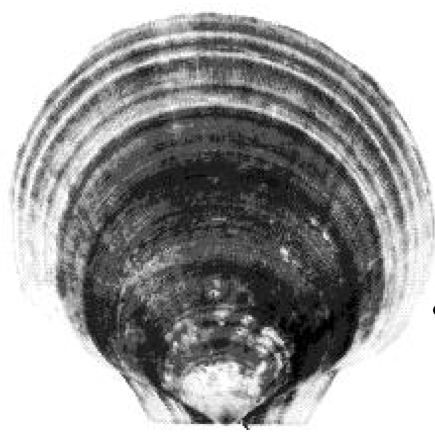
Throughout your paper, use metric (but it's OK to put English units in parentheses if you want).

The Performance of a Scallop Dredge with 102 mm (4") Rings in the Context of an Area Rotation Management Scheme

Title should be tight and direct. Nothing clever or creative here, please!



There's really no need to include a picture on the title page. I just tossed it in so you guys would know what a scallop looks like.

Kevin Goff

Virginia Institute of Marine Science

No page number here, because the title page isn't really a page. Starting with the abstract, your paper should be at least 6 pages long (not including graphs and figures) …which really should be easy, since that's an average of one double-spaced page per section (although your Intro & Discussion sections should be longer than the Abstract, Methods, Results, and Reference sections). So PLEASE resist the urge to artificially lengthen your paper by plunking in fluff and filler and redundantly redundant redundancies!!!

To save paper, I used single spacing, but you should use double

Abstract

During the 1990's, five large areas on Georges Bank and the Mid-Atlantic Bight were closed to all scalloping gear. Under those closures, Atlantic sea scallops (*Placopecten magellanicus*) grew tremendously both in individual size and in population density. From 1999 to 2001, each of these closed areas opened for one or more limited, carefully regulated fisheries. Catch rates were exceptional, harvests were huge, and most scallops met or exceeded the optimal size and age for maximizing the stock's yield per recruit. The success of these closed area fisheries revealed the great potential for managing the scallop stock through a program of rotating closures and openings. Such a management scheme would require an amendment to the Sea Scallop Fishery Management Plan administered by the New England Fishery Management Council, and as in past amendments, this would probably include new regulations to define the dimensions of the fishing gear. This study investigated the performance in closed areas of a scallop dredge fitted with a collecting bag made of steel rings 102 mm (4.0") in diameter relative to the performance of a dredge with the standard 89 mm (3.5") rings. On a series of seven trips to three of the five closed areas, the 102 mm rings consistently outfished the 89 mm rings on optimal size scallops, while simultaneously diminishing the capture of pre-optimal scallops. At the same time, the wider rings substantially reduced the volume of trash (invertebrates and debris) retained by the collecting bag, and also reduced the bycatch of certain species of finfish. By improving harvest efficiency on larger scallops while diminishing the mortality of smaller discards, 102 mm rings would serve a rotational management scheme's primary objective of delaying the age of harvest in order to improve yield per recruit. By removing fewer invertebrates and less benthic substrate from the seafloor, by cutting the capture of finfish, and by decreasing the amount of dredge time on bottom needed to harvest a fixed limit of scallop meats, the wider rings would serve rotational management's secondary objective of moderating the damage inflicted on benthic communities by scallop gear.

Genus & species names in italics

The Abstract briefly summarizes the research and its results. The reader can then decide whether or not to read the entire paper for details.

Introduction & Literature Review

In 1998, in order to protect a strong set of Atlantic sea scallop (*Placopecten magellanicus*) recruits, the New England Fishery Management Council (NEFMC) took "emergency action" under the Sea Scallop Fishery Management Plan (SSFMP) and closed two productive scallop grounds on the Mid-Atlantic Bight: the Hudson Canyon Area off the coast of New Jersey and Delaware, and the Virginia Beach Area off the coast of Virginia and North Carolina (Figure A). Since 1994, three large regions on Georges Bank – Closed Area I, Closed Area II, and Nantucket Lightship – had also been closed to all mobile bottom gear, including scallop dredges, not to rebuild scallops but to protect collapsed stocks of groundfish (cod, haddock, yellowtail flounder, etc.). Prior to the 1998 closures, the U.S. scallop fishery was being managed solely through measures designed to constrain the

Abbreviations spelled out the first time

Helpful map of study sites

Important background info, plus historical & social context

Citation by Law and Year

Citation by Agency and Year

industry's fishing effort: a moratorium on the issuing of vessel permits, a maximum crew size of seven, and a restricted number of days-at-sea that each boat could annually fish. In the wake of the Sustainable Fisheries Act of 1996, which outlawed overfishing in federal waters and mandated the restoration of all fish stocks within ten years (Magnuson-Stevens, 1996), the NEFMC established a new days-at-sea schedule which imposed on the fleet a decade of steady, severe reductions in fishing days. The goal was to rebuild the depleted Georges Bank and Mid-Atlantic scallop stocks to a biomass (B_{MSY}) that would enable harvesting at Maximum Sustainable Yield by the year 2008. Yet by the summer of 2000, long before the most severe days-at-sea reductions went into effect, biomass had already reached record highs, with the Georges Bank stock above B_{MSY} and the Mid-Atlantic stock nearly so (NEFSC, 2001). However, this remarkable recovery was only partly the result of effort restrictions. The principal reason that overall biomass had risen so high was the closure in 1994 and 1998 of those five expansive scallop grounds.

