48	-	-	-	51.95
2¼B	-	-	-	51.09	-	-	-	51.98	-	-	-	51.57
2¼Bo	-	-	-	51.38	-	-	-	52.02	-	-	-	51.25

Day	1	2,3		4		6	5,7,8			9,10	11	12
Treatment	**Jonesport**				**Cutler**				**Lubec**			
C	**57.09**	**60.56**		**50.85**		**58.99**	**52.29**			**49.83**	**46.27**	**52.69**
T	57.15	59.38		-		58.81	52.46			49.16	-	-
To	-	60.06		-		-	51.42			-	46.90	-
M	57.07	60.41		***51.66**		59.73	50.70			***50.45**	****47.75**	-
Mo	-	59.74		-		-	-			-	-	-
B	57.70	61.64		****52.17**		58.16	52.10			****51.19**	-	52.68
Bo	-	59.60		-		-	50.59			-	45.72	-
E	-	****62.85**		-		58.83	52.32			***50.38**	-	51.74
Eo	-	60.07		-		-	52.10			-	****47.43**	-
2¼T	-	-		50.42		-	51.55			-	-	52.71
2¼To	-	-		50.15		-	51.48			-	-	51.95
2¼B	-	-		51.09		-	51.98			-	-	51.57
2¼Bo	-	-		51.38		-	52.02			-	-	51.25

Blue, underlined – higher than that day's control (C) tows.
Bold * – significantly higher than that day's control (C) tows per Dunnett's test q', P < 0.05.
Bold ** – highly significantly higher than that day's control (C) tows per Dunnett's test q', P < 0.01.

Note: Maine's legal minimum sea urchin diameter is 52.39 mm.

Table 9. Mean sea urchin diameters (mm), from data pooled by treatment and day, including only those days with mean diameter less than 52.39 mm for that day's control (C) tows (days 4, 7, 8, 9, 10, and 11 from Table 8 above). Means for tows with the outer bag are for the contents of the drag only.

Day	4	7	8	9	10	11
Treatment	**Jonesport**	**Cutler**		**Lubec**		
C	**50.85**	**52.12**	**51.96**	**49.99**	**49.69**	**46.27**
T	-	-	-	50.67	48.55	-
To	-	51.42	-	-	-	46.90
M	***51.66**	49.24	51.87	****51.95**	49.46	****47.45**
Mo	-	-	-	-	-	-
B	****52.17**	-	52.46	****51.82**	***50.50**	-
Bo	-	50.59	-	-	-	45.72
E	-	-	-	***50.70**	49.97	-
Eo	-	52.10	-	-	-	****47.43**
2¼T	50.42	-	51.55	-	-	-
2¼To	50.15	-	51.48	-	-	-
2¼B	51.09	-	51.98	-	-	-
2¼Bo	51.38	-	52.02	-	-	-

Blue, underlined – higher than that day's control (C) tows.
Bold * – significantly higher than that day's control (C) tows per Dunnett's test q', $P < 0.05$.
Bold ** – highly significantly higher than that day's control (C) tows per Dunnett's test q', $P < 0.01$.

Note: Maine's legal minimum sea urchin diameter is 52.39 mm.

Table 10. Percent of catch less than 52.39 mm (% sublegal), from data pooled by treatment and day. Percentages for tows with the outer bag are for the contents of the drag only.

Day	1	2	3	4	5	6	7	8	9	10	11	12
Treatment	**Jonesport**				**Cutler**				**Lubec**			
C	**20.5%**	**9.8%**	**7.7%**	**56.9%**	**45.5%**	**14.7%**	**51.4%**	**52.7%**	**57.3%**	**59.0%**	**73.8%**	**44.0%**
T	17.5%	16.0%			45.6%	15.8%			52.9%	63.4%		
To			9.9%				55.0%				69.6%	
M	19.7%	12.8%		54.3%		13.0%	65.0%	54.5%	49.4%	60.6%	69.9%	
Mo			8.3%									
B	19.3%	7.9%		49.5%	47.3%	22.1%		50.6%	48.1%	56.8%		43.3%
Bo			12.9%				58.7%				79.2%	
E		7.1%			48.3%	17.2%			51.4%	58.3%		48.0%
Eo			9.0%				51.1%				72.1%	
2¼T				60.9%				54.0%				45.7%
2¼To				64.2%				54.6%				45.4%
2¼B				56.5%				52.5%				49.3%
2¼Bo				57.4%				52.1%				48.2%

Table 11. Percent of catch less than 52.39 mm (% sublegal), from data pooled by treatment and day, including only those days with mean diameter less than 52.39 mm and % sublegal greater than 50% for that day's control (C) tows (days 4, 7, 8, 9, 10, and 11 from Table 10 above). Percentages for tows with the outer bag are for the contents of the drag only.

Day	4	7	8	9	10	11
Treatment	**Jonesport**	**Cutler**		**Lubec**		
C	**56.9%**	**51.4%**	**52.7%**	**57.3%**	**59.0%**	**73.8%**
T				52.9%	63.4%	
To		55.0%				69.6%
M	54.3%	65.0%	54.5%	49.4%	60.6%	69.9%
Mo						
B	49.5%		50.6%	48.1%	56.8%	
Bo		58.7%				79.2%
E				51.4%	58.3%	
Eo		51.1%				72.1%
2¼T	60.9%		54.0%			
2¼To	64.2%		54.6%			
2¼B	56.5%		52.5%			
2¼Bo	57.4%		52.1%			

Blue, underlined – lower than that day's control (C) tows, but not significantly so.

Table 12. Size and escape rate data for Jonesport area tows that used the outer catch bag.

									Drag and Bag combined				
Day	Tow Number	Treatment Type	Drag/ Bag	Urchins Caught	Sublegals Caught	Percent Sublegal	Mean Diam.(mm)	Median Diam of Sublegals	Median Diam of Sublegals	Percent Sublegal	Percent Escapement	% of Sublegals Escaping	% of Legals & Over Escaping
3	7	To	drag	58	7	12.1%	59.6	50.5	50.5	12.1%	0.0%	0.0%	0.0%
			bag	0	0								
3	8	To	drag	18	4	22.2%	60.4	51.5	51.5	22.2%	0.0%	0.0%	0.0%
			bag	0	0								
3	9	To	drag	59	3	5.1%	60.4	49.1	49.1	5.1%	0.0%	0.0%	0.0%
			bag	0	0								
3	10	To	drag	26	2	7.7%	59.9	46.2	46.2	7.7%	0.0%	0.0%	0.0%
			bag	0	0								
3	17	Mo	drag	32	4	12.5%	57.7	47.9	47.9	12.5%	0.0%	0.0%	0.0%
			bag	0									
3	18	Mo	drag	36	3	8.3%	59.8	51.0	51.0	8.3%	0.0%	0.0%	0.0%
			bag	0									
3	19	Mo	drag	53	3	5.7%	60.9	44.4	44.4	5.7%	0.0%	0.0%	0.0%
			bag	0									
3	13	Bo	drag	43	10	23.3%	57.1	48.5	48.0	25.0%	2.3%	9.1%	0.0%
			bag	1	1	100.0%	14.5	14.5					
3	14	Bo	drag	57	7	12.3%	60.3	50.2	50.2	13.8%	1.7%	12.5%	0.0%
			bag	1	1	100.0%	18.9	18.9					
3	15	Bo	drag	63	5	7.9%	59.9	51.2	45.4	9.4%	1.6%	16.7%	0.0%
			bag	1	1	100.0%	15.7	15.7					
3	16	Bo	drag	8	0	0.0%	65.5		no sublegals	0.0%	0.0%		0.0%
			bag	0	0								
3	1	Eo	drag	78	6	7.7%	60.1	49.7	49.7	8.9%	1.3%	14.3%	0.0%
			bag	1	1	100.0%	13.3	13.3					
3	2	Eo	drag	39	4	10.3%	59.5	47.7	47.7	10.3%	0.0%	0.0%	0.0%
			bag	0	0								
3	3	Eo	drag	62	5	8.1%	60.6	50.1	50.0	9.5%	1.6%	16.7%	0.0%
			bag	1	1	100.0%	11.0	11.0					
3	4	Eo	drag	32	4	12.5%	59.7	48.5	48.5	12.5%	0.0%	0.0%	0.0%
			bag	0	0								
4	17	2¼ To	drag	404	240	59.4%	50.9	48.2	48.2	59.7%	0.7%	1.2%	0.0%
			bag	3	3	100.0%	43.0	43.4					
4	18	2¼ To	drag	233	145	62.2%	49.9	47.5	47.5	62.6%	0.9%	1.4%	0.0%
			bag	2	2	100.0%	46.5	46.5					
4	19	2¼ To	drag	377	266	70.6%	49.4	46.7	46.6	71.2%	2.3%	3.3%	0.0%
			bag	9	9	100.0%	39.6	41.8					
4	6	2¼Bo	drag	308	208	67.5%	49.7	47.7	47.7	67.7%	0.6%	1.0%	0.0%
			bag	2	2	100.0%	48.2	48.2					
4	7	2¼Bo	drag	159	72	45.3%	53.2	48.6	48.3	46.7%	4.8%	7.7%	2.2%
			bag	8	6	75.0%	48.9	46.9					
4	8	2¼Bo	drag	284	151	53.2%	52.2	48.2	48.1	53.8%	2.1%	3.2%	0.7%
			bag	6	5	83.3%	40.1	37.2					

Table 13. Size and escape rate data for Cutler area tows that used the outer catch bag.

									Drag and Bag combined				
Day	Tow Number	Treatment Type	Drag/ Bag	Urchins Caught	Sublegals Caught	Percent Sublegal	Mean Diam (mm)	Median Diam of Sublegals	Median Diam of Sublegals	Percent Sublegal	Percent Escapement	% of Sublegals Escaping	% of Legals & Over Escaping
7	7	To	drag	345	224	64.9%	49.5	46.3	46.3	64.9%	0.0%	0.0%	0.0%
			bag	0	0								
7	8	To	drag	190	69	36.3%	54.7	47.7	47.7	36.6%	0.5%	1.4%	0.0%
			bag	1	1	100.0%	42.8	42.8					
7	9	To	drag	264	169	64.0%	50.4	47.3	47.3	64.0%	0.0%	0.0%	0.0%
			bag	0	0								
7	10	To	drag	156	63	40.4%	53.4	47.4	47.4	41.1%	1.3%	3.1%	0.0%
			bag	2	2	100.0%	40.5	40.5					
7	13	Bo	drag	308	189	61.4%	50.5	46.6	46.6	61.6%	0.6%	1.0%	0.0%
			bag	2	2	100.0%	44.1	44.1					
7	14	Bo	drag	437	272	62.2%	50.1	46.8	46.7	62.5%	0.7%	1.1%	0.0%
			bag	3	3	100.0%	34.2	29.5					
7	15	Bo	drag	263	168	63.9%	49.3	45.6	45.5	64.4%	1.5%	2.3%	0.0%
			bag	4	4	100.0%	36.9	34.2					
7	16	Bo	drag	326	154	47.2%	52.5	46.3	46.2	47.6%	0.6%	1.3%	0.0%
			bag	2	2	100.0%	43.0	43.0					
7	1	Eo	drag	501	256	51.1%	52.6	48.1	48.0	51.3%	0.4%	0.8%	0.0%
			bag	2	2	100.0%	34.9	34.9					
7	2	Eo	drag	320	187	58.4%	50.2	46.6	46.5	58.7%	0.6%	1.1%	0.0%
			bag	2	2	100.0%	42.6	42.6					
7	3	Eo	drag	440	195	44.3%	53.0	47.5	47.4	44.6%	0.5%	1.0%	0.0%
			bag	2	2	100.0%	42.4	42.4					
7	4	Eo	drag	194	106	54.6%	52.0	46.6			2.0%		
			bag	4	missing								
8	17	2¼To	drag	402	256	63.7%	50.4	47.6	47.6	63.7%	0.0%	0.0%	0.0%
			bag	0	0								
8	18	2¼To	drag	158	86	54.4%	51.5	47.9	47.9	54.4%	0.0%	0.0%	0.0%
			bag	0	0								
8	19	2¼To	drag	340	149	43.8%	52.7	48.4	48.4	43.8%	0.0%	0.0%	0.0%
			bag	0	0								
8	6	2¼Bo	drag	532	288	54.1%	51.7	48.5	48.5	54.2%	0.2%	0.3%	0.0%
			bag	1	1	100.0%	41.8	41.8					
8	7	2¼Bo	drag	335	176	52.5%	51.9	48.7	48.7	52.4%	0.3%	0.0%	0.6%
			bag	1	0	0.0%	54.7						
8	8	2¼Bo	drag	255	121	47.5%	52.8	48.8	48.8	47.3%	0.4%	0.0%	0.7%
			bag	1	0	0.0%	56.2						

Table 14. Size and escape rate data for Lubec area tows that used the outer catch bag.

