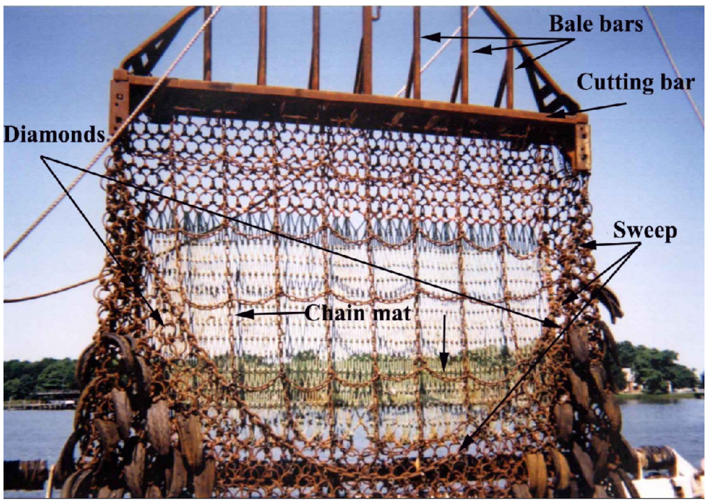
RESULTS OF GEAR MODIFICATION TESTS TO REDUCE BYCATCHES OF COMMERCIAL FINFISH IN SEA SCALLOP DREDGES



Soern Henriksen, Edward Welch, and Shane Therrien
SER Enterprises, 42 Water Street, Fairhaven, MA 02719
Ronald Smolowitz

Coonamessett Farm Foundation, Inc

277 Hatchville Road
East Falmouth, MA 02536
508-648-2018 FAX 508-564-5073
cfarm@capecod.net
www.coonamessettfarmfoundation.org

Paul J. Struhsaker
15631 22e Rue, St-Antoine des Laurentides, QC, CANADA J7Z 5T4
Cliff Goudey
MIT Sea Grant, Bldg E-372, 292 Main Street, Cambridge, MA 02139
Hauke Kite-Powell
Woods Hole Research Consortium, WHOI, Woods Hole, MA 02543

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II. ABSTRACT

Three modifications to standard sea scallop dredges were tested to determine their effects on incidental catches of commercial finfishes. The modified dredges were compared to standard dredges at 140 stations of paired tows during 6 trips to Georges Bank. Catch data were recorded for scallops, yellowtail flounder, "other flatfish," monkfish, skates, cod and "other fish." Results were evaluated with t-tests of paired comparisons and indicate that an eight inch square mesh twine top significantly reduces the catch of flatfish and cod. Square root transformations of catch data did not yield statistical results inherently superior to those of untransformed data. An economic evaluation of the impact on fishermen of excluding finfish from scallop dredges was conducted. The analysis revealed that the proposed modification will have no direct impact on fishing vessel income.

III. EXECUTIVE SUMMARY

This report summarizes the results of six experimental trips conducted under the auspices of the S-K program. These trips were primarily of an exploratory nature to test techniques which could result in an effective scallop dredge finfish extruder. Vessels using New Bedford style sea scallop dredges have traditionally caught and landed groundfish with this gear. As the management regimes for groundfish and sea scallops evolve, this groundfish catch has been defined as a bycatch and placed under limits. In addition, groundfish management area closures have been defined in a manner that prohibits the operation of any gear type that can catch groundfish. This action has prevented scallop fishing on historical scallop grounds and has thus motivated the scallop industry to examine ways to reduce the bycatch of groundfish in their dredges. SER Enterprises, a scallop company, received S-K funds to examine some potential means to exclude finfish from commercial sea scallop dredges. Building on recent Canadian scallop industry research, SER Enterprises focused primarily on enlarging the meshes of the twine top portion of the dredge.

Replacing the 6-inch mesh top of standard dredges with 10-inch webbing resulted in statistically significant reductions in catches of yellowtail flounder (30-63%) and other fish categories; however, there were also significant reductions in scallop catches. Replacing the standard top with 8-inch webbing hung on the square (4 inches on a side) produced significant reductions in yellowtail flounder (34-41%) and other fish categories with no reduction in scallop catches. The addition of a gooseneck roller to the bail of a standard dredge did not reduce finfish bycatches or influence scallop catches. A highly significant positive correlation of scallop and yellowtail flounder catch numbers was found for one trip; a significant negative relation during another, and no significant relations in abundance during the other four trips.

IV. PURPOSE

A. Identification of problem

The fishery for sea scallops, *Placopecten magellanicus,* is one of the most important fisheries on the USA Northeast Atlantic coast. In a good year (1990) 40 million pounds of meat were landed worth over $150 million dollars ex-vessel. Most of these scallops are caught using the New Bedford style dredge. This gear can also catch groundfish, especially flounders and monkfish.

Sea scallop dredge gear has lead a charmed life in that the gear has avoided scrutiny by those outside the scallop industry. The gear work that has been done has entailed the examination of ring size impacts on scallop selectivity. Scallop fishermen have been very hesitant about advocating any other dredge research but that is now changing. The key driving force is groundfish by-catch. The concern about by-catch and other gear-related impacts is not just a local trend.

Worldwide environmental interests are focusing on marine fisheries. In response, the United Nations FAO has issued a Code of Conduct for Responsible Fishing. Member nations are required to examine the environmental aspects of their fisheries including impacts on the sea bed, ecology, and by-catches.