When citing a paper by three or more authors, use "et al." (Latin for "and others")

Some biology of the target species, especially as it's relevant to the study

In these closed areas scallop stocks flourished, dramatically demonstrating the potential to manage sea scallops by way of "rotating" area closures and openings. Three life history traits make the sea scallop a good candidate for using an area management scheme to optimize yield per recruit: (1) they are essentially sessile, (2) grow quite rapidly, and (3) have only a modest natural mortality rate (Murawski et al., 2000). *Placopecten magellanicus* is a large epifaunal bivalve that rests atop the benthic substrate of the continental shelf in the Northwest Atlantic Ocean from the Gulf of St. Lawrence to Cape Hatteras, where it supports large offshore fisheries on Georges Bank and the Mid-Atlantic bight (Lai & Rago, 1998). The sole part of the animal that is marketable is its thick, round adductor muscle (the "meat" or "eye"), which it uses for sealing and swimming (by clapping the shells together and jetting out water). Although capable of swimming short distances, recapture of tagged individuals shows that scallops do not conduct mass migrations (Bourne, 1964) and so can feasibly be managed by sub-areas within their range. Though difficult to measure, natural mortality is generally taken to be 10% annually. This modest mortality rate would permit significant numbers of scallops, if unfished, to reach sizes close to their asymptotic height and weight. Scallops approach that asymptotic height and weight rapidly, increasing their shell height by as much as 80% between ages 3 and 5, while quadrupling their meat weight (Serchuk et al., 1979). Closures would therefore need to last only a few years to return substantial gains in yield per recruit. A scallop's annual growth rate does not fall below 10%, the assumed natural mortality rate, until age 8 or 9, so that delaying harvest to age 8 would, with perfect fishing, theoretically maximize the yield per recruit (Serchuk et al., 1979; Posgay, 1979; Cushing, 1981). However, gains would be slight beyond age 6, which corresponds to a shell height of about 115-120 mm (dorsal hinge to ventral margin), and this may be defined as the "optimal" size and age at which to first harvest scallops.

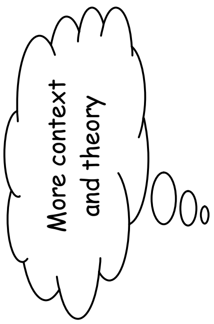
When citing a paper by two authors, name them both

Citation by Author and Year

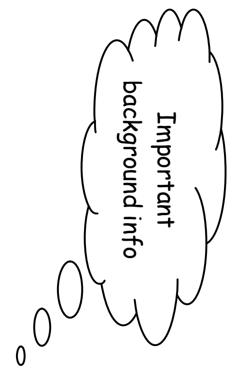
Data from previous studies

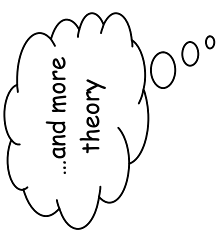
Citation of several different papers, separated by semicolons.

Underlying Theory

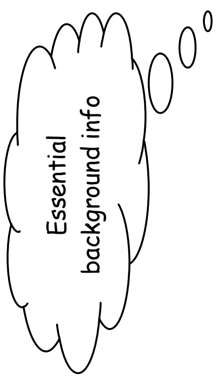


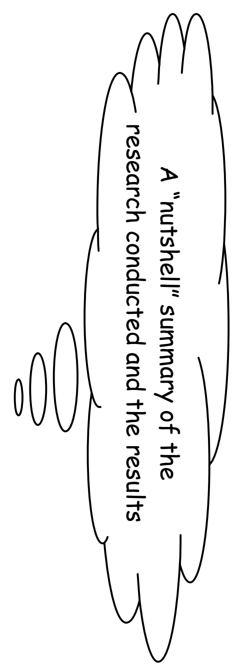
These life history traits, then, might enable management to wield area closures as a sort of "selective gear," capable of sorting young scallops from old in the interest of achieving optimal yield per recruit. Indeed, between 1999 and 2001, the NEFMC opened each of the five Closed Areas for one or more limited scalloping seasons. With each opening, high catch rates and large meats attracted many vessels, temporarily shifting much of the industry's fishing effort onto the denser, larger scallops of the freshly opened area and off of the sparser, smaller scallops outside it (NEFMC, 1999a; NEFMC, 1999b; NEFMC, 2000). An area management scheme might therefore delay harvest to the optimal size and age by way of a three-step "rotation." First, an area bearing a strong juvenile year class is closed before the animals recruit to the fishing gear. Several years later the area opens, thereby gravitating the fleet away from younger scallops elsewhere. Once fished down, the area may close again to allow the small, young scallops left behind to grow up.





In any rotating harvest scheme, the rotations will be defined largely in terms of the time interval between successive openings (Caddy, 1993), and success depends on the degree to which the incidental mortality of pre-optimal individuals can be reduced during each opening. Since the survival of young scallops greatly depends upon their evasion of or escapement from the fishing gear, a rotational management strategy may profit from the use of dredges fitted with collecting bags made of rings wider than the current standard. Nearly ninety percent of the annual U.S. scallop harvest is taken by "New Bedford" dredges (NEFMC, 1999b; NEFMC, 2000), heavy metal frames typically 4.6 m (15 ft) in width, towed in pairs across the seafloor – one from a starboard gallows and one from port – and trailed by collecting "nets" or "bags" made of circular steel rings (Figure B). Smaller scallops may pass through and between these rings and so escape capture. Those that do not escape end up on the fishing vessel's deck, where the crew culls the catch for scallops of some desired size and then shovels the remainder, often still alive and viable, back into the water.





This study examined the performance of a dredge with 102 mm (4.0") rings compared to that of the standard 89 mm (3.5") rings in seven trips to three different closed areas, in order to explore the experimental gear's potential as an instrument for leaving pre-optimal scallops behind and in good health while still efficiently harvesting scallops of optimal size and age during a typical closed area fishery. It also assessed the ability of wider rings to reduce the incidental bycatch of unwanted species of finfish and invertebrates, as well as its potential to diminish damage to the benthic habitat. If in fact the NEFMC adopts an area rotation strategy in the near future for sea scallops, a shift from 89 mm to 102 mm rings may well improve the proximity to which the fishery approaches the stock's Optimum Yield, while at the same time diminishing the environmental impact of dredges.