Day	Tow Number	Treatment Type	Drag/ Bag	Urchins Caught	Sublegals Caught	Percent Sublegal	Mean Diam.(mm)	Median Diam of Sublegals	Drag and Bag combined: Median Diam of Sublegals	Drag and Bag combined: Percent Sublegal	Percent Escapement	% of Sublegals Escaping	% of Legals & Over Escaping
11	7	To	drag	1,017	770	75.7%	44.7	42.8	42.5	76.1%	1.5%	2.0%	0.0%
			bag	16	16	100.0%	24.7	24.7					
11	8	To	drag	268	163	60.8%	49.2	47.2	46.2	63.3%	6.3%	9.9%	0.0%
			bag	18	18	100.0%	20.1	19.4					
11	9	To	drag	220	159	72.3%	46.9	45.2	45.0	72.5%	0.9%	1.2%	0.0%
			bag	2	2	100.0%	37.3	37.3					
11	10	To	drag	249	172	69.1%	47.1	44.8	44.8	69.6%	1.6%	2.3%	0.0%
			bag	4	4	100.0%	36.6	38.2					
11	13	Bo	drag	218	186	85.3%	44.8	44.8	42.9	88.2%	19.6%	22.2%	0.0%
			bag	53	53	100.0%	28.8	28.6					
11	14	Bo	drag	298	217	72.8%	46.6	45.0	44.0	74.1%	7.2%	8.8%	2.4%
			bag	23	21	91.3%	29.2	26.8					
11	15	Bo	drag	414	337	81.4%	44.9	43.3	41.9	83.4%	11.7%	13.8%	1.3%
			bag	55	54	98.2%	28.8	30.3					
11	16	Bo	drag	297	232	78.1%	46.6	45.7	44.9	79.6%	6.9%	8.7%	0.0%
			bag	22	22	100.0%	29.2	30.7					
11	1	Eo	drag	365	279	76.4%	47.3	46.4	45.9	78.1%	12.0%	13.9%	5.5%
			bag	50	45	90.0%	38.2	37.8					
11	2	Eo	drag	189	133	70.4%	46.9	45.5	43.3	75.6%	20.6%	26.1%	3.4%
			bag	49	47	95.9%	37.1	37.4					
11	3	Eo	drag	198	135	68.2%	47.1	45.0	42.5	74.9%	25.8%	32.5%	6.0%
			bag	69	65	94.2%	35.0	35.6					
11	4	Eo	drag	555	395	71.2%	47.8	46.0	45.0	74.7%	12.9%	17.0%	0.6%
			bag	82	81	98.8%	31.5	31.8					
12	21	2¼ To	drag	56	28	50.0%	51.9	48.4	42.3	63.2%	26.3%	41.7%	0.0%
			bag	20	20	100.0%	18.3	14.0					
12	22	2¼ To	drag	50	22	44.0%	52.0	47.4	43.8	53.3%	16.7%	31.3%	0.0%
			bag	10	10	100.0%	16.6	15.9					
12	23	2¼ To	drag	79	34	43.0%	51.9	48.2	42.7	52.1%	16.0%	30.6%	0.0%
			bag	15	15	100.0%	17.2	12.8					
12	15	2¼Bo	drag	404	214	53.0%	50.0	45.8	44.3	57.8%	10.8%	18.3%	0.5%
			bag	49	48	98.0%	32.0	32.9					
12	16	2¼Bo	drag	38	14	36.8%	53.6	46.6	45.0	60.8%	48.6%	68.9%	17.2%
			bag	36	31	86.1%	38.1	42.6					
12	17	2¼Bo	drag	546	248	45.4%	52.0	46.8	45.1	49.9%	10.3%	18.4%	2.3%
			bag	63	56	88.9%	37.3	35.1					

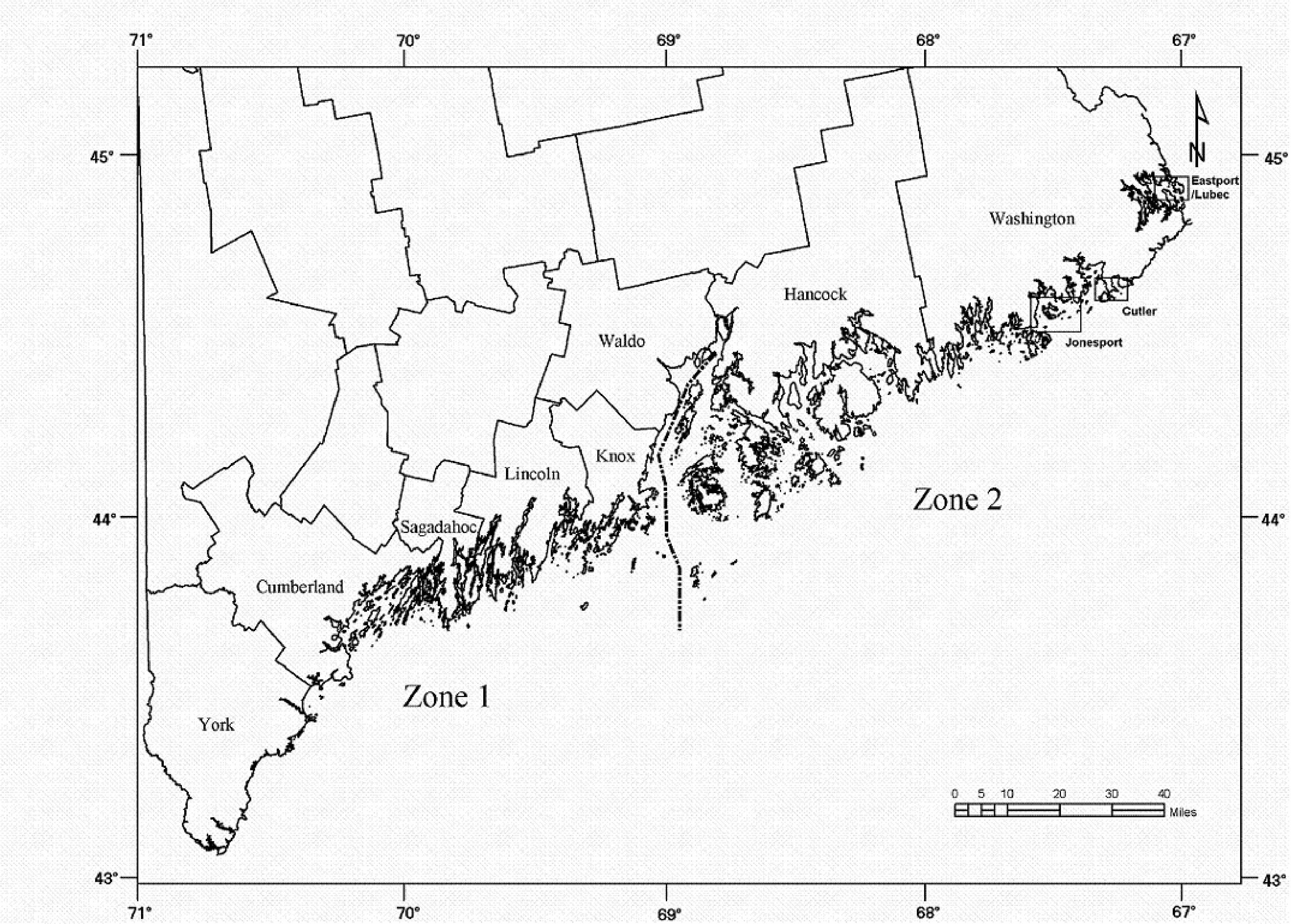


Figure 1. Maine coastal counties, sea urchin management zones, and the three project study areas.

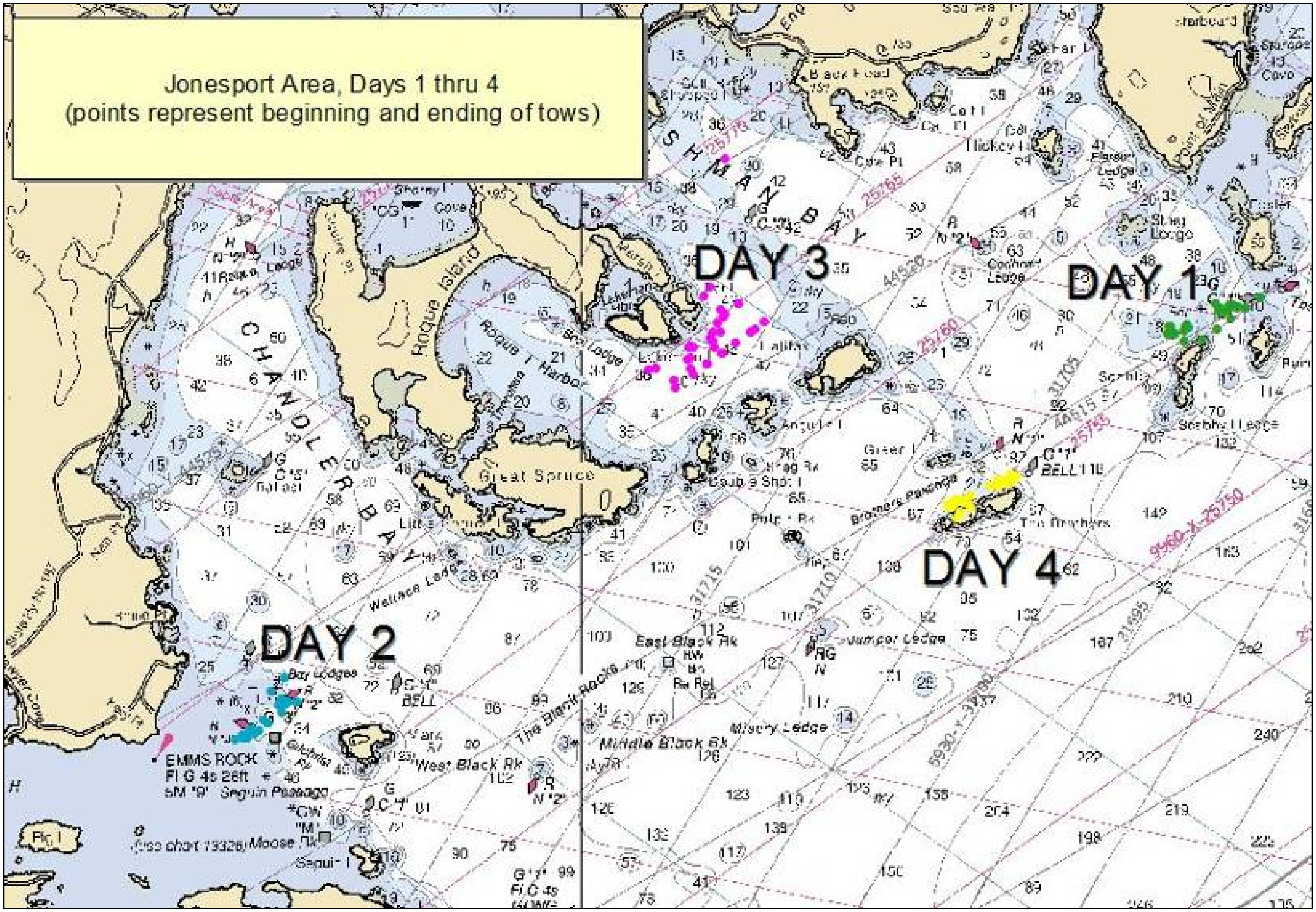


Figure 2. Approximate locations of the beginning and ending of tows for days 1-4, Jonesport area. Some points may appear on land because of problems in the conversion from loran coordinates to latitude-longitude.