Fishing gear specialists from around the world, meeting as an FAO Ad Hoc Working Group defined selective fishing as "The ability to target and capture fish by size and species during harvesting operations, allowing by-catch, i.e. small (or juvenile) fish and non-target species to escape unharmed. Furthermore, selectivity means abandoning the traditional emphasis on quantity and making a definite shift to sustainable harvesting practices. It means catching targeted fish, allowing the escape of those fish that are not wanted, as well as turtles and marine mammals, in a condition that they can survive, thus reducing overall pressure on the marine resource."

To be quite frank, most scallopers never thought about fish as an unwanted by-catch. It was not until the passage of Amendment Four to the scallop plan that groundfish became a by-catch in the scallop fishery. In the future, monkfish and lobsters will probably become a regulatory by-catch as well.

The New England groundfishery is highly over-exploited, consequently, managers are looking at severe measures to curtail any fishery that catches groundfish. Scallop vessels have found themselves excluded from lucrative scallop grounds because of their fish bycatch. If a means can be found to reduce potential fish catch, managers would have more flexibility in designing regulations and closing areas.

Reducing By-catch

Historically, there has been no research conducted on how to decrease fish bycatch in New Bedford style scallop gear before 1995. There exists some underwater video observations of an eight-foot wide New Bedford dredge, recording the behavior of several species of fish to the gear, on different bottom types (Smolowitz, 1979). Based on these observations the best approach might be to deter and guide fish away from the front of the dredge. It may be viable to physically block fish entrance into the dredge and/or provide means for their escape once in the dredge. It must be noted that New Bedford style scallop dredges fish differently depending on bottom type thus extensive testing may be required. Smolowitz et al (1985) found no significant difference in the catch of finfish between rock chain and standard dredges on hard and sand bottom. The dredges did catch more fish on sand bottom but no firm conclusions could be drawn from the data. Also, the gear used today is very different from that observed in previous studies. It is larger and heavier than that studied by Caddy (1968,1973) or Smolowitz (1979) and Smolowitz et al (1985).

One other important point that should be mentioned is that modifications made to a dredge to keep swimming fish from entering, may also decrease the catch of small scallops. Small scallops, under 80 mm in shell height, are active swimmers and have shown flight responses from dredges . Modifications to elicit escape responses in fish may therefore improve dredge size selectivity for scallops. On the other hand, openings in the dredge that allow fish to escape after entering will also be large enough to allow even the largest scallop to exit.

In 1995, the Canadian scallop industry started a research effort to reduce fish catch in scallop dredges. A number of trips have been made by Canadian commercial vessels testing various approaches including windows in the rope back, square mesh rope back, tickler chains on the bale, netting at the drag opening, and a large window the full width of the dredge. The Canadian industry provided Coonamessett Farm with the proprietary data they collected. A significant amount of very interesting observations were collected including day/night variations, impact of time on grounds, and effects of operational procedures. The bottom line though was that there was no clear cut successful solution in the 1995 trials. Most recently, the Canadian industry conducted another round of testing of some promising modifications that seem to work in areas of high scallop density. The results at this time have not been made public.

The catch rates of fish in scallop drags is relatively low thus an extensive amount of tows is required to come up with statistically significant results. Since one of the major concerns of any scallop gear modification is the impact on retention of scallops, it is very important that the test area contain relatively large amounts of scallops and fish; a difficult criteria to meet in today's environment outside of the groundfish closed areas.

B. Objectives of the project

1. To identify potential dredge modifications, through literature search and discussions with fishermen, that would reduce the catch of cod, haddock, and flounder without significantly reducing the catch of harvestable scallops.

2. To test several of the most promising sea scallop dredge modifications using paired tows and to record complete catch data.

3. To obtain underwater video of the sea scallop dredge in operation to evaluate potential gear modifications as well as other aspects of dredge operation (ie, habitat impact, sediment suspension, incidental mortality, etc).

4. To perform an economic evaluation of the potential impacts of dredge modifications that reduce finfish catch.

5. To prepare a detailed final report covering all aspects of the project.

V. APPROACH

A. Work performed

Identification of modifications

It was our planned intent to hold a workshop with commercial scallop captains to identify gear modifications that would reduce the catch of finfish. Their were a large number of scallop meetings held during the project period, sponsored by the New England Fishery Management Council, in which the bycatch issue was discussed. We took this opportunity to solicit information and hold discussions with the scallop fishermen who attended these meetings. While there was interest in holding a focused gear workshop, it was virtually impossible to schedule with all the other meetings being held. A large amount of information was gathered at the Council sponsored meetings.

We also held a meeting with Canadian industry and government representatives on the specific subject of finfish excluders. The Canadians that came to New Bedford included Chris Cooper (Chief, Technology Branch, DFO), Michael Pittman (Fleet Manager, Deep Sea Trawlers), and James Mosher (President, Scotia Trawler Equipment Ltd.). The Canadians had conducted a number of trials and had more planned. We exchanged information and ideas at this meeting and numerous phone conversations during the project period.

The third leg of our information gathering program was a literature search. This search uncovered a number of published papers on scallop gear operations that had useful observations as well as the Canadian trip reports from the trials mentioned previously.

Sea trials

Two vessels from the fishery were utilized for these tests: F/V Westport and F/V Canton. Sea scallop vessels routinely tow two 15-foot wide dredges, one from each side of the stern. For these trials, standard dredges were variously modified; these are referred to as "experimental" (or "treatment") dredges. During each trip, a series of paired comparative tows (or "stations") with experimental and standard (or "control") dredges were then conducted. The dredges were occasionally shifted between sides in order to randomize the experiments, but this was not always done on a routine basis. The participants representing the vessel and project were confidant that each dredge fished the same before modifications and there were no differences in fishing power between sides of the vessels.