The theoretical reasoning behind the specific hypotheses

(The only reason I'm using English units here instead of metric is that the government regulates scallop gear in inches)

Hypotheses

Wider rings – specifically, 4.0" (102 mm) rings in contrast to 3.5" (89 mm) – should permit greater escapement of smaller, younger scallops, but not larger scallops, thereby pushing the size/age distribution of the catch in the positive direction. Average shell heights and meat weights should increase. The trend seen with past ring studies (DuPaul et al., 1999) suggests that the size of 100% retention (that is, the size above which no scallops can escape the bag) will be close to the optimal harvest size of 120 mm (age 5-6). The mean catch of underage scallops should decline, but not that of optimal-age scallops. In other words, boats will not lose any efficiency on older scallops, but overall efficiency on younger scallops will diminish.

Hypotheses are usually predictions about the MEANS of each RESPONSE Variable(s). Subscripts indicate treatment levels within the INDEPENDENT Variable. Notice that this study has only one I.V. (3.5" vs. 4.0"), yet several RV's.

Null & Alternative Hypotheses

With respect to the mean shell height (S) of the catch:

$$\mathbf{H_o}: \quad \mathbf{S_{3.5} = S_{4.0}}$$

$$\mathbf{H_a}: \quad \mathbf{S_{3.5} < S_{4.0}}$$

With respect to the mean meat weight (W) of the catch:

$$\mathbf{H_o}: \quad \mathbf{W_{3.5} = W_{4.0}}$$

$$\mathbf{H_a}: \quad \mathbf{W_{3.5} > W_{4.0}}$$

With respect to the mean overall efficiency (E) on each sub-optimal size class (<120mm):

$$\mathbf{H_o}: \quad \mathbf{E_{3.5} = E_{4.0}}$$

$$\mathbf{H_a}: \quad \mathbf{E_{3.5} > E_{4.0}}$$

With respect to the mean overall efficiency (O) on each optimal size class (≥ 120mm):

$$\mathbf{H_o}: \quad \mathbf{O_{3.5} = O_{4.0}}$$

$$\mathbf{H_a}: \quad \mathbf{O_{3.5} \leq O_{4.0}}$$

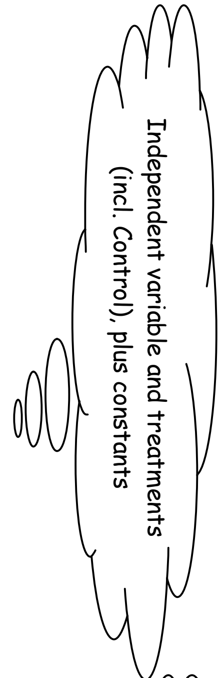
M&M is not a recipe! Just describe what you did.

No need for every last detail, but enough for the reader to visualize the experiment.

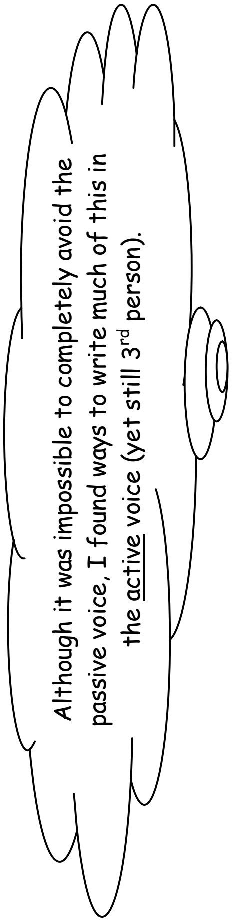
Materials and Methods

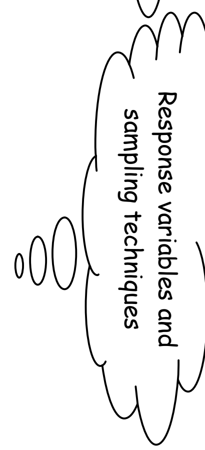
This study conducted seven research trips aboard the commercial scallop vessel *F/V Celtic* into three of the Georges Bank and Mid-Atlantic Closed Areas: three trips into Closed Area II (in July 2000, September 2000, and June 2001), two trips into the Hudson Canyon Closed Area (June and September 2001), and two trips into Closed Area I (both in October 2000). The goal was to evaluate the performance of the experimental gear in a variety

Clear statement of study site, time, and target population of closed area fisheries, on different bottom types with different scallop distributions, similar to those expected under an area management scheme.

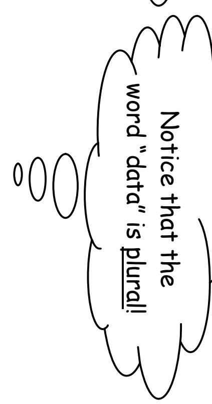


In this study there was one independent variable – ring diameter – with two treatment levels: 3.5" (89 mm) versus 4.0" (102 mm). The experiment employed a paired design: two dredges – a control dredge fitted with the 3.5" rings and an experimental dredge fitted with the 4.0" rings – deployed simultaneously and towed side-by-side from the port and starboard gallows. All other conditions were held constant. Both dredges were 4.6 m (15') wide offshore New Bedford dredges, with bags configured as identically as possible, except for the dimensions of the rings themselves (Figure C). Fishing generally followed commercial practices, with the captain and crew selecting tow sites, tow durations, and size of culling, except that port and starboard catches were kept separate.