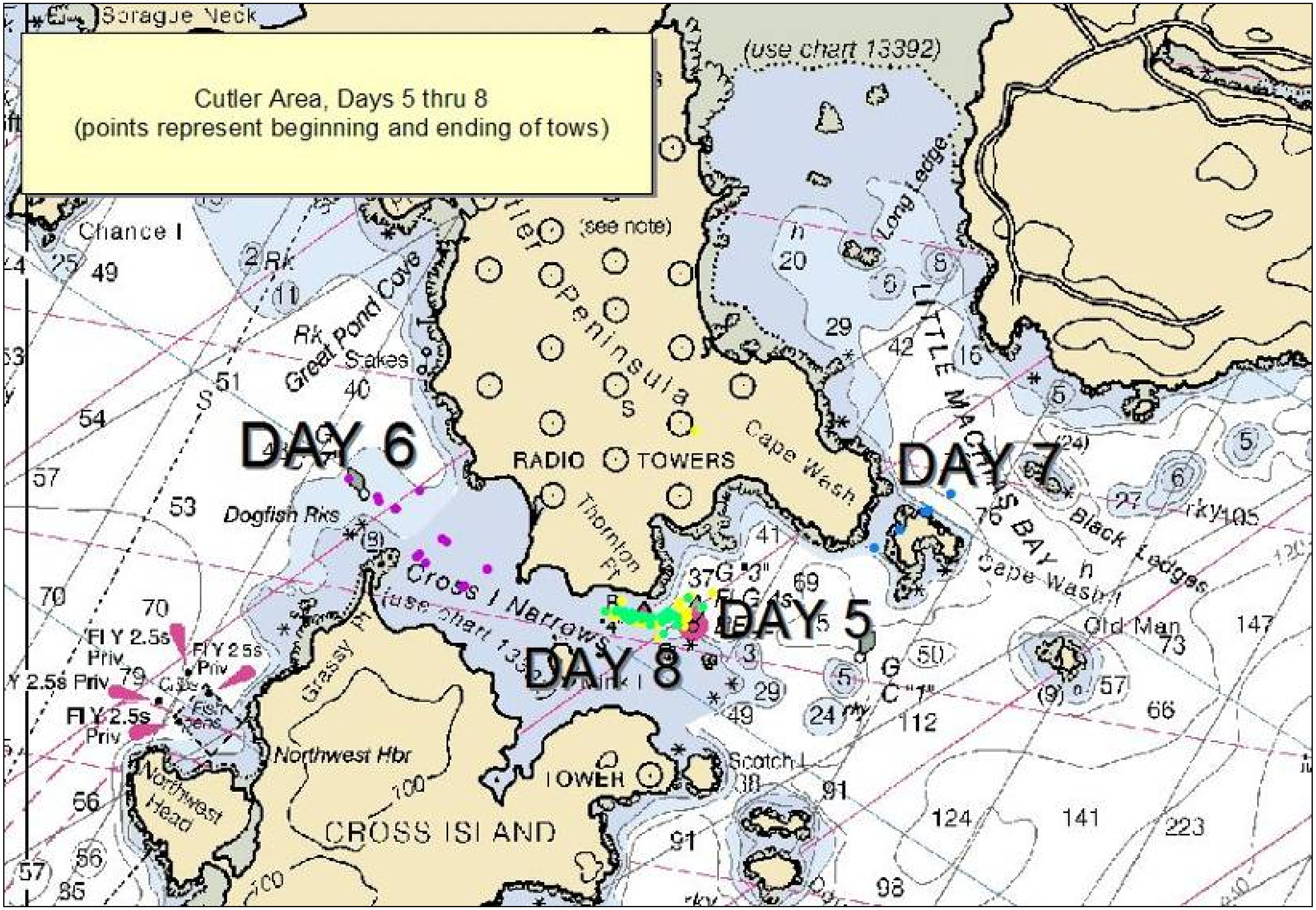


Figure 3. Approximate locations of the beginning and ending of tows for days5-8, Cutler area. Some points may appear on land because of problems in the conversion from loran coordinates to latitude-longitude.

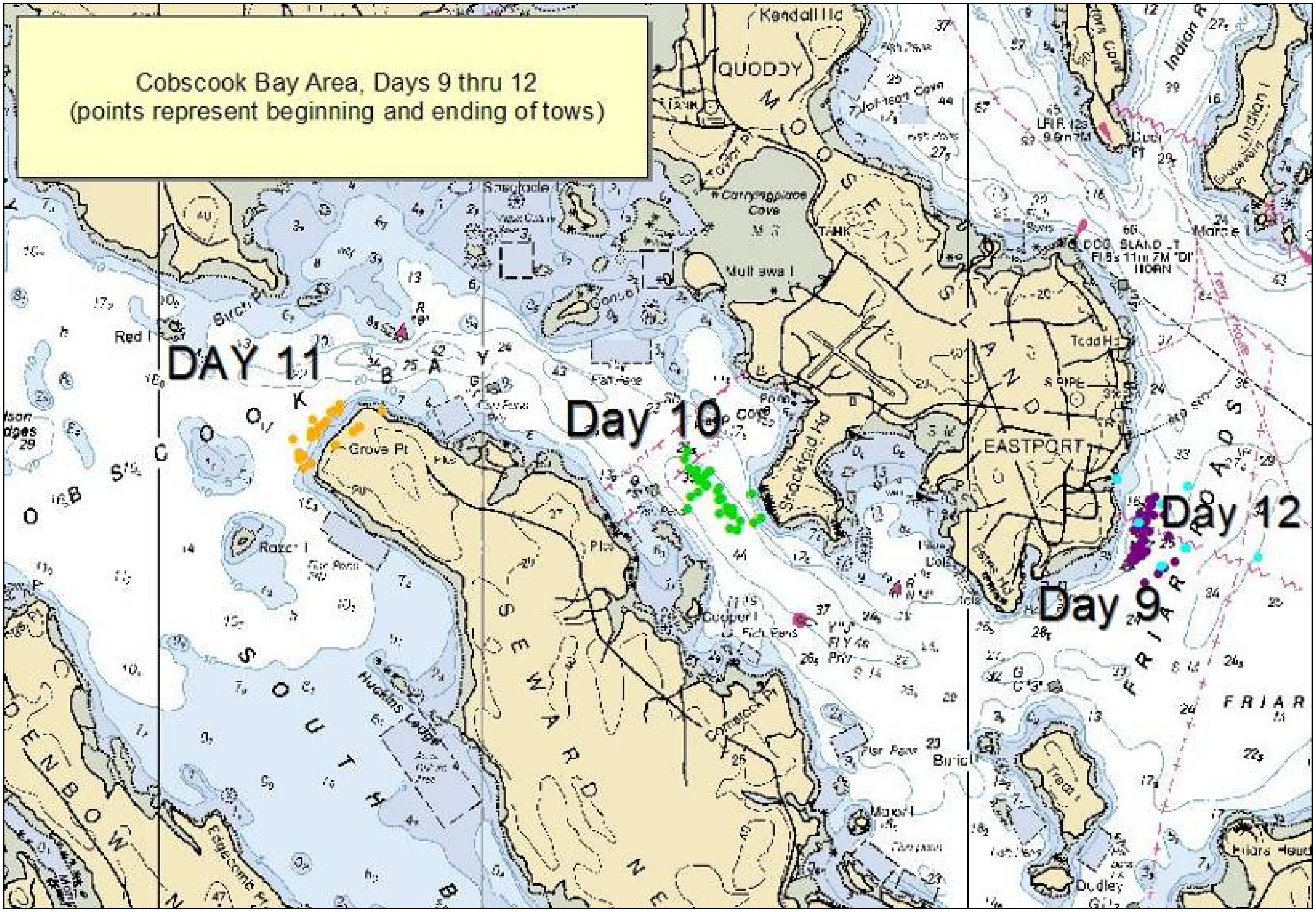


Figure 4. Approximate locations of the beginning and ending of tows for days 9-12, Cobscook Bay (Eastport/Lubec) area. Some points may appear on land because of problems in the conversion from loran coordinates to latitude-longitude.

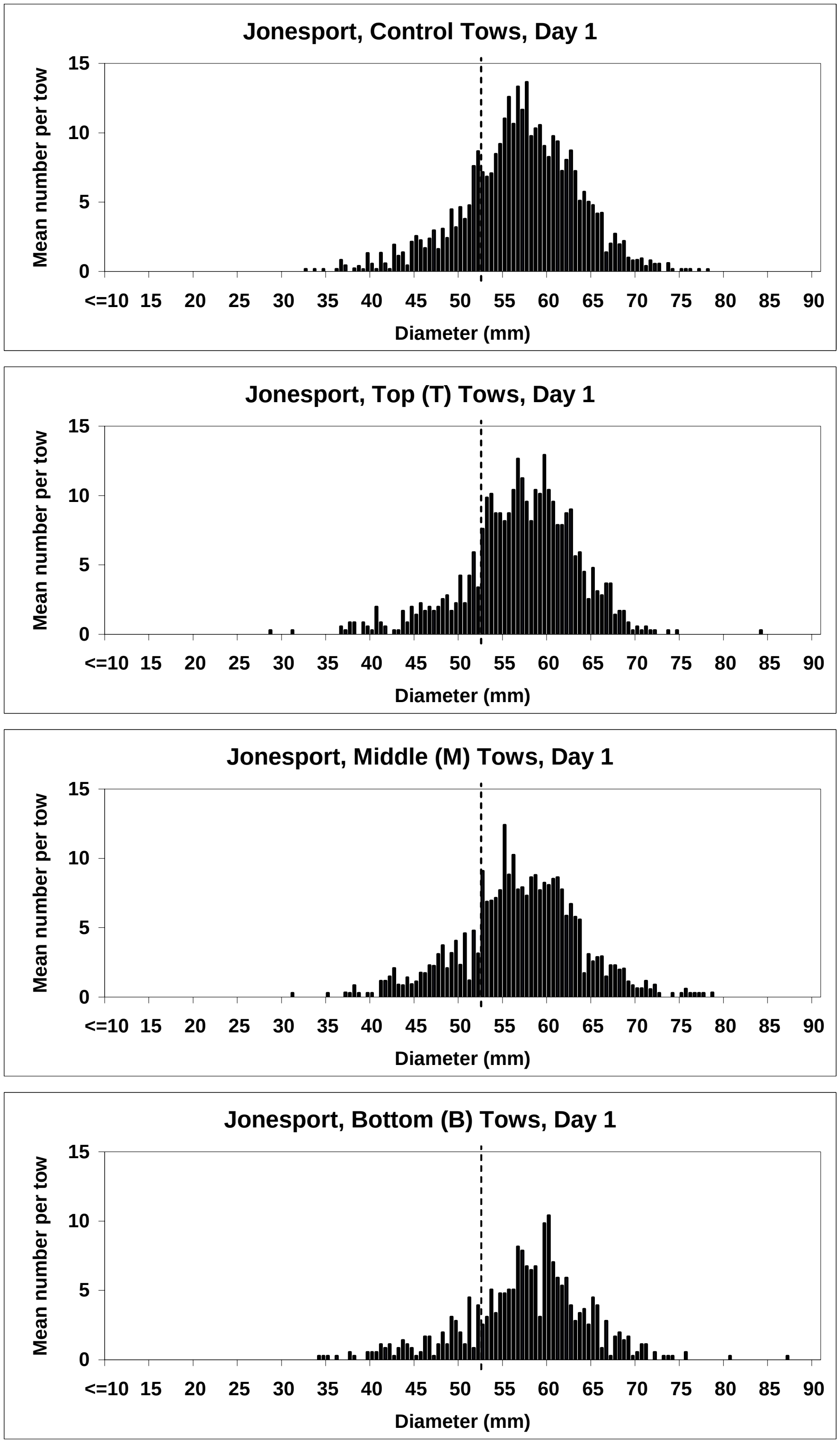


Figure 5. Jonesport area, day 1, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