Three types of basic dredge modifications were tested. During trips #1-3, experimental dredges with a 10-inch (254 mm) stretch mesh webbing top were tested against the standard 6-inch (152 mm) webbing top. The experimental top was a lighter twine than standard, and loosely hung. During trip #4 a gooseneck roller was mounted on the bail of a standard dredge and tested against a standard dredge without a roller. Some participants in the scallop fishery feel that rollers reduce fish catches. During trips #5 & 6, the experimental dredge was fitted with an 8-inch (203 mm) stretch mesh webbing top hung on the square (square mesh; 4" on a side).

During Trip #6 two impromptu changes were made to the experimental dredges to observe if highly obvious changes in catch rates would result (none occurred). At four stations (#25-28), large holes were cut in the top webbing next to the apron (the aft part of the twine top where it attaches to the steel rings). These holes were subsequently repaired. At the last nine stations (#44-52) a 90 mm wide "pressure" plate was welded to the bail of the experimental dredge. Because the experimental dredges in these series of tows had, effectively, two variables, the possibility arose that we could effect tests between the two types of experimental dredge. However, examination of the four and nine tows immediately preceding these series of tows, showed that in both cases significantly more yellowtail flounder (totals of experimental and standard dredges) were taken during the tows with the secondary modifications than during the preceding tows (t-test between means). Further testing between primary and secondary modifications was thus precluded. In the following discussions, Trip #6 refers to only the 39 tows where the square mesh top was tested against standard dredges (tows #1-24 & #29-43). Trip #6A refers to the nine tows where the square mesh top dredge with a pressure plate on the bail was tested against the standard dredge (tows #44-52). The four paired tows with holes cut in the square mesh top of the experimental dredge are not considered further (tows #25-28). For trip #3, the data for both dredges from one tow (#7) appear anomalous; this station is deleted from the following analyses.

Test areas were chosen on the basis that they would probably have high fish catches associated with the scallop catches; thus, these catch data may not reflect the usual finfish/scallop catch ratios of the fishery. The six trips were in areas offshore of Cape Cod out to the eastern part of Georges Bank.

Tow times ranged from 45 to 75 min, but most stations were 60-70 min in duration. Many of the tows were "turning tows" rather than "straight tows". This was done so that the same general area was sampled during a single tow; a common industry practice. No obvious discrepancies were noted between "inside and "outside" dredges during the trips, but the possibility of a consistent, subtle difference cannot be ruled out at the present. Towing speeds were consistently held at 4-5 knots.

Upon completion of a tow, the catches from each dredge type were sorted by species or species group and counted or measured. The finfish were categorized as follows: yellowtail flounder (Limanda), Atlantic cod (G. morhua), monkfish (Lophius), skates (Raja spp), other flatfish and other fishes. The "other flatfish" group comprised gray sole (*Glyptocephalus cynoglossus*), winter flounder (*Pseudopleuronectes americanus*), window pane (*Lophopsetta* *maculata*), four-spot flounder (*Paralichthys oblongus*) and an occasional fluke (*P. dentatus*). The following species made up most of the "other fishes" category: sculpin (Cottidae), sea robins (Triglidae), hake (Merluccius), and eels (Congridae). All sea scallops (Placopecten) were measured (shell height, mm) and grouped in 5-mm size categories: total counts for each tow were then obtained from these data. Total lengths were obtained for all skates and grouped in 3-cm size categories.

Station data and catches for each category are given in Appendix I.

Statistical methods

The paired tows of experimental and control dredges effected during the trials permit the use of the t-test for paired comparisons of catches between dredge types. This test is simple to apply and much more powerful than a t-test of the difference between two means or a completely randomized analysis of variance.

The raw catch data were converted to catch per hour for the more numerous species categories such as yellowtail flounder, scallops, other flatfishes and skates. The t-tests were run with untransformed catch data and data transformed to square roots. Rough plots of catch data for a few trips showed the distributions to the skewed to the right, as expected, and a few trial tests indicated that there might be significant differences in the variances of experimental and control dredges. Although the t-test with equal size groups is insensitive to differences in variances, and slight skewing has little effect on test results (Sokal and Rohlf,1995), the transformed data were run for two reasons. They were: to obviate possible criticism, and to provide comparative test statistics permitting evaluations of transformation effects.

When tests indicated probabilities were $0.1 > P > 0.001$, precise probabilities were estimated by obtaining critical values of t through harmonic interpolation, when necessary, and then linear interpolation using logarithms of the bracketing two-tailed probability values.

Some species categories such as cod occurred infrequently: in these cases the individual catches (not #/h) of each dredge type for a trip were pooled. Exact probabilities of the observed ratio occurring by chance were determined with the binomial expansion or estimated with a normal approximation to the binomial distribution (which is equivalent to the chi-square test corrected for continuity).

Underwater video

Video observations of the New Bedford type dredge were obtained using two methods. The first method used a dredge-mounted camcorder in an underwater housing. This system proved to be a convienient method of observation as the commercial practice of dredge setting and hauling is relatively unaffected. The disadvantages are the lack of real-time viewing, the

inability to easily determine the effects of changes in towing parameters, and the potential exposure to damage to the camera and housing from a back job. This system used a Sony TR-V81 Hi-8 cam corder in an underwater housing made by Gates Underwater Products. During tows taken aboard the F/V Westport, recordings were made with the camera facing the sweep and
facing ahead of the dredge. In both cases, the housing was mounted between the pressure plate and the cutting bar. These observations provided revealing views of the action of the cutting bar with respect to scallops entering the dredge and the suspension of sand and sediments.