For each dredge the scientists collected data on the following response variables: (1) Basket Count (bushels of harvest size scallops deliberately kept by the crew for shucking and landing), (2) Shell Height Frequency of all scallops including crew discards (width of the upper valve from the dorsal hinge to ventral extreme; grouped into size classes of 5 mm intervals), (3) Volume of "Trash" (invertebrates and debris, in baskets), and (4) Finfish Bycatch Frequencies (with the total length of all fish except skates measured to the nearest centimeter). For estimating shell height frequencies, the scientists took sub-samples, usually measuring two or three randomly selected baskets of retained scallops per side and usually one quarter of the discards. Sub-sampling of discards was systematic, with discards always selected from the same region of the port and starboard piles on any given tow, but from an ever-changing region of the piles on successive tows. Trash was sub-sampled from the same portion of the pile as the discards. The captain or mate of the vessel recorded the vessel position at the start (brake set) and end (initiation of haulback) of each tow, as well as the tow duration, velocity, and heading.



For each Closed Area, data on shell height and trash were analyzed in a paired fashion on a tow-by-tow basis, using paired t-tests on the means to determine statistical significance. The catch of each size class of scallops by 102 mm rings relative to that of 89 mm rings was calculated both on a per tow basis and for each closed area as a whole. Scallops of optimal harvest age and size (approximately age 6 and up, shell height 115 mm and above) were partitioned from pre-optimal scallops, and their relative capture by the two gears evaluated. Data on tow durations allowed computation and comparison of catch rates for both landed and discarded scallops, as well as the amount of time required by each gear to harvest a fixed volume of scallops. Relative bycatch of finfish was calculated for all seven trips combined, with some size partitioning where warranted by the data.

This section should be brief! Just state results, emphasizing big trends, but avoid interpreting them yet.

Results

Size Selectivity & Harvest Efficiency

Let your graphs and tables tell the story!

An oddity of my study. But you should stay w/ metric!

In Closed Area II (3 trips, 101 tows), the 102 mm (4.0”) rings consistently captured fewer small scallops than did the 89 mm (3.5”) rings (because the NEFMC legislates minimum ring diameters in inches, not millimeters, rings will hereafter be referred to simply as 4” and 3.5” rather than the metric equivalents). At the same time, the 4” rings actually captured more large scallops than the 3.5” rings. As the catch totals show (Figure D-1), Area II was home to a strong year class of young scallops size 50 mm to 70 mm. The 4” rings permitted more of these pre-optimal scallops to escape. Thousands of scallops of optimal size and age, from 115 mm to 155 mm, were also represented in the catch, and the 4” rings harvested slightly more of these than did the 3.5” rings.

Unlike Area II on Georges Bank, which was originally closed to protect cod and other groundfish, the Hudson Canyon Area was closed in 1998 to protect an exceptionally strong year class of juvenile scallops. By the summer of 2001, these scallops were approaching the optimal harvest age and the area was reopened to fishing. It was at this time that the two Hudson Canyon trips were taken, and this strong year class can be seen as a high peak in the total catch (Figure D-2; 58 tows). The 4” rings harvested these scallops just as efficiently as the 3.5” rings. Meanwhile, the 4” rings allowed substantially more scallops size 80 mm to 100 mm to escape.

Note that Data Tables are lettered separately from Figures!

My graphs are a bit tricky, so I did some explaining here. Normally, though, you can let the reader figure out how to read your graphs for herself.

A tow-by-tow analysis bears these trends out. When the catch is analyzed in a paired manner, such that the catch taken by 4” rings *on each tow* is expressed relative to the catch taken by the 3.5” rings *on that same tow*, the 4” rings prove to consistently allow better escapement of pre-optimal scallops. In Figure D, this is reflected in the 4” Fraction data points, where for each individual tow the catch by 4” rings was calculated as a fraction of the combined catch (that is, the 4” catch plus the 3.5” catch on that tow), and then averaged together for all the tows conducted in that Closed Area. A 4” Fraction of 50% means that both dredges fished equally well on that size class. Any fraction below 50% means that tow-by-tow, the 4” rings on average caught less than the 3.5” rings. Values above 50% mean that the 4” rings on average caught more than the 3.5” rings. In both Area II and Hudson Canyon, the 4” rings were less likely on any given tow to bring scallops smaller than 110 mm on deck. At the same time, 4” rings were slightly more likely to bring scallops larger than 110 mm on deck.

In Area II overall, the 4” rings improved the capture of harvest-ready “optimal” scallops (115+ mm, age 6+) by nearly 15%, taking an average of 36 more scallops per tow ($p << 0.05$) (Table A). The experimental rings improved the escapement of pre-optimal scallops (<115 mm) by almost 9% overall, taking 203 fewer scallops per tow (Table B). The latter difference, however, was not statistically significant ($p = 0.07$). In Hudson Canyon, the

4” rings did not significantly improve harvest efficiency, but did diminish the pre-optimal catch by nearly 19% overall and 281 scallops per tow ($p << 0.05$).

In Closed Area I (2 trips, 33 tows), these patterns are less evident. As with the other trips, the 4” rings did outfish the 3.5” rings on larger scallops; however, escapement of smaller scallops was not much better with 4” rings than 3.5” rings (Figure D-3). The overall harvest of optimal scallops was almost 11% better with 4” rings, at a rate of 234 more scallops per tow ($p < 0.05$). The 4” rings reduced the pre-optimal catch by 5%, at a statistically insignificant rate of 43 fewer scallops per tow ($p = 0.19$).

Habitat Impacts: Dredge Time on Bottom and Bycatch

Because scallop dredges are known to physically damage benthic habitat, the duration of towing – or “Dredge Time on Bottom” – is an important variable. In Closed Areas I and II, the 4” rings were able to harvest a fixed volume of scallops in 8-10% less time than 3.5” rings (Table C). In Hudson Canyon, the reduction was only 2%.