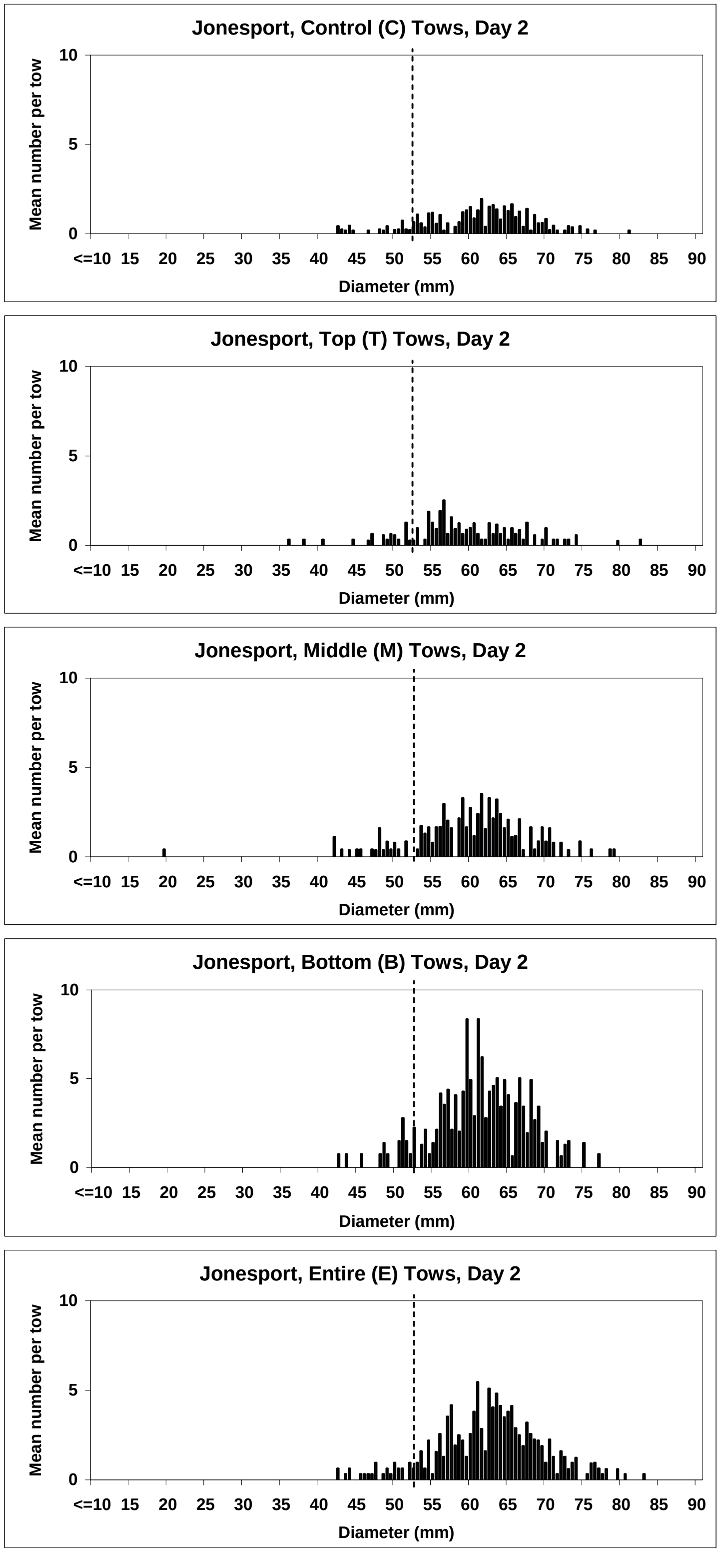


Figure 6. Jonesport area, day 2, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

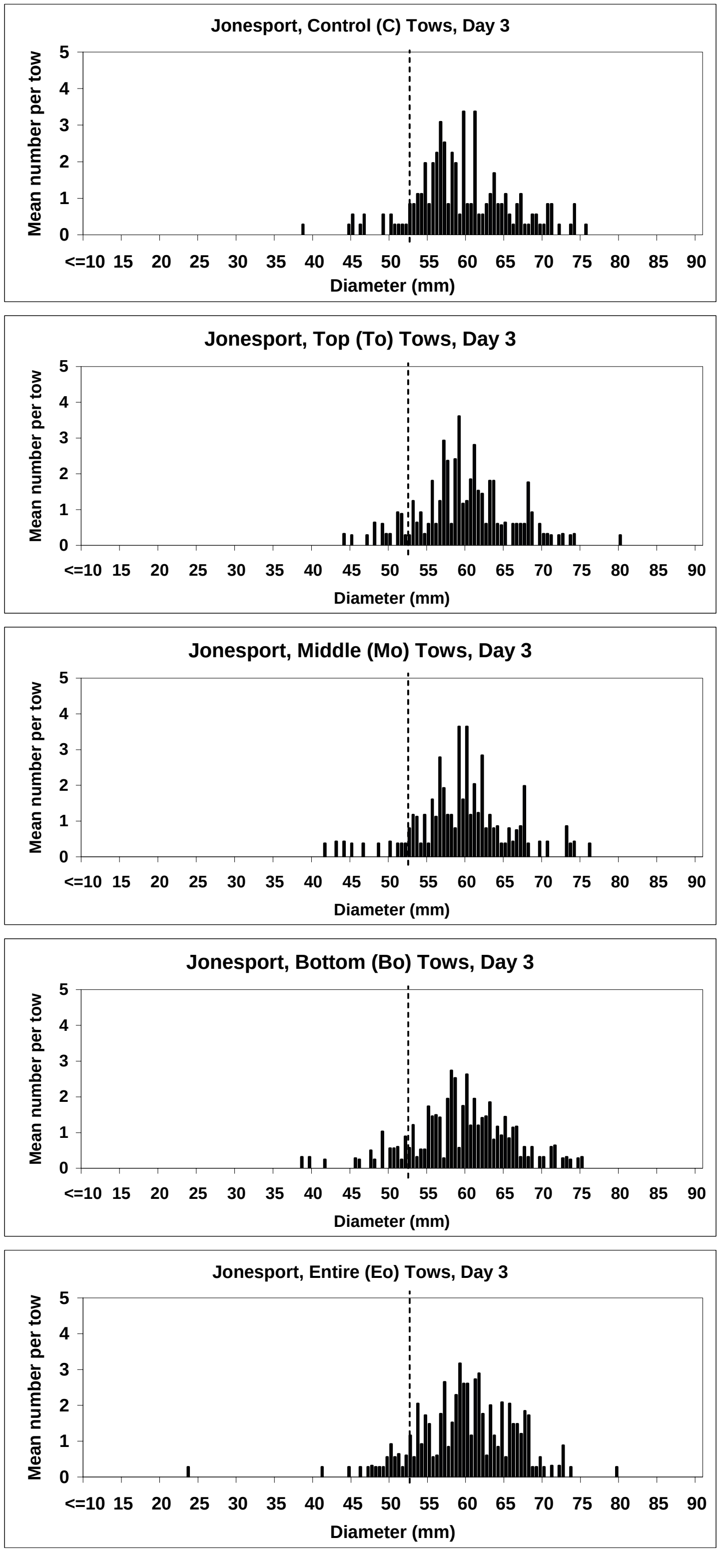


Figure 7. Jonesport area, day 3, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

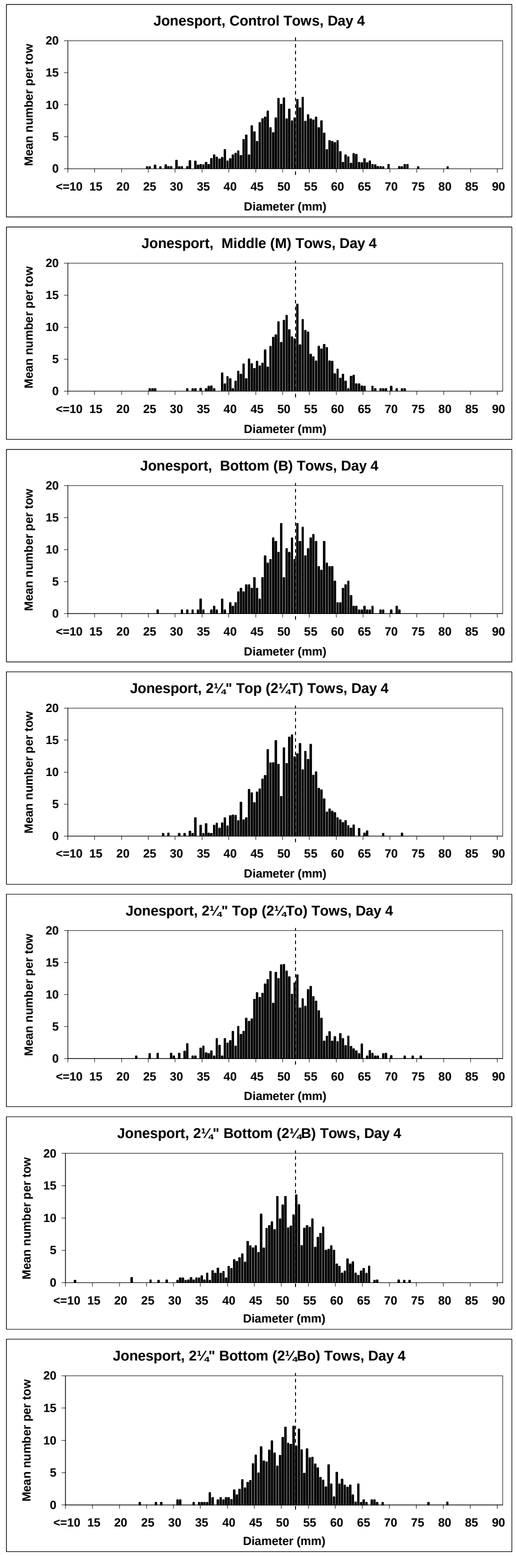


Figure 8. Jonesport area, day 4, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