The second method of observation involved the use of the electromechanical tether developed for the Towed Underwater Gear Observation System (TUGOS). Using the tether, real-time video could be provided in the pilot house and direct insight on the effects of varying the towing parameters could be obtained.

Our original plans for using the entire TUGOS system were modified due to the relatively small viewing area of interest and the high speeds used in commercial dredging. The control of the TUGOS vehicle cannot be assured beyond its design operating range of 2 to 4 knots. The 5 to 6.5 knot dredging speeds presented too-much risk to the vehicle.

Custom cabling harnesses were assembled for both ends of the TUGOS tether. At the underwater end of the tether, connections for the following components were provided:

1. Forward-looking 0.03 lux monochrome CCD camera in a custom housing
2. Rear-looking 0.03 lux monochrome CCD camera in a custom housing
3. Two 12VDC UP&W underwater lights
4. An altitude sensor

At the upper end of the tether an adapter was assembled to connect to the following power and display components:

1. BNC connecter to video monitor 1
2. BNC connecter to video monitor 2
3. 12 VDC power to cameras
4. Power to each light
5. Interface to the altitude display

The forward-looking camera was fitted with a 4mm wide-angle, manual-iris lens. The rear-looking camera was fitted with an 8mm lens. At no time was the artificial lighting required due to the high sensitivity of the two monochrome cameras.

The tether-based system was used aboard the F/V Sandra Jane in two modes of operation. Initially the tether was stopped off to the dredge tow cable at 50-foot intervals. This method caused delays in the setting of the dredge and resulted in the flipping of the dredge on the first tow and no useful images.

Subsequent tows were deployed without connecting the tether to the tow cable and the system worked fine. Through real-time viewing in both forward and rear directions, the correlation of dredge performance with changes in scope, towing speed, and vessel turning was possible. The observation of fish behavior both ahead of the dredge and before entry into the bag was made possible.

Economic evaluation

The economic evaluation was performed by developing a model based on catch records of several New Bedford scallopers. Details of the economic analysis are given in the findings section of this report.

VI. FINDINGS

A. Actual accomplishments and findings

Effects of finfish excluder devices

General Results

Modifications to the webbing in the tops of scallop dredges resulted in significant reductions of incidental catches of finfishes and show the most promise of the techniques tried to date, at least in areas of limited scallop density. The addition of a gooseneck roller on the bale of the dredge did not reduce the catches of any of the species categories examined.

Yellowtail Flounder

Yellowtail flounder was the principal species of concern in the finfish extrusion tests. It was ubiquitous, being taken at every tow at catch rates of 3 to 51 per hour for standard dredges. It was less common during the first two trips than during the others. The statistics for the t-tests of paired comparisons (paired dredge tows) are summarized in Appendix II, Table 1. Highly significant ($P < 0.001$) differences in catches between experimental and control dredges were observed during trips #1,2,5,6 & 6A. Similar results were obtained during trip #3: here the probabilities were higher, but still very significant ($P = 0.0059$ for untransformed variables). However, during trip #4 (roller on bail) more yellowtails were taken in experimental dredges: this difference is significant at $P = 0.0525$ for untransformed variables.

For all trips there were inconsequential statistical differences between tests utilizing untransformed and transformed variables (Appendix II, Table 1). As expected, the F ratios for variances between experimental and control dredges are reduced with transformed variables. However, in either case the differences in variances between dredge types were not significant. Additionally, transformations had little effect on the outcome of the t-tests for significant differences between the paired tows, although the transformations did yield a higher t value in most cases.

Table 2 (Appendix II) presents average catches for experimental and standard dredges and the differences as a percentage of the average for the standard dredge. Average catches of scallops of all dredge hauls for a trip are also given as a general indication of scallop abundance in the test area. There were marked reductions in yellowtail flounder catches in all experimental dredges except for trip #4 where there was a 16.8% increase in yelllowtail flounder catches. For the remaining trips, the dredge modifications produced average catch reductions of 30.1 to 62.6%. It is noted that the extremes of this range represent trips where relatively few tows were effected (trips #1 & 3) and larger variations in catch rates were experienced. For the remaining trips, a 50% reduction was obtained during trip #2 with 10-inch mesh, 34.4 and 37.3% reductions during trips #5 & 6 with 8-inch square mesh, and 41.4% reduction during trip #6A with 8-inch square mesh and a pressure plate. There does not appear to be a relation between yellowtail flounder catch reductions and the relative abundance of scallops in each sampling area.

Confidence limits provide a useful summary of these test results: limits of 95%, 99% and 99.9% were calculated for the untransformed average catches of yellowtail flounder in experimental and standard dredges for all trips except #6A (App. II, Table 3). Figure 1 provides a graphical comparison of the results for all trips by displaying the general distributions of their average catches and 95% confidence limits. Individual trip results for catch ranges, average catches and 95%, 99% and 99.9% confidence limits are shown in Appendix II, Figures 2-7.

Other Flatfish

The numbers of "other flatfish" taken during the first two trips varied greatly. Consequently, there were only 6 stations during trip #1 and 4 stations during trip #2 where enough were taken to permit t-tests of paired comparisons. However, this species group was well represented at all stations during the remaining trips when average catch rates in standard dredges ranged from 25.6 to 109.9 per hour.