Scallop dredges also affect benthic communities by actually removing benthic substrate (sand, shell, and rocks) and benthic invertebrates (clams, sand dollars, crabs, sea stars, sea cucumbers, lobster, etc.). Collectively known as “Trash,” this benthic debris and fauna was quantified by volume for each dredge, tow-by-tow. On all trips the 4” rings dramatically diminished the amount of trash retained (Table D), by an average of one to several baskets per tow ($p << 0.05$) and by 16-31% overall.

Finally, scallop dredges also capture certain species of demersal fish. With 4” rings the bycatch of commercially valuable finfish species did not generally diminish, although there were some exceptions (Table E). The catch of red hake (*Urophycis chuss*) and silver hake (*Merluccius bilinearis*), both of which bear a fusiform shape and thus may be able to wriggle through and between the rings, was cut by 18% and 16% respectively over the course of all seven trips combined. The overall catch of commercially sought flatfish species – yellowtail flounder (*Limanda ferruginea*), witch flounder (gray sole, *Glyptocephalus cynoglossus*), American plaice (*Hippoglossoides platessoides*), and winter flounder (blackback, *Pseudopleuronectes americanus*) – was not at all reduced by 4” rings, which is not surprising given the body form of these fish. However, the 4” rings did dramatically reduce the catch of younger, smaller individuals of these species. The catch of yellowtail flounder whose total body length was under 30 cm was diminished by 55% with 4” rings. The catch of witch flounder shorter than 35 cm was 61% less with 4” rings, and the catch of plaice shorter than 35 cm was 32% less. The final commercially valuable species that frequently turns up in scallop dredges is the monkfish (goosefish, *Lophius americanus*). Most individuals of this species are far too large to pass through or between the rings, and the 4” rings gave no reduction in monkfish bycatch over the 3.5” rings.

Notice p-values are given in parentheses rather than the main sentence. Use a single "<" if its under 0.05 (hence "statistically significant"), and a double "<<" if it's under 0.01 (hence "very

In the text of your paper, just report the big numbers (sums & means only), and leave the rest in the tables

The 4” rings also reduced the bycatch of some species that are not commercially valuable yet commonly turn up in scallop dredges. The catch of fourspot flounder (*Paralichthys oblongus*), sculpin (*Myoxocephalus* spp.), and sea raven (*Hemitripterus americanus*) were cut by 27%, 39%, and 26% respectively with 4” rings. The catch of windowpane flounder (*Scopthalmus aquosus*) was undiminished with 4” rings. The catch of skates (various species), most of which are far too big to fit through either size ring, was virtually identical between the two dredges on all seven trips.

My "Results" section is long because the study was so data intensive. But yours'll be brief.

Discussion & Conclusions

The "Discussion" is the most important part of the paper!!! Now's the time for thoughtful interpretation of the cold results. Emphasize meaning, suggest importance, make predictions & extensions ...even speculate! Go "BIG PICTURE"!!!

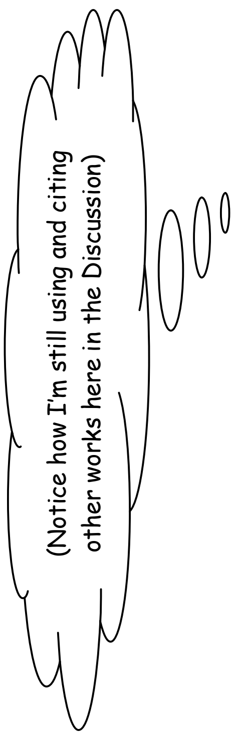
Delaying Age of Harvest to Optimize Yield

If the NEFMC adopts a rotational management scheme for sea scallops in the near future, the primary purpose will be to optimize the stock’s yield per recruit. But the promise of rotational management does not reside in its capacity to constrain and control fishing effort and fishing mortality, for this is something the Council already effectively regulates through days-at-sea limitations coupled with vessel tracking by satellites. The real promise of area rotations lies in its potential to separate young scallops from older ones, leaving good sets of recruits on the seafloor until they are ripe for optimal harvest. Such sorting by age and size is something that ring size restrictions alone were never able to adequately accomplish. Yet although the fishing gear by itself cannot cleanly delay harvest to age 6 or later, it will still have a vital role to play under rotational management.

Interpreting results in the context that I described in the Intro section

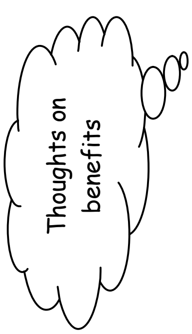
Given the reality that no scallop dredge or trawl will ever be sharply size selective, the best possible gear under rotational management might be one that in no way diminishes the capture of scallops of optimal age and size, yet permits the maximum possible escapement of pre-optimal scallops. In this study, the dredge with 4” rings yielded a size of 100% retention that fell near 110 mm, just shy of the optimal size of 110-120 mm. On no trips did the 4” rings undermine the harvest of optimal scallops, and in many cases it substantially improved their harvest. The reason for the improved harvest efficiency is probably that wider rings are slower to become congested with trash and pre-optimal scallops. This would affect the flow of water through the collecting bag, which in turn might affect the capture efficiency (the rate at which scallops lying in the path of the dredge actually enter its mouth). As the cutting bar, tickler chains, and sweep (Figure B) churn scallops off the bottom, or else stimulate them to swim upward, some will enter the mouth of the collecting bag while some will pass over it or off to one side (Caddy, 1968; Smolowitz & Serchuk, 1989). If water flows freely for longer durations through the 4” rings, and if this improved flow reduces the pressure wave and turbulence that advance out in front of the dredge, this might promote the passage of scallops into the collecting bag. Whatever the mechanism at work, 4” rings exhibit a potential to not only keep harvest efficiency on optimal scallops undiminished, but to actually augment it during area openings under rotational management.