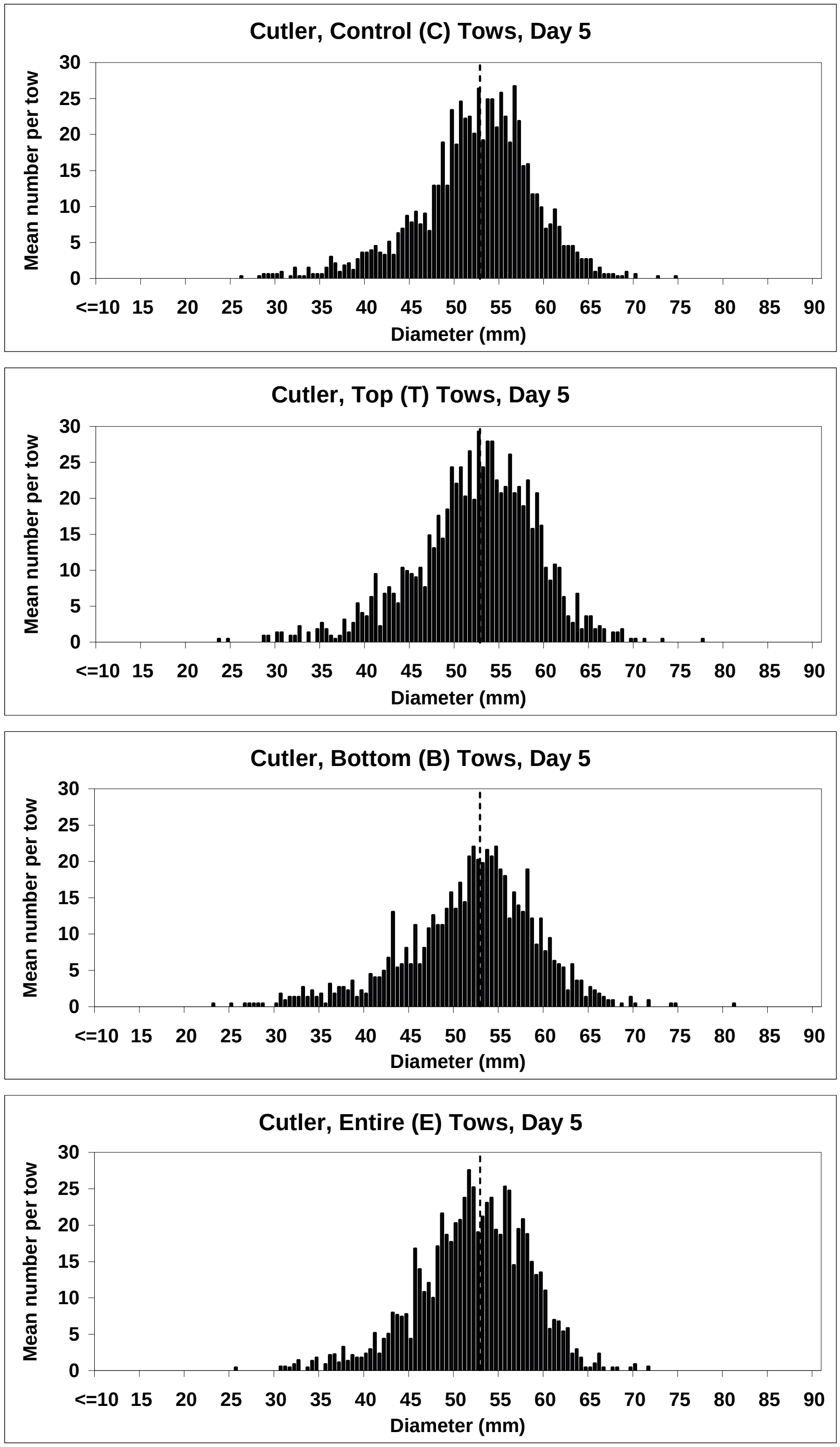


Figure 9. Cutler area, day 5, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

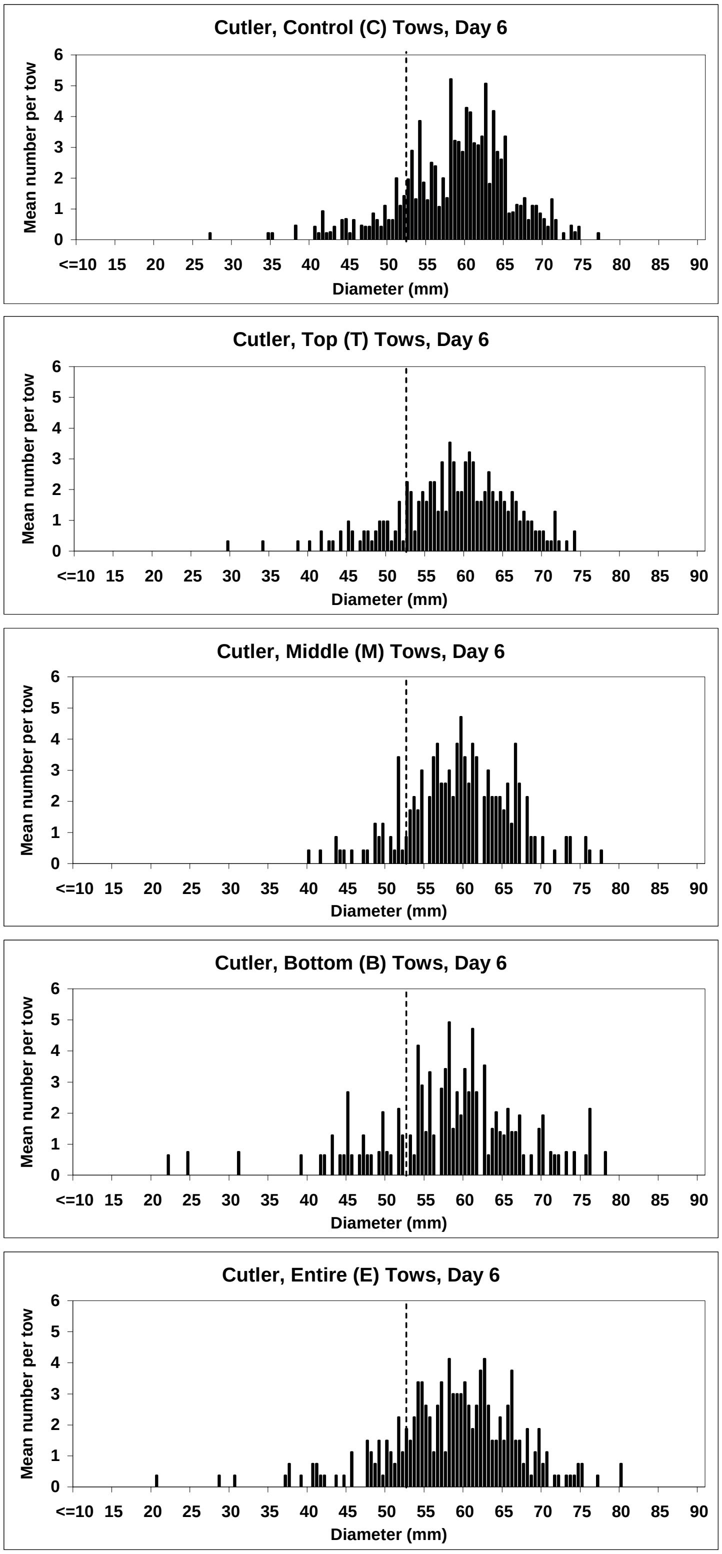


Figure 10. Cutler area, day 6, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

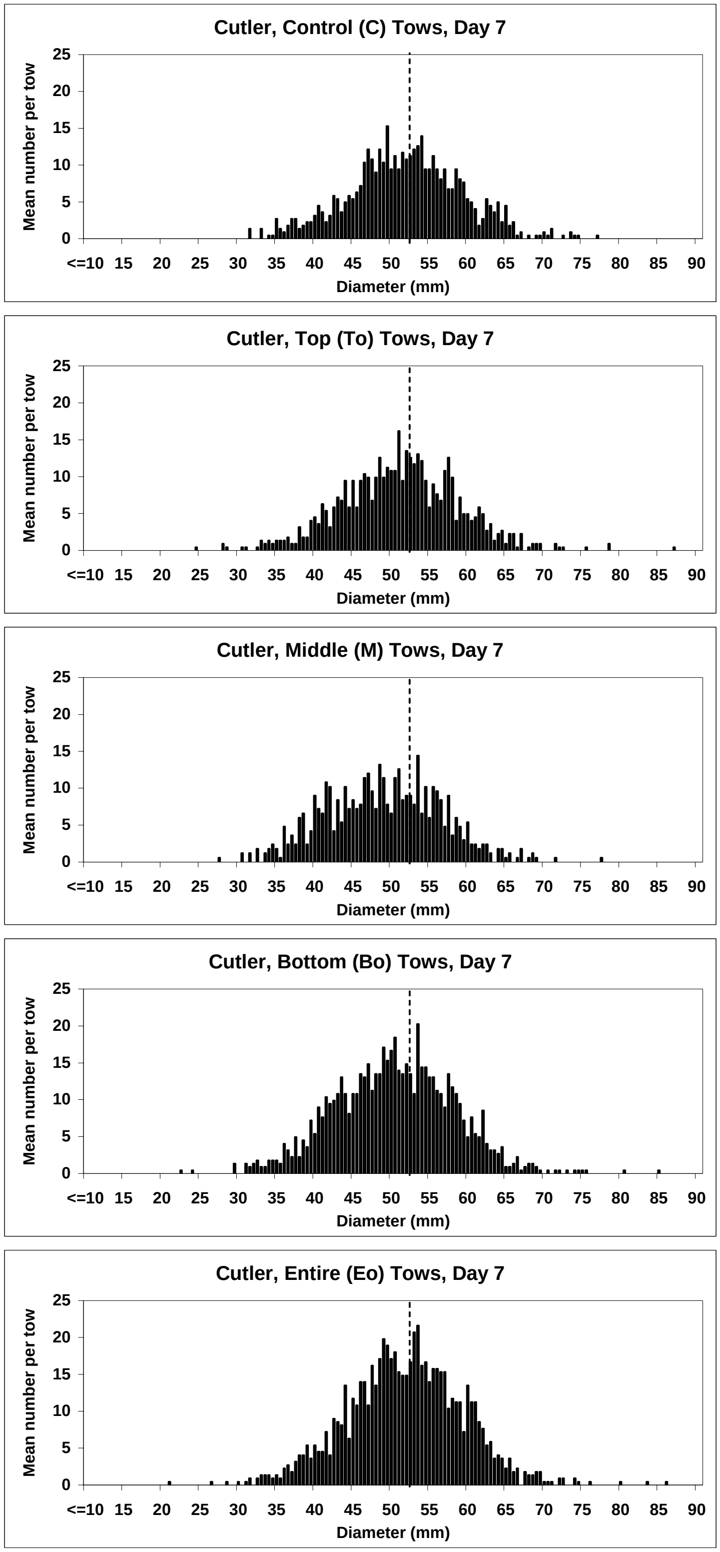


Figure 11. Cutler area, day 7, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

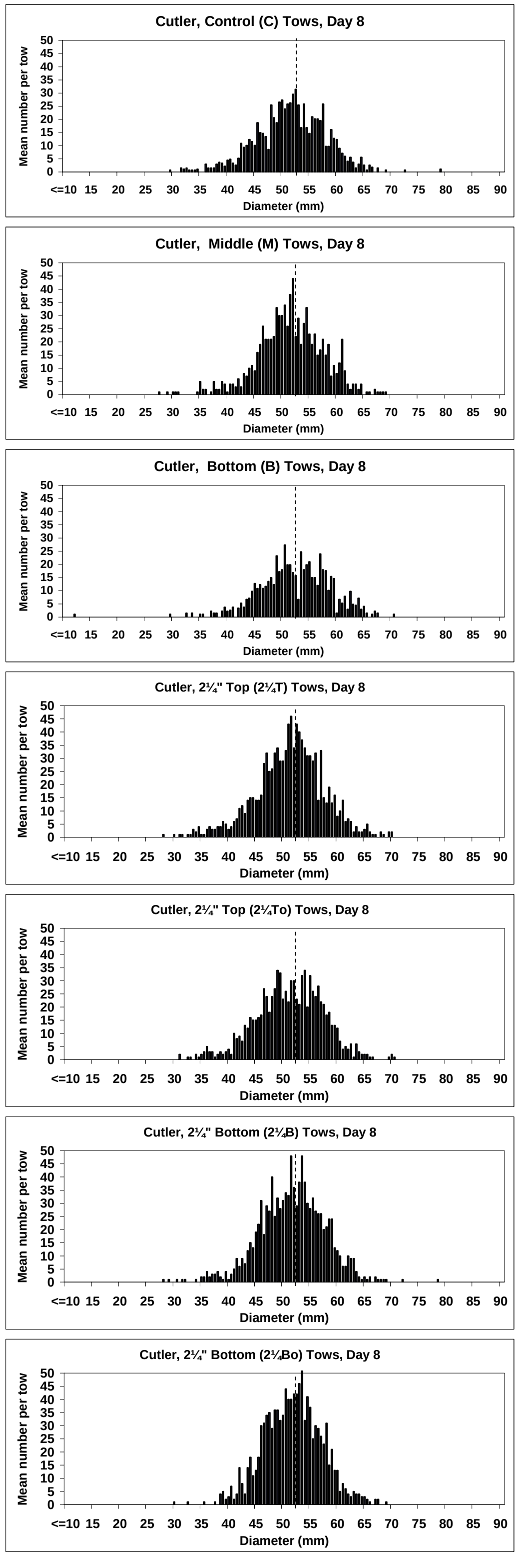


Figure 12. Cutler area, day 8, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