The statistics for the t-tests of paired comparisons are summarized in Appendix II, Table 4. As with yellowtail flounders, there were significant reductions in bycatches of flatfish in experimental dredges during all trips except for trip #4 (roller on bail). Although an average 5.1% catch reduction was observed during this trip (Appendix II, Table 2), it was not statistically significant. There were highly significant ($P<0.001$) reductions in flatfish catches in experimental dredges during trips #5 & #6. For trip #3, the probabilities were nearly as significant, being 0.0046 for untransformed variables and 0.0032 for transformed variables. For trips #1, #2 & #6A the probabilities were higher, with a range of 0.014 to 0.043.

The six paired tows examined during trip #1 comprised 93.3% of the total fish in the category of "other flatfish." Of the remaining 21 fishes, seven were taken in experimental tows and 14 were taken with control tows: this difference was not significant. The four paired tows of trip #2 comprised 58.2% of the total fishes taken. Of the remaining 66 fishes, 18 were obtained with experimental dredges and 48 with control dredges, a highly significant difference (2-tail exact probability = 0.0003).

For all trips there were inconsequential statistical differences between tests utilizing untransformed and transformed variables (Appendix II, Table 4), as was the case for yellowtail flounders. The transformations had no effect upon the outcome of the tests for reduction in bycatch, although they did result in higher t values in all cases but one (trip #5). There were no significant differences in variance between experimental and standard dredges for all trips except

#6 & #6A. Highly significant probabilities ($P < 0.001$) were obtained for both untransformed and transformed variables for trip #6: a significant probability ($P < 0.05$) was obtained for untransformed variables during trip #6A. As discussed, t-tests are insensitive to differences in variance between groups of equal size.

These results are summarized in Appendix II, Table 2 where average catches for experimental and standard dredges are given, as are their differences as a percentage of the average catch for the standard dredge. Average catches of scallops at all evaluated dredge stations are also given. Reductions of the flatfish bycatch ranged from 19.5% to 60.6% during the first three trips when the 10-inch mesh top was tested. It is noted, however, that only six and four paired tows were evaluated for trips #1 & #2. Bycatch reductions of 41.6% and 46.0% were obtained during trips #5 & #6 (square mesh top) when adequate numbers of paired tows were obtained and substantial catches of flatfishes were made. During trip #6A when 9 tows of the square mesh top with a pressure plate added were effected, and catch numbers were intermediate between those of trips # 5 & #6, a bycatch reduction of 60.6% was obtained. This is an even more pronounced difference in percentages for these three trips than noted for the yellowtail flounder bycatches. As stated earlier, the available data does not permit tests of significance to determine if the pressure plate increased the extruding efficiency of the square mesh top. Further examination of this possibility is warranted.

Aside from noting that fewer scallops were present in the stations examined for the first two trips, there is no apparent relation between scallop abundance and percent reductions in flatfish catches.

Skates

Skates were present in substantial numbers at most stations during the trials, with average catch rates for standard dredges ranging from 40 to 184 per hour. This species group usually contributed most to the biomass of the finfish bycatches. Only a few individuals were present at seven stations during trip #2 and they are not included in the analysis for that trip. The statistics for the paired comparisons of skate catches are summarized in Appendix II, Table 5.

The results of the dredge modifications on bycatches of skates were much more variable than for those for yellowtail flounders and other flatfishes. Although on the average fewer skates were taken in experimental dredges than in control dredges during every trip, in only two cases were the differences significant. Bycatch reductions in average catches of 16.4%, 14.4% and 22.8%, respectively, were indicated for trips #1, #2 & #3 (10-inch mesh tops). However, only the reduction for trip #3 ($P \div 0.003$ for untransformed variables) was statistically significant. A catch reduction of 11.7% observed for trip #4 (roller on bail) was not significant. The 26.6% bycatch reduction of skates during trip #5 was highly significant ($P < 0.001$).

Monkfish

Monkfish were taken in sufficient numbers during the first two trips to permit t-tests of paired comparisons. During trip #1 there was a very significant (P ÷ 0.007) reduction of monkfish bycatch in experimental dredges where catches averaged 7.4/h vs 11.1/h in control dredges. The result of trip #2 was similar, but with a higher probability (P = 0.0508) and a smaller difference between average catches, 6.4/h for experimental dredges vs 7.8/h for control dredges. During trip #3, 3-18 monkfish were taken at every station. There were no differences between the pooled catches of experimental dredges (110 individuals) and control dredges (114) individuals. We cannot explain these varying results from the three trips where modifications to the experimental dredge were identical (10-inch mesh top).

For the remaining trips, there were no significant differences between experimental and standard dredges. During trip #4 (roller on bail) this species was present in 15 of the 18 stations: the pooled catches of monkfish were 27 in experimental dredges and 29 in standard dredges. During trip #5 (square mesh), 1-3 individuals were present in 22 of the 30 stations. Pooled catches were 34 for experimental dredges and 23 for standard dredges. During trip #6 (square mesh), 1-3 individuals were taken at 36 of the 52 stations. Pooled catches were 36 for experimental dredges and 37 for standard dredges.

These results might be explained by the unique physiognomy of the monkfish. The highly dorso-laterally flattened skull of this species would make it susceptible to being retained by the standard 6-inch top of the experimental dredge of trip #4 and the eight inch square mesh tops (4-inch on a side) of those for trips #5 & #6. Conversely, the larger 10-inch mesh, conventionally hung, tops of the experimental dredges for trips #1-3 would seem to offer a larger diamond-shaped opening that would permit a monkfish to slip through "sideways."