Offering a speculative explanation for this somewhat surprising result of the study



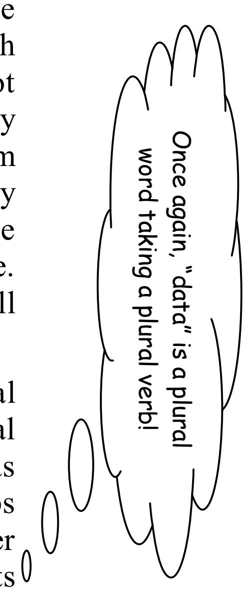
Meanwhile, in this study the 4” rings generally reduced the capture of pre-optimal scallops, sometimes quite dramatically, and especially under those fishing conditions that were most similar to those expected under rotational management. The greatest gains in escapement seemed to be with 50 to 95 mm scallops, with gains gradually declining to either side of this size range. Probably underlying this pattern is a sigmoid (S-shaped) selectivity curve typical of trawls and dredges in most fisheries (Pope 1966; ICES, 1996). This curve plots the probability of capture against size class, and the sigmoid shape results from the fact that sufficiently small individuals have a near zero probability of being retained by the gear, sufficiently large individuals have a 100% probability of retention, and individuals at intermediate size classes have a probability of retention that increases with size but that levels out toward either extreme. Thus at small enough shell heights, escapement through both the 3.5” and 4” rings was not much different, meaning that very small scallops could pass through 3.5” rings just as easily as they could through 4” rings. It should be noted that scallops smaller than 50 or 60 mm were poorly represented in the catch, which probably accounts for the high variability in the relative catch at these size classes (see Figure D). Such noisiness is typical of “rare” size classes (ICES, 1996). At larger sizes, however, clearer patterns emerge. As scallops approach the size of 100% retention, they begin to “feel” the gear, bumping into the rings more often. Scallops will feel the 3.5” rings at earlier ages than they will the 4” rings, and this accounts for that window of maximum difference in selectivity from 50 to 95 mm. Then from 95 to 110 mm, as the underlying selectivity curve for the 4” bag levels out, the differences between the two dredges shrink to zero.

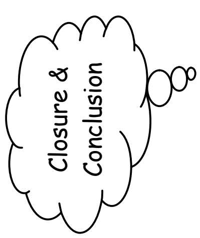
This trend in size selectivity was less distinct on the Area I trips. However, the conditions here were typical of neither open area nor closed area fishing. This part of Georges Bank had been closed for six years (again, to protect groundfish, not scallops), a period much longer than a rotational management strategy would apply. As a result, the seafloor was exceptionally dense with very old, very large scallops. A brief tow of only 5 or 10 minutes would fill the collecting bag to the sweep. Consequently the bag was quickly congested with large scallops, something that blocks the escape of most smaller ones.



Under rotational management, the primary benefit of this size selectivity would be a reduction in “deck mortality” of discards (small scallops unwanted by the crew). On a typical tow, many discards are crushed on deck either by the heavy gear during dumping or by the crew as they step on them during culling. On four of seven trips, the scientists estimated the rate of deck mortality due to crushing, counting as lethally wounded any scallop whose shells were dislocated, shattered, punctured, or fractured past the perimeter of the mantle (following the criteria of Medcof & Bourne, 1962). Estimates of deck mortality ranged from 12% to 25%. Clearly deck mortality is not inconsequential to the stock.

These are probably conservative estimates of the total deck mortality, for more scallops will also die due to exposure and desiccation. Scallops are resilient animals, and most will probably survive if returned to sea soon after capture. A mark and recapture study estimated that 90% of discards were still alive several days later (Murawski & Serchuk, 1989). Nevertheless, when the duration of exposure to air is long, especially during daytime in warmer seasons, deck mortality may escalate severely. Of particular concern within the context of rotational management is the practice of "deck loading." In the early weeks of the closed area fisheries of 1999 to 2001, the catch rate exceeded the shucking capacity of the seven-person crew. Fishing effort was also often concentrated in tight areas, making boat traffic heavy. In response a vessel would often make a handful of tows, heaping the deck high with scallops, then anchor elsewhere to shuck the pile down. The crew might not shovel the discards back into the water for many hours. Deck loading may further aggravate mortality by returning discards a bottom some distance from the habitat where they were captured and thriving. Since the central strategy of rotational management is the cultivation of dense grounds of optimal size scallops, this phenomenon of deck loading will be an important issue. Adopting a gear that can limit the number of discards brought on deck will become more essential than ever.





The dredge with 4" rings, then, appears to come very close to that ideal dredge for rotational management in which the harvest efficiency on optimal scallops is at its maximum while the escapement of pre-optimal scallops is as high as possible without compromising the catch of optimal scallops. Perhaps a dredge with slightly wider rings, say 4.25" or 4.5", might come even closer to that ideal, and the data here suggest that this possibility warrants investigation. At the very least, though, 4" rings would seem more fit for a rotational management scheme than the standard 3.5" rings.

Moderating Dredge Damage to Benthic Communities

Nearly every opening of a Closed Area to scallop boats from 1999 to 2001 was complicated, limited, or foreshortened by matters of habitat degradation and finfish bycatch. Certain finfish that are currently protected under the Multispecies FMP, especially flounder species, are vulnerable to scallop dredges. Dredges may also physically disturb the "essential fish habitats" that are protected under the Sustainable Fisheries Act, mainly bottoms with three-dimensional relief and structure where juvenile fishes take shelter from predators (Magnuson-Stevens, 1996). With each proposed opening of a closed area to scalloping, environmental activists and/or other fisheries have lobbied against the plan, often filing legal injunctions and lawsuits to block it. In some cases this directly led to a loss of yield. The first opening of Closed Area II was ultimately closed when the fleet passed a preset limit of yellowtail flounder bycatch (as monitored by government officials on boats). A large portion of Closed Area I's rebuilt scallop grounds was omitted from the October 2000 opening in order to protect groundfish and the benthic environment. A proposed re-opening of the rich Nantucket

An opinion ...perfectly allowable in this part of the paper

Lightship grounds was abandoned in the face of protests that the fishery would destroy essential fish habitats. In all these cases, old scallops ripe for harvest have been lost to natural mortality. Such difficulties are sure to complicate the implementation of a rotational management plan for scallops.