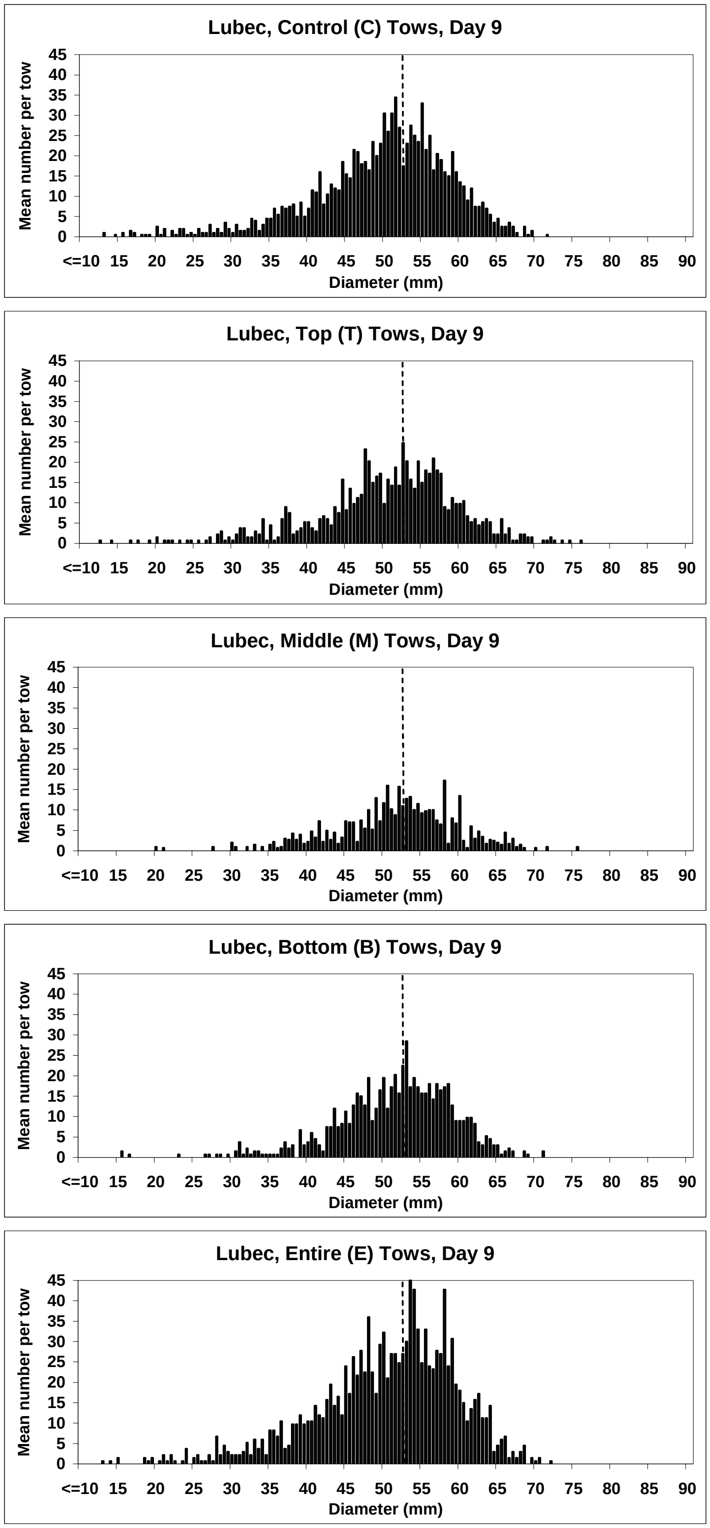


Figure 13. Lubec area, day 9, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine’s legal minimum size.

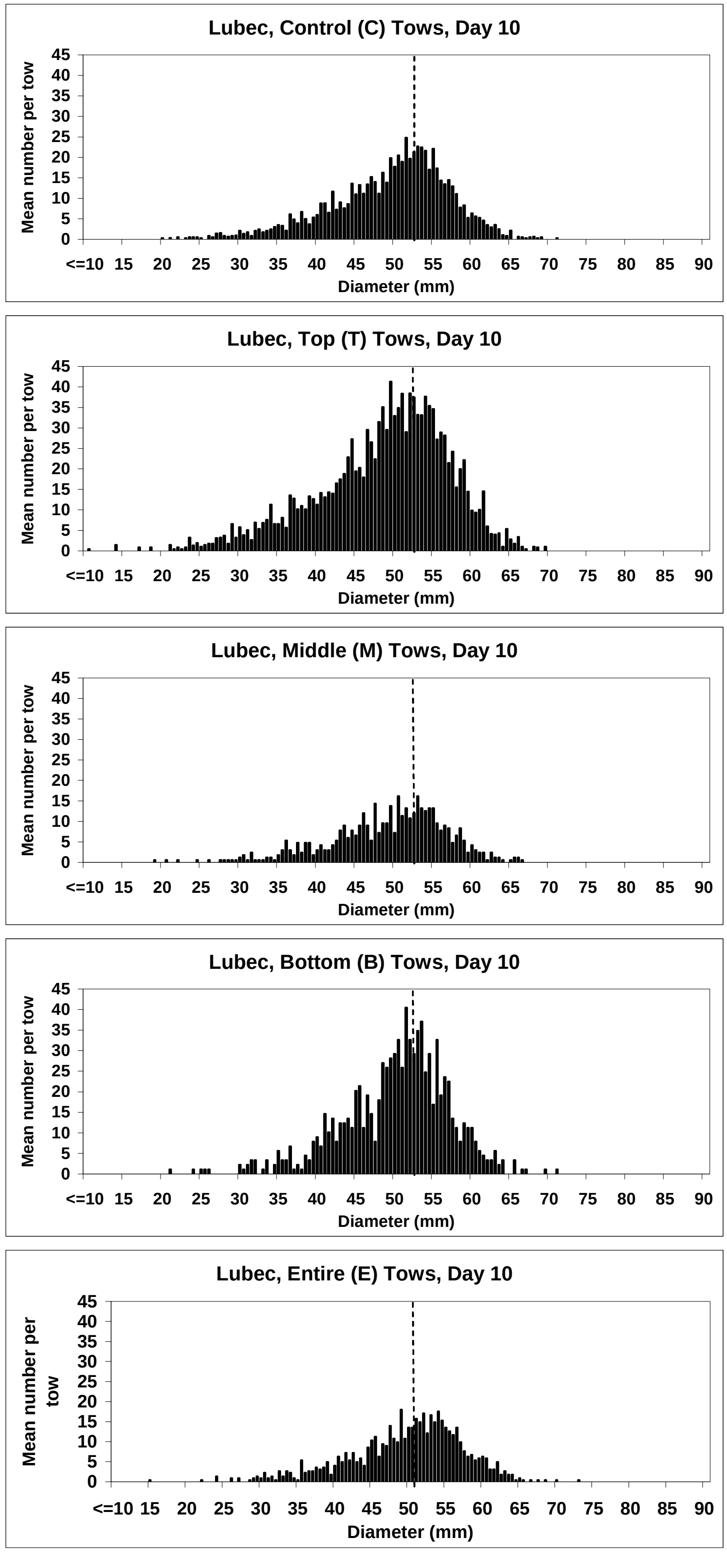


Figure 14. Lubec area, day 10, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

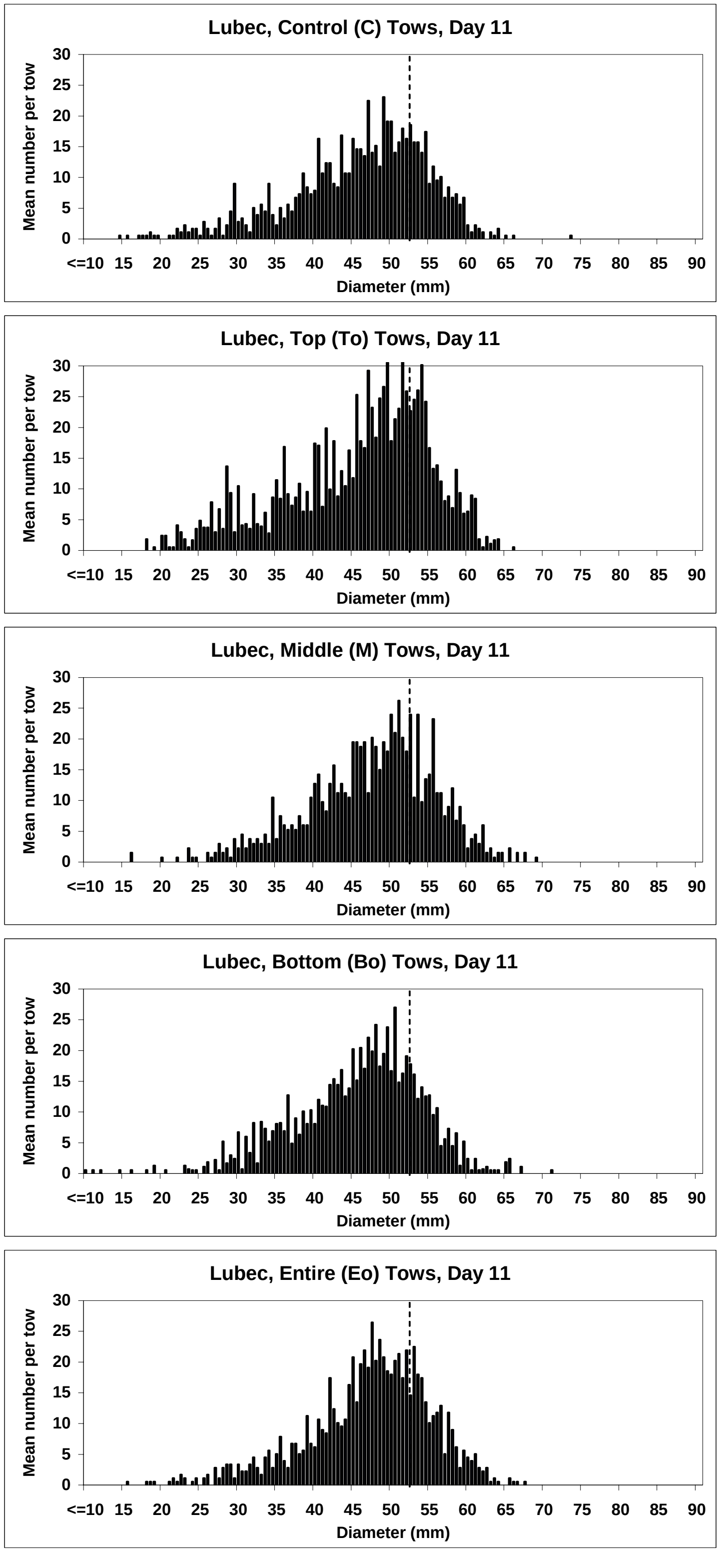


Figure 15. Lubec area, day 11, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