Atlantic Cod

No cod were taken during trips #1 and #3, while only five were caught during trip #4 (two in experimental dredges and three in standard dredges). However, significant bycatch reductions in experimental dredges were observed for the remaining trips. Although only 16 cod were taken during trip #2, the ratio of 3 in the experimentals and 13 in controls was significant (2-tail exact probability = 0.02).

During trips #5, #6 and #6A not one cod was taken with experimental dredges, all of which had 8-inch square mesh tops. That the binomial probabilities for the observed catch ratios of 0/23 for trip #5 and 0/50 for trip #6 are due to chance are very small. The 2-tail probability that the observed ratio of 0/8 for trip #6A is due to chance is 0.0039. The finfish extrusion arrangement of an eight inch square mesh top (4" on a side) seems to be an effective method of reducing incidental catches of cod.

Other Fish

Significant reductions of bycatches of "other fish" occurred only during trips #2 and #3. For trip #2 a 65% reduction was indicated when, for pooled catches, 15 fishes were taken in experimental dredges and 46 in control dredges ($P < 0.001$). During trip #3 a total of 24 fishes were taken, 5 in experimentals and 19 in controls for an indicated 74% reduction ($P \div 0.003$). For the remaining trips the trend for a reduced bycatch in experimental dredges continued, although none of the differences was significant. The pooled catches for experimental dredges (E) and control dredges (C) were as follows. Trip #1: E=10, C=11; Trip #4: E=47, C=59; Trip #5: E=21, C=24; Trip #6: E=42, C=59; Trip #6A: E=3, C=7.

Effects of finfish excluders on scallop catches

Although reductions of finfish bycatches in dredge hauls are desirable, concurrent reductions of scallop catches are not. The dredge modifications tested during the six trips had varying effects upon the scallop catches. To better understand the test results, t-tests of paired comparisons were made for total scallop catches (Table 6), large scallops (greater than 90 mm shell height, Table 7) and small scallops (less than 90 mm shell height, Table 8). Although scallops were taken at every station, occasionally the small scallop size-group was not represented.

The addition of a gooseneck roller on the bail of a standard dredge during trip #4 had no effect on the scallop catches.

Mixed results were obtained from the three trips with 10-inch mesh tops on the experimental dredges. During trip #2 there were highly significant ($P < 0.001$) reductions in experimental dredge catches for total scallops (Table 6), large scallops (Table 7) and small scallops (Table 8). There was a 48.4% difference between the average catches for total scallops, a 35.2% difference for large scallops and a 52.6% difference for small scallops. During trip #1 there was a significant reduction of total scallop numbers in the experimental dredges ($P \div 0.022$ for untransformed data). This may be attributed to the significant reduction ($P \div 0.025$, 50.8%) in the small scallop catches: there was not a significant difference between dredges for large scallops. Finally, during trip #3 there were no significant differences in scallop catches.

Less tentative results were obtained during the remaining trips when the experimental dredges were fitted with 8-inch mesh tops hung on the square. No significant differences between dredge types were obtained for scallop catches during trips #6 and #6A (pressure plate added). Interestingly, during trip #5 there was a significant ($P \div 0.0024$) increase in catches of 13% for large scallops (Appendix II, Table 7).

As were the cases for yellowtail flounders and other flatfishes, the square root transformations of catch data resulted in only small differences from the untransformed variables for the statistical results. Again, in most instances, the transformations yielded slightly higher values for the t-test.

<u>Yellowtail flounder and scallops: Correlations of association</u>

It is of interest to determine if there are significant relations between the observed catches of yellowtail flounders and scallops. To do this, we ran correlation coefficients and linear regressions for untransformed catch data of total scallops (both dredges) as independent variables and total yellowtail flounder (both dredges) as dependent variables. The same analyses were done for square root and logarithmic transformations of the data. Pertinent statistics for untransformed and square root transformed data are given in Appendix II, Table 9. Logarithmic transformations produced similar results. Essentially, both transformations had no effect on the statistical outcomes.

No significant correlations in abundance of the two species were found during the first four trips. This is not surprising, considering the great variations in catches of scallops and yellowtail flounders and the relatively few stations made at these times. There were no indications of positive or negative trends during the trips #1,#2, and #4. During trip #3 a positive correlation coefficient of $r = 0.393$ was obtained for 11 tows: this is not significant ($P > 0.1$).

A significant negative correlation ($r = -0.406$) in abundance of the two species was obtained for the catches during trip #5 ($P \div 0.026$). A highly significant ($P < 0.001$) positive correlation of $r = 0.601$ was obtained for the "standard" 39 tows of trip #6. As an additional exercise, data from all 52 tows (including dredge hauls with secondary modifications to experimental dredges) for this trip were also run. This resulted in a much lower correlation coefficient of $r = 0.24$ that is not significant at traditional levels ($P \div 0.0877$). This dramatic change is due to an outlier station (#45) which produced the lowest scallop catch (172) and the highest yellowtail catch (66), completely opposite to the trend of the remaining stations. Deleting this station resulted in a positive correlation coefficient of $r = 0.366$ that is very significant ($P \div 0.008$).

Finally, for the 52 tows of trips #6, there were no significant relations between total catches of scallops and other flatfishes ($r = -0.142$) or between total catches of yellowtail flounders and other flatfishes ($r = 0.214$).

Obviously, no firm conclusions may be drawn from these varying results other than there are spatial and temporal variations in the association of scallops and yellowtail flounder that cannot be resolved without further investigation.