The irony is that area rotations offer perhaps the most effective management scheme for moderating dredge damage to benthic communities. Under rotational management boats entering a newly opened area will presumably have trip limits (that is, a maximum quantity of meat allowed per trip). Since the strategy of area rotations will be to cultivate scallops that are not only old and large but also *densely concentrated in localized patches*, catch rates will be high. That means that boats will harvest their limit of scallops with less towing time. Meanwhile, a boat's shucking capacity will be limited by the maximum crew size of seven, with the result that dredges will often hang idle in the gallows while the crew catches up in the shucking box. As a result, each boat will tick off its annual allotment of days-at-sea, but with less total towing time, hence less dredge damage to the seafloor.

In this context, too, 4" rings would seem to complement a rotational management strategy. The results of this study suggest that 4" rings may improve the harvest efficiency and thereby diminish the Dredge Time on Bottom per unit harvest. The experimental rings also dramatically reduced the amount of invertebrates and substrate (trash) that the gear removed from the seafloor, which probably means that the 4" rings degraded the benthic habitat less severely than the 3.5" rings. The 4" rings also helped to reduce the bycatch of certain finfish, and since the deck mortality of finfish is very high, this is an important benefit. Bycatch was cut by sixteen to thirty-nine percent on five species, including the two commercially valuable hake species. Although 4" rings did nothing to diminish the overall bycatch of the four commercially valuable flounders, they did dramatically improve the escapement of the younger individuals of three of those species (yellowtail, plaice, and gray sole).

Closure & Conclusion

On multiple levels, then, 4" rings show promise for softening the impact of scallop dredges on both the benthic communities and other fisheries. If one of the objectives of rotational management will be to mitigate such ill effects, then here again 4" rings would appear to serve the cause.

Science papers usually use a format different from that in English papers ...Author or Agency first, then Year, then Title, then publishing info last.

This is NOT a bibliography! You cite ONLY those works that you made actual reference to in the TEXT of your paper!

Literature Cited

Bourne, N. 1964. Scallops and the offshore fishery of the maritimes. Fisheries Research Board of Canada Bulletin No. 145. 60 pp.

Once again I'm single-spacing to save paper. But YOU should double space these and use a hanging indent (simply highlight this entire section of your paper, then go to the Format menu... Paragraph... and set the indentation to "Hanging" by 0.5")

Caddy, J. F. 1968. Underwater observations on scallop (*Placopecten magellanicus*) behaviour and drag efficiency. Journal of the Fishery Research Board of Canada 25(10): 2123-2141.

Article from a science journal

Caddy, J. F. 1993. Background concepts for a rotating harvesting strategy with particular reference to the Mediterranean red coral, *Corallium rubrum*. Marine Fisheries Review 55(1): 10-18.

Cushing, D. H. 1981. Fisheries Biology: A Study in Population Dynamics. (2nd ed.). University of Wisconsin Press, Madison, WI. 295 pp.

A Book

ICES 1996. Manual of Methods of Measuring the Selectivity of Towed Fishing Gears. Wileman, D. A., Ferro, R. S. T., Fonteyne R., and Millar, R. B. (Eds.). ICES Cooperative Research Report No. 215.

A work with editors

Lai, H. and Rago, P. 1998. Status of fisheries resources off northeastern United States for 1998: sea scallops. Retrieved April 12, 2001, from http://www.nefsc.nmfs.gov.

A Website ...try to find author & "date last modified." Otherwise, cite the agency and the year you accessed it.

Magnuson-Stevens Fisheries Conservation and Management Act, amended through October 11, 1996, including the Sustainable Fisheries Act. Public Law 94-265.

Medcof, J. C. and Bourne, N. 1962. Causes of mortality of the sea scallop, *Placopecten magellanicus*. Proceedings of the National Shellfish Association 53: 33-50.

Article w/ two authors

Murawski, S. A. and Serchuk, F. M. 1989. Environmental effects of offshore dredge fisheries for bivalves. ICES C. M. 1898/K:27.

Murawski, S. A., Brown, R., Lai, H.-L., Rago, P. J., and Hendrickson, L. 2000. Large-scale closed areas as a fishery-management tool in temperate marine systems: the Georges Bank experience. Bulletin of Marine Science 66(3): 775-98.

Multiple authors (do NOT use "et al." here ...list ALL their names!)

NEFMC 1999a. 1999 Scallop Fishery Management Plan SAFE Report (Stock Assessment and Fishery Evaluation). Saugus, MA. 184 pp.

NEFMC 1999b. Framework Adjustment 12 to the Atlantic Seas Scallop FMP, with options for Framework Adjustment 33 to the Northeast Multispecies FMP. Saugus, MA. 160 pp.

Two sources by the same author in the same year ...so designated as "a" & "b"

NEFMC 2000. 2000 Scallop Fishery Management Plan SAFE Report (Stock Assessment and Fishery Evaluation). Newburyport, MA. 271 pp.

NEFSC 2001. [Report of the] 32nd Northeast Regional Stock Assessment Workshop (32nd SAW). Stock Assessment Review Committee

Paper by an agency rather than an author

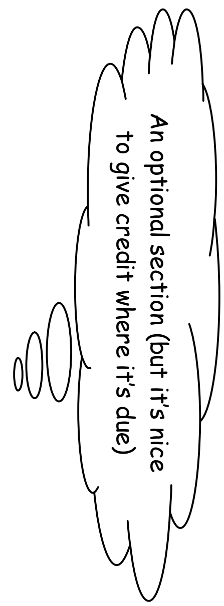
(SARC) consensus summary of assessments. B. Sea Scallops. January 2001 Draft, pp. 77-190.