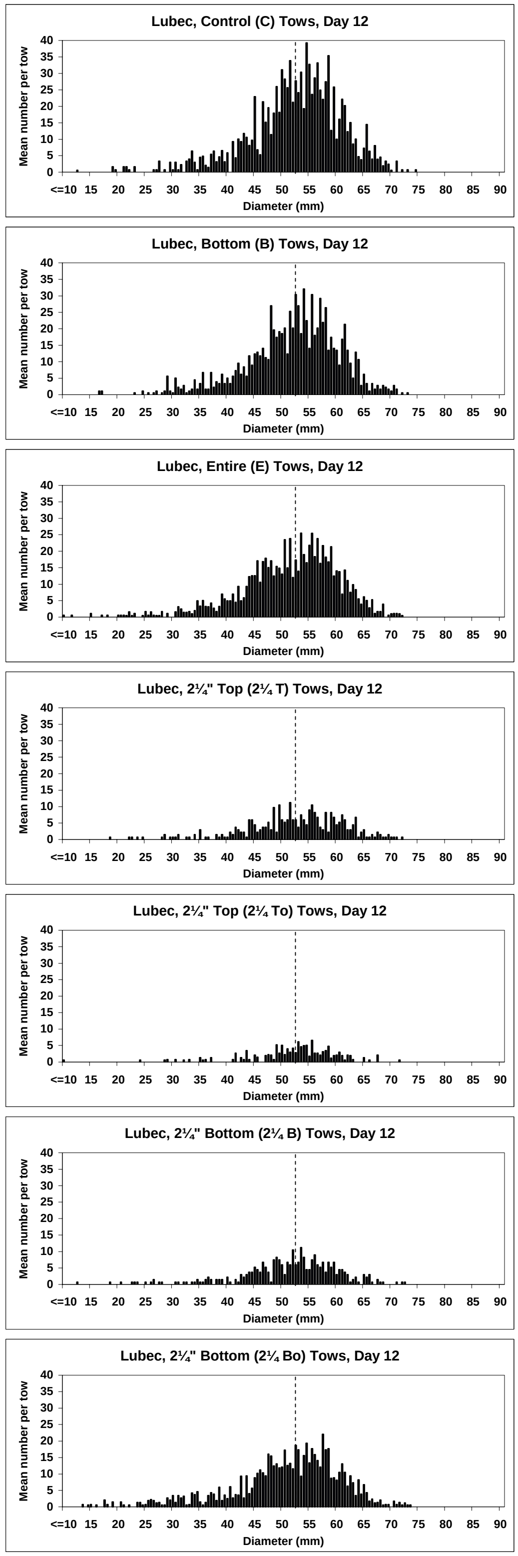


Figure 16. Lubec area, day 12, mean number per standardized tow at size (diameter in ½ mm intervals), from data pooled by treatment type and day. Dotted line is at 52.39 mm, Maine's legal minimum size.

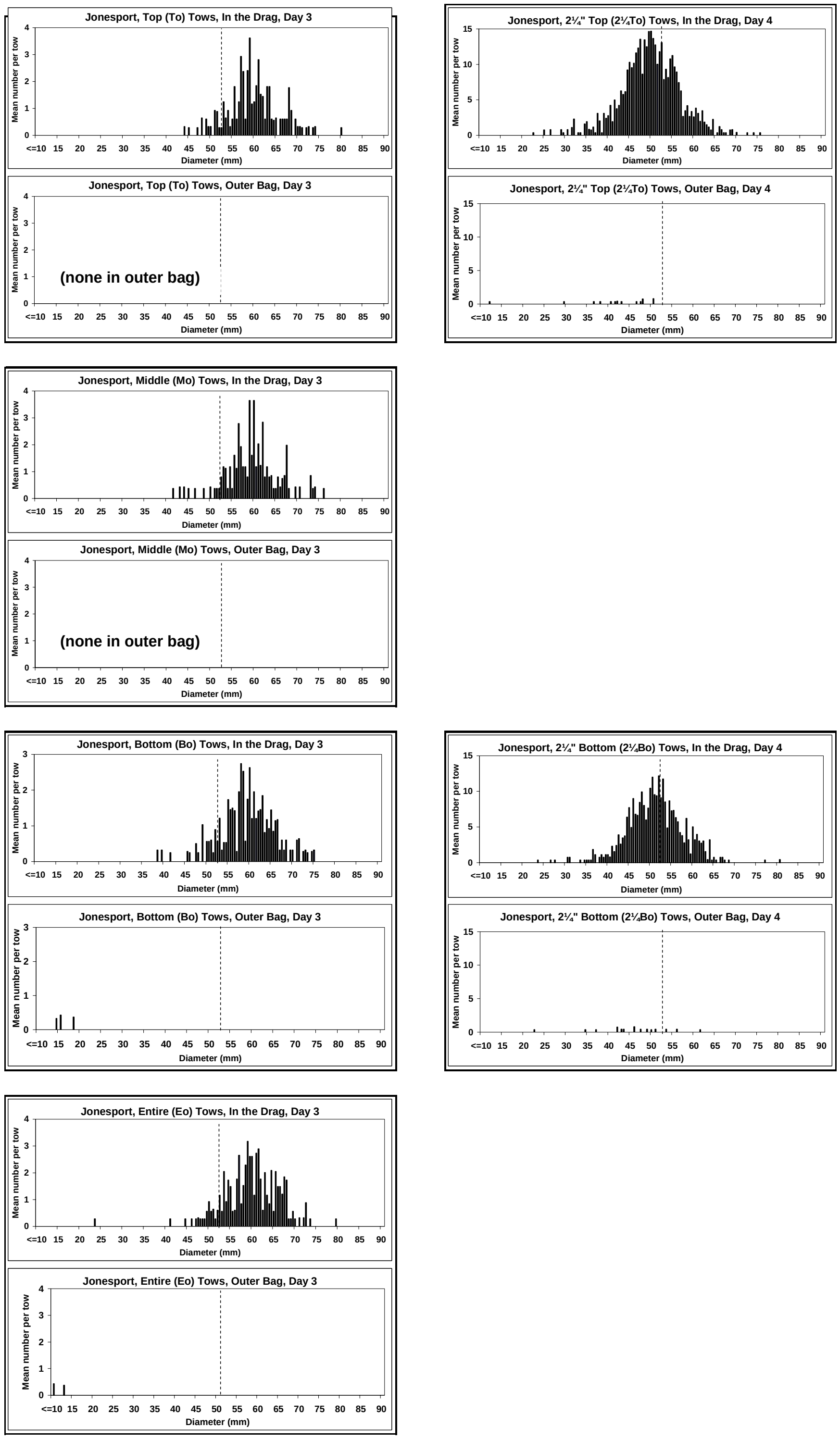


Figure 17. Jonesport mean number per standardized tow at size (diameter in ½ mm intervals) in the drag (above) and in the outer bag (below), from data for tows that used the outer bag, pooled by location, treatment type, and day. 2-inch mesh escape panel treatments are on the left, and 2¼-inch mesh treatments are on the right. Dotted line is at 52.39 mm, Maine's legal minimum size.

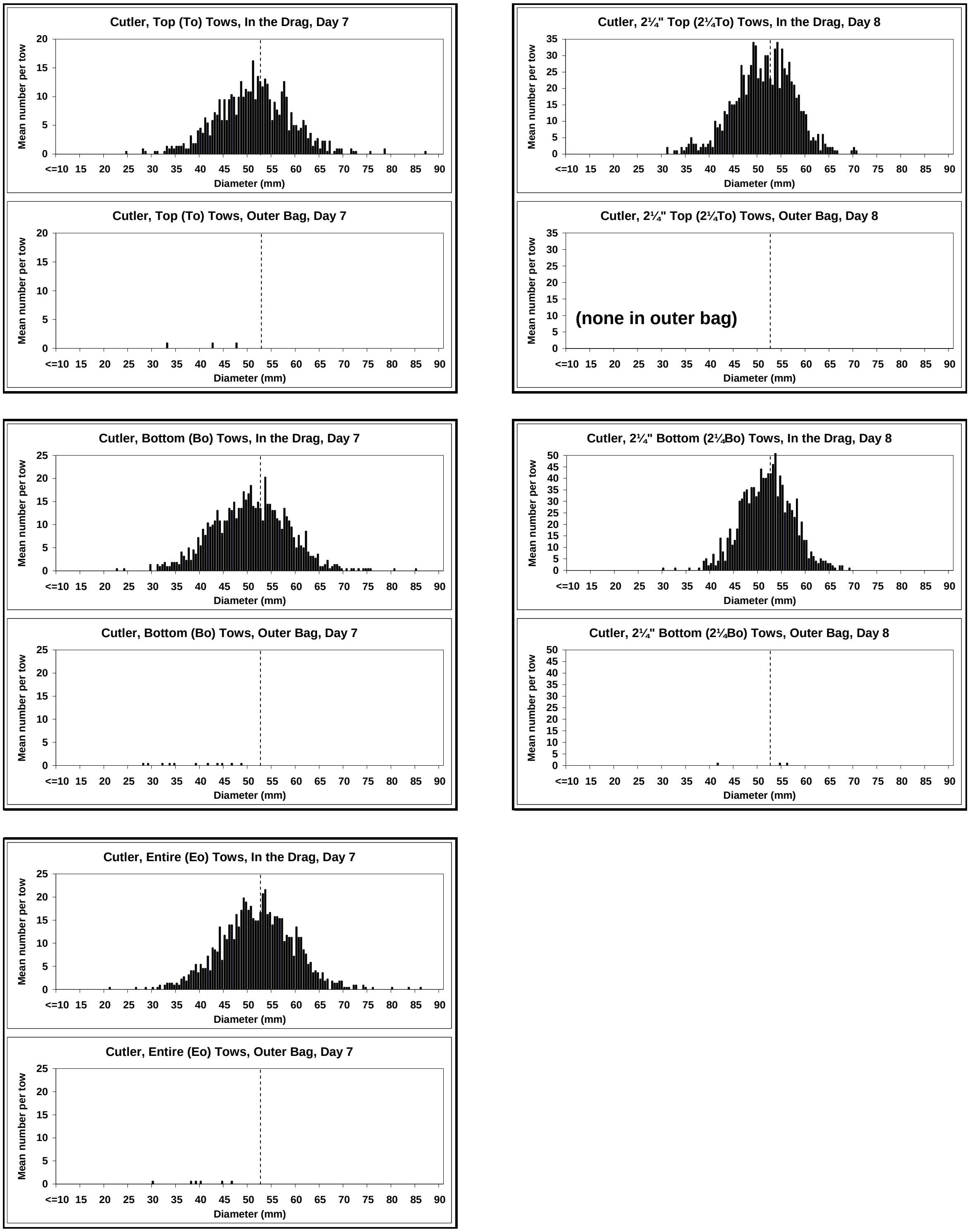


Figure 18. Cutler mean number per standardized tow at size (diameter in ½ mm intervals) in the drag (above) and in the outer bag (below), from data for tows that used the outer bag, pooled by location, treatment type, and day. 2-inch mesh escape panel treatments are on the left, and 2¼-inch mesh treatments are on the right. Dotted line is at 52.39 mm, Maine's legal minimum size.