Economic Analysis

The use of a finfish excluder can affect the economics of a scallop vessel in several ways. It may increase the cost of equipment, maintenance, and fuel use; it may reduce the scallop catch; and it will eliminate the revenue associated with landed groundfish bycatch. Preliminary observations suggest that the added operational cost is negligible and that scallop catch is not affected significantly by use of the excluder. However, the finfish (groundfish including monkfish) bycatch historically has contributed significantly to scallopers' revenue, and the elimination of finfish bycatch can have significant effects on the vessels' profitability. Therefore, we focus here on the revenue from landed fish bycatch, and how its elimination affects vessel owners/operators' decisions and profits. Our model results suggest that the use of a finfish excluder that excluded monkfish as well as other groundfish would force vessels to remain idle during some winter months, and reduce annual profits by more than 60 percent. Recently, scallop vessels have had significant limitations placed on their landings of regulated groundfish species. Most vessels no longer land these species in order to avoid violations that would result in the seizure of their entire catch.

Economic Model

Our model considers a single, "typical" scallop vessel operating in southern New England. The vessel's owners/operators seek to maximize annual profits by choosing either to fish or to leave the vessel idle in each period i, where i = 1, 2, 3, ..., 12 (twelve months make up the year). Following established economic theory, they achieve this goal by operating the vessel in period i whenever the expected revenue in period i is greater than the variable cost of operating the vessel in period i (Ri > Ci).

The variable cost (Ci) for period i is the average daily variable cost (expendable supplies, labor, etc.) multiplied by the number of days at sea in period i. Revenue (Ri) is the product of landing weight and dockside price for each species (scallops, finfish). Landing weight, in turn, is the product of average daily catch in period i and the number of days at sea in period i.

The model estimates Ri and Ci for a typical scallop vessel under two scenarios: (A) under the "historical" condition where no finfish excluder is used, and the vessel lands groundfish bycatch as well as scallops, and (B) under hypothetical conditions where a finfish excluder eliminates all finfish bycatch, and only scallops are landed. It then determines the profit-maximizing operating schedule (the periods in which the vessel will fish under each scenario), and estimates the resulting profitability.

Economic Data and Results

Our analysis is based mainly on detailed cost and landings data from two typical scallop vessels operating from southeastern Massachusetts during 1994 and 1995. These vessels were at sea for about 15 two-week trips per year, or slightly over 200 days per year. Operating expenses (fuel, ice, stores, etc.) average just over $1000 per day at sea, and crew costs ("wages") average just under $1000 per day at sea; the total variable cost of operating the vessel is just over $2000 per day at sea. (In fact, crews are not paid regular wages but a percentage of revenues adjusted for certain costs.) Under scenario A, the boat owners' share of revenues, including groundfish bycatch landings, averages about $1000 per day at sea, or just over $200,000 per year. These numbers are consistent with data reported by Buss and Kitts (1995) for commercial fishing vessels in the northeast United States. Buss and Kitts suggest that fixed costs for the scallop vessels in question should be around $140,000 per year, leaving a profit of about $60,000 per year under scenario A.

The only significant finfish landed by the scallopers we analyzed is monkfish. The vessels occasionally also landed small quantities of yellowtail, gray sole (witch flounder), blackback (winter flounder), cod, sea dab, and sand dab; but none of these contributed significantly to revenue. Over the year, these vessels catch an average of 500 pounds of scallops and somewhat more than 200 pounds of monkfish per day at sea. Scallop and groundfish catch rates and landings follow significant seasonal patterns (see Figure 1): in the warm months, when scallop catch is high, little or no monkfish is landed; in the colder months, when scallop catch is low, monkfish may account for all vessel revenue on some trips.

Dockside prices also follow seasonal patterns; scallop prices tend to peak in winter and hit a low in late spring, rising again gradually through late summer and fall (see Figure 2). Year-round, dockside prices average more than $5 per pound for scallops and less than $2 per pound for landed groundfish bycatch.

Total annual revenue for a vessel under scenario A is about $550,000. Scallop landings account for about 85 percent of annual revenue when finfish excluders are not used; the remaining 15 percent come from landed groundfish bycatch (see Figure 3).

Under scenario B, the use of a finfish excluder eliminates all groundfish bycatch landings, which would cost the scallop vessel more than $90,000 in annual revenue if the vessel remained on a year-round operating schedule. Thus, the vessel could not be operated profitably year-round with a finfish excluder. Figure 4 shows revenue and variable cost for both scenarios. While it is economically sensible to operate the vessel year-round when finfish bycatch can be landed (scenario A), the model suggests that under a finfish excluder regime (scenario B), the vessel should stay idle during much of the winter (the months of November, December, January, and February), when average daily scallop catch rates are too low (despite higher than average prices) to justify fishing for scallops alone.

By staying in port from November to February, and fishing about 20 days per month the rest of the year, the vessel can operate profitably with a finfish excluder. Although some scallop catch is lost, the winter idle time saves more than $110,000 in annual operating costs, and allows the vessel to turn an annual profit of about $20,000 (about 30 percent of the profit realized under scenario A). (The exact outcome depends on the prevailing revenue sharing arrangement; we assume here that about half of the reduced revenue is reflected as lower crew wages, and half in reduced revenue for the vessel owners.) Thus, by adjusting their operating schedule, scallop vessels can remain profitable with finfish excluders, though their annual profits will be reduced by more than 60 percent from historical baselines. Reduced days-at-sea schedules and future monkfish regulations will have impacts that far out-weigh the impact of eliminating the landing of regulated groundfish; which for all intent and purposes has been effectively eliminated by existing regulation.

Conclusions

1. Modifications to the standard 6-inch (152 mm) webbing in the "top" of sea scallop dredges show the most promise as methods of extruding incidental catches ("bycatches") of commercial finfish from scallop dredge hauls in areas of low scallop density.

2. Substituting a 10-inch (254 mm) webbing in the top of the dredge effected highly significant reductions in bycatches of yellowtail flounder (30-63%) and other finfish categories. It also produced significantly fewer scallops during two of the three trips this modification was tested.

3. Substituting an 8-inch (203 mm) webbing hung (installed) on "the square" (4 inches on a side) in the top of the dredge resulted in highly significant reductions in the bycatches of yellowtail flounder (42-61%) and other finfish categories with no accompanying reduction in scallop catches.

4. There were indications (statistically untestable with available data) that the addition of a pressure plate to the bail of dredges with 8-inch square hung tops produced lower flatfish bycatches than those without the plate. Further examination of this technique is warranted.

5. We suspect that the 10-inch mesh webbing may be more effective in extruding flatfishes and monkfishes than the 8-inch square hung webbing. This may be because the "diamond shape" of the conventionally hung webbing permits species with dorso-laterally flattened shapes (including scallops) to more readily escape dredges than do dredge tops of square webbing. This hypothesis cannot be tested with existing data.

6. Attaching a gooseneck roller to the bail of a standard dredge did not result in bycatch reductions of yellowtail flounder and other species, nor did it influence the scallop

catches. This result is of significance because many members of the scallop fishery believe a roller on the dredge will reduce the finfish catch.

7. Correlations of relative abundance between scallops and yellowtail flounders produced mixed results. Although significant positive and negative relations were observed for two trips, there were no such tendencies for the remaining four trips. Substantial spatial and temporal variation in the occurrence of the two species is indicated, and should be considered in future studies.

8. Square root transformations of catch data for the t-tests of paired comparisons and the regression and correlation analyses did not yield results with any meaningful statistical advantage over untransformed data. Although catch data for yellowtail flounder and other flatfishes tended to have skewed distributions and, occasionally, a nearly significant difference in variances of treatment and control dredges, the test results were unaltered by transformations.

9. Substantial reductions in the incidental catches of yellowtail flounder and associated species have been effected with the modifications tested to date. However, it is desirable to attain bycatch reductions of at least 80%. One recommendation for further trials is to modify the dredge top with 10-inch webbing hung on the square (5 inches on a side). Perhaps this configuration would incorporate the advantages of both the conventionally hung 10-inch webbing tops and the square hung 8-inch webbing tops.

B. Problems Encountered

The primary problem encountered during this project was not being allowed access into the groundfish closed areas to conduct the experimental tows. The closed areas contain high concentrations of groundfish and scallops that would have allowed for greater statistical power for confirming results in fewer tows. This would of then allowed for trials of additional modifications. In addition, Canadian results indicate that modifications that work in areas of low abundance may not be successful in areas of higher abundance of target and bycatch species. Since this project was focusing on the management problem of scallop harvesting in the closed areas we do not have results that may apply in those areas.

C. Additional Work

There is the need to continue testing further modifications to reduce bycatch in scallop dredges and to confirm our test results in the groundfish closed areas.

EVALUATION

The following is a brief review of the projects goal and objectives and the degree to which they were attained.

1. Video recordings of scallop dredges

   We obtained many hours of underwater video of commercial scallop dredges using dredge mounted cameras. The videos examine the area in front of the oncoming dredge and observe escapement of scallops, lobsters, and finfish. The videos also look aft into the dredge to observe behaviors around the sweep chain and twine top. The video footage provides some insight into potential gear modifications. We did not get any remarkably good video showing fish escape attempts because of the amount of turbulence around the gear. In addition, we destroyed one camera when an underwater housing flooded due to snagging on the twine top. It is very difficult to safely mount cameras on scallop gear so we are pleased with the results we did get though they could be better.

2. Identification of bycatch reduction techniques

   This was a continuous activity involving discussions with USA and Canadian fishermen. We rapidly homed in on the concept of large mesh twine tops as the most obvious modification to test based on these discussions. We successfully accomplished this task by the fact that this modification worked well.

3. Testing the modifications

   Due to the low catches it took the entire project's sea time to confirm the bycatch reduction of an eight inch square mesh. However, the testing went well and a massive amount of solid data was obtained for a number of species. The data was examined by the Scallop Plan Development Team and accepted for the purposes of making a recommendation to the Scallop Committee. A significant amount of the data collected has not been analyzed (ie fish length frequencies) due to the lack of time/money.

4. Evaluate other aspects of scallop dredge operations

   While we have extensive video of sediment suspension generated by the scallop dredge, we did not have the time to evaluate the impact of sediment suspension. No incidental fishing mortality data was collected due to the other overwhelming sampling requirements.

5. Economic analysis

The economic situation changed during the project period. Scallopers no longer land any significant amount of fish bycatch thus fish excluders do not have an economic impact to evaluate, at least from the perspective of an individual scalloper. Since our preferred modification did not impact scallop catch there was no economic impact here as well. It was beyond the scope of this project to determine the overall impact to the groundfish resource due to finfish excluders on scallop dredges as one would have to speculate on what would be the proposed management regime.

Overall, the project has to be considered highly successful in that we developed a modification that greatly reduces finfish bycatch without a loss of marketable scallops. It would have been much better to confirm this in the groundfish closed areas where this modification is truly needed.

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APPENDICES

Appendix I Catch Data

Table One: Station data
Table Two: Scallop catch data
Table Three: Fish catch data
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Appendix II Statistical Analysis

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Appendix III Economic analysis

Figure One: Average landing rates
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