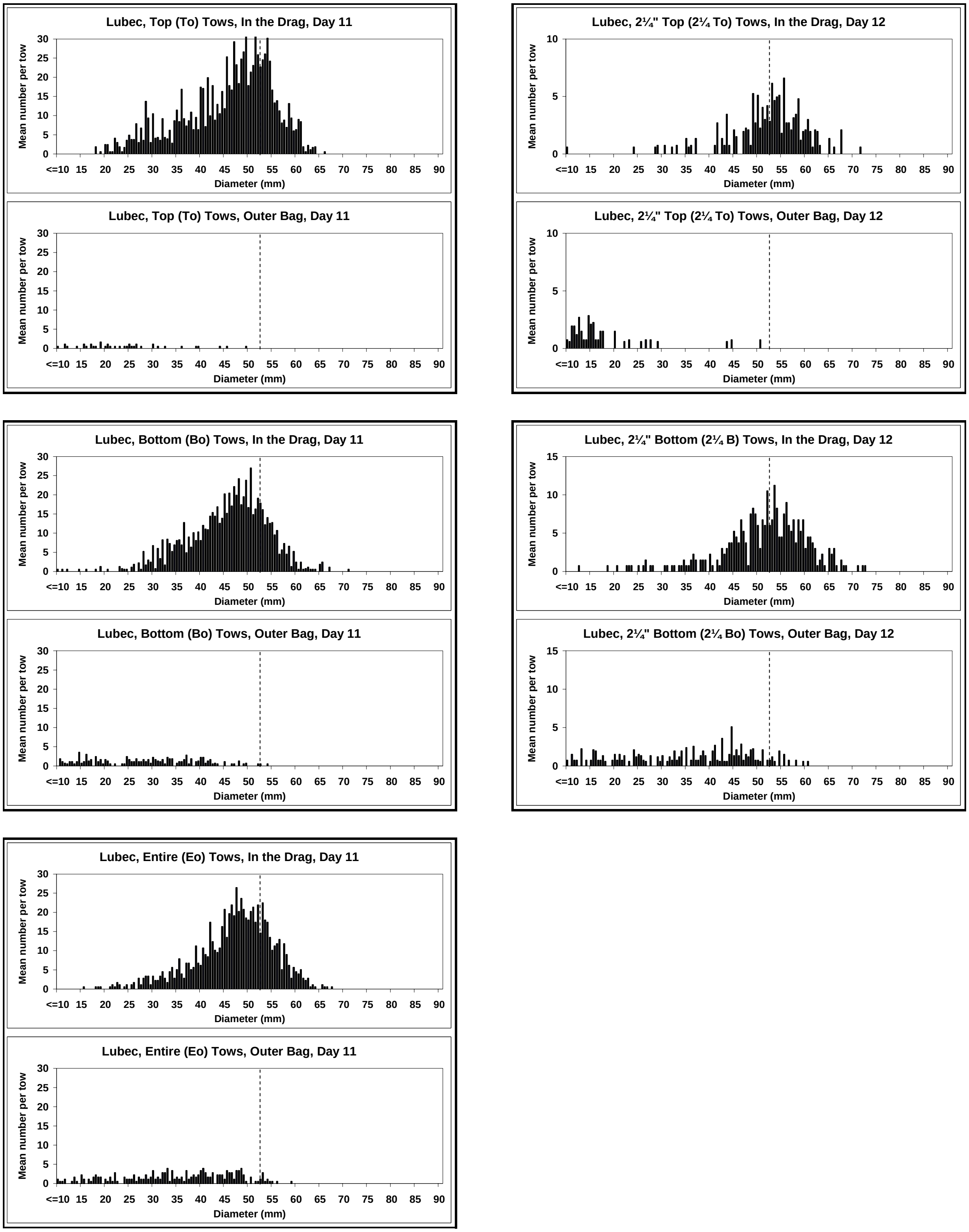
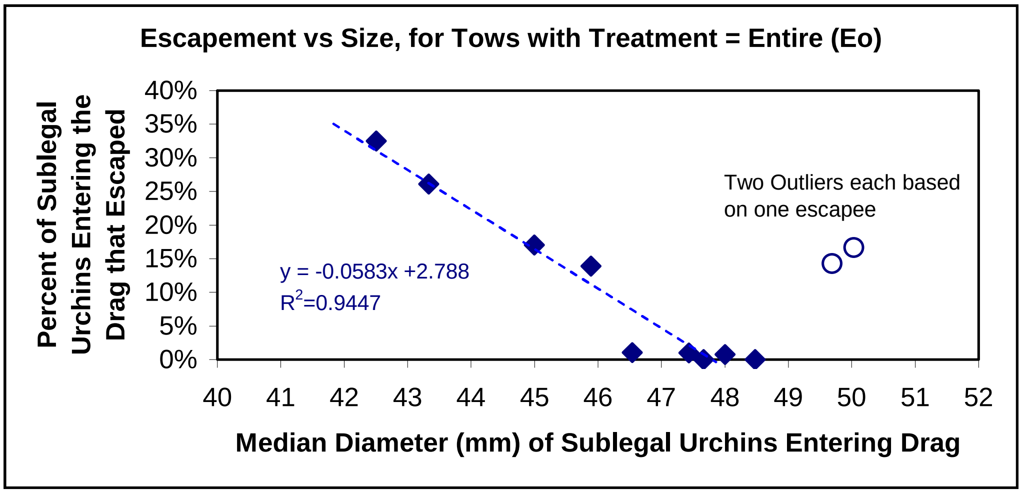


Figure 19. Lubec mean number per standardized tow at size (diameter in ½ mm intervals) in the drag (above) and in the outer bag (below), from data for tows that used the outer bag, pooled by location, treatment type, and day. 2-inch mesh escape panel treatments are on the left, and 2¼-inch mesh treatments are on the right. Dotted line is at 52.39 mm, Maine's legal minimum size.



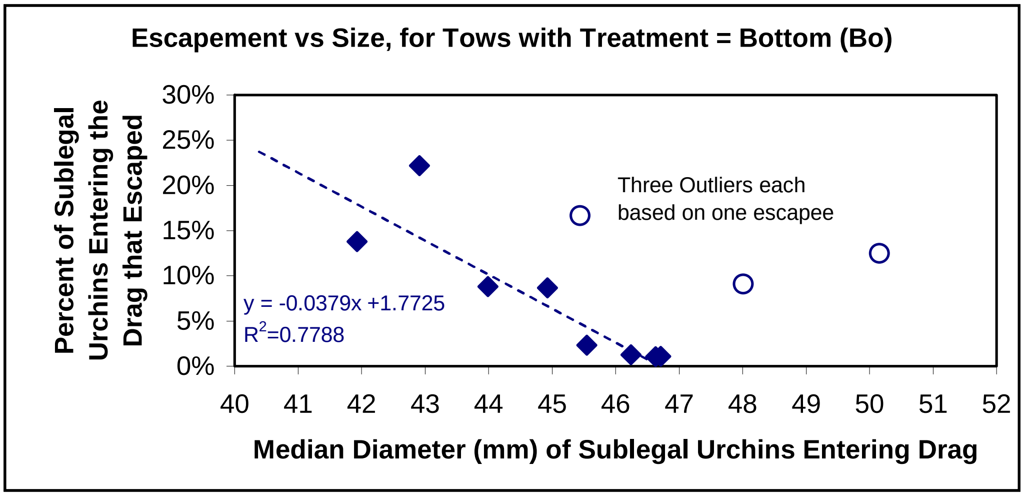


Figure 20. Rate of escapement (%) vs. the median diameter of the sub-legal sea urchins entering the drag, from tows using the outer bag, all locations, for treatment Entire above, and Bottom below.

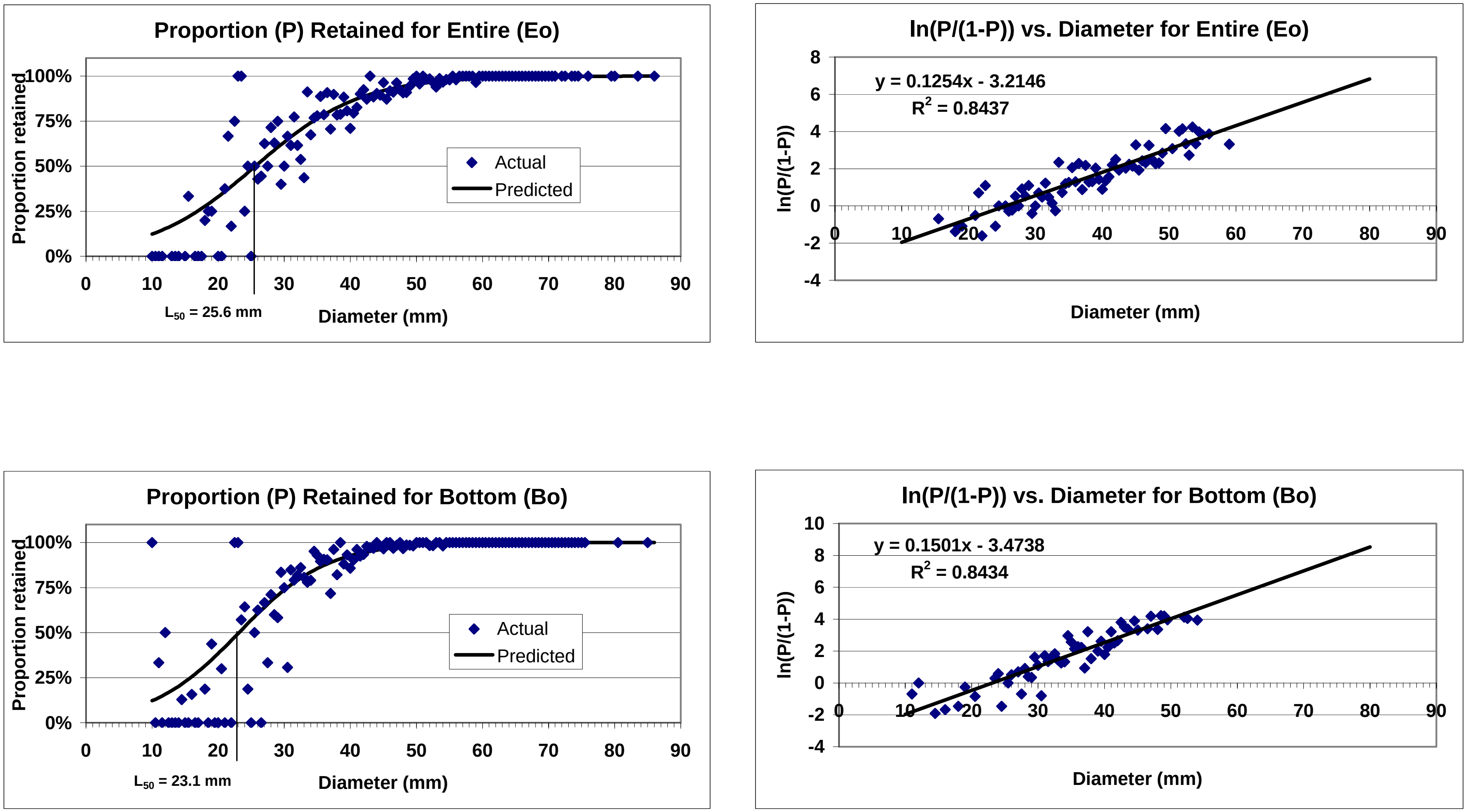


Figure 21. Selectivity curves (proportion retained in the drag vs. diameter (left), and log-linearized (right)), from tows using the outer bag, pooled for all locations, for treatment Entire above, and Bottom below. P = proportion retained, L_{50} = the predicted urchin diameter at which P = 50%.

Photo 1. FV *Northern Eagle* with experimental sea urchin drag.

Photos by Andrew Gowen

Photo 2. Sea urchin drag being configured with small mesh covering the bottom two-thirds of the back of the drag, to simulate an escape panel in the top third.

Photo 3. The front of the drag, and a good catch.

Photo 4. Bottom front of the drag.

Photo 5. Sorting the catch.

Photo 6. Typical catch, about 25% urchins.

Photo 7. Cleaner catch.

Photo 8. Measuring the sea urchins.

Photo 9. A range of sea urchin sizes. The one being measured is $2^{1}/_{16}$ inch diameter, Maine's minimum legal size.

Photo 10. Reconfiguring the escape panel by rolling the 2-inch mesh out of the way and replacing with 2¼-inch mesh. Note smaller mesh covering the top two-thirds of the net, to simulate a 2¼-inch escape panel in the bottom third.

Photo 11. The outer bag catch purse on the back of the drag, designed to catch whatever escapes through the escape panel, which, in this case, is the bottom panel of the drag.

Photo 12. Attaching the outer bag.

Photo 13. Deploying the drag, with the outer bag on the back.