Pope, J. A. 1966. Manual of methods for fish stock assessment, Part III: Selectivity of fishing gear. FAO Fisheries Technical paper No. 41.

Posgay, J. A. 1979. Population assessment of the Georges Bank sea scallop stocks. Rapp. P.- v. Reun. Cons. int. Explor. Mer 175: 109-13.

Serchuk, F. M., Wood, P. W., Posgay, J. A., and Brown, B. E. 1979. Assessment and status of sea scallop (*Placopecten magellanicus*) populations off the northeast coast of the United States. Proceedings of the National Shellfish Association. 69: 161-91.

Smolowitz, R. J. and Serchuk, F. M. 1989. Developments on sea scallop gear design. In: Proceedings of the 1988 World Symposium on Fishing Gear and Vessel Design, pp. 531-410.

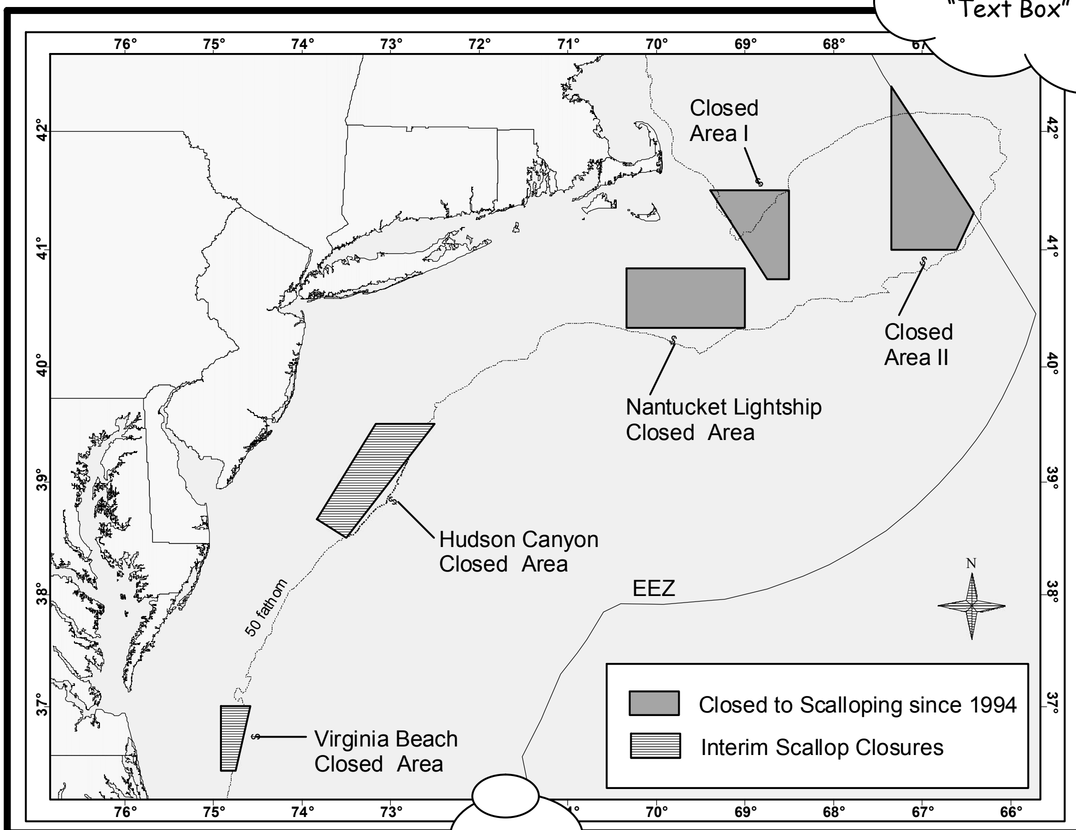


Acknowledgements

I am deeply obliged to everyone who contributed time, thought, and sweat on behalf of the 4" ring project. Above all, I am grateful to my advisor Dr. Bill DuPaul, who introduced me to the fascinating world of the sea scallop fishery, broke me in, and guided me through. I also thank my colleagues on the VIMS scallop team – Todd Gedamke, David Lange, and Dave Rudders – not only for the long, long hours of sea time they put in, but also for their smart insights, moral support, and good company. I am grateful to Cheryl Teagle and Barbara Kriete for handling all those administrative and logistical tasks that befuddle most of us, and especially to Dianne Roberts for many hours of data entry. And I am utterly obliged to the excellent Captain Charlie Quinn and crew of the *Celtic* – Flavio Bolarinho, Armando Demello, Paul Desmarais, Billy Eldridge, Robbie Medeiros, Mike O'Malley, and Shane Sturgeon. A smarter, more helpful, or more fun crew to go to sea with, I cannot imagine.

Figure A – Closed Areas on Georges Bank and the Mid-Atlantic bight.

Each Figure & Table MUST have a CAPTION! (Advice: in MS Word, create a "Text Box" for these)



For studies with a spatial aspect, you should give the reader a map of the study area, even if it's a hand-drawn or computer-drawn schematic.

CBGS has a scanner for your use.

Also, you can create your own topographical maps online at www.digital-topo-maps.com …just zoom in and navigate left, right, up, & down to center your study area on the screen. When you're ready to save your map, click "Print from your computer: Landscape/Portrait" down below. A larger picture will download. Then right-click on the picture and "Save picture as…"

If you swipe a map from somewhere, be sure to acknowledge the source!!! Also, you'll probably want to add your own labels to the map using MS Word Text Boxes, Arrows, and Autoshapes.

Figure B – Underside of a “New Bedford” scallop dredge. Inset: Four-inch rings with split links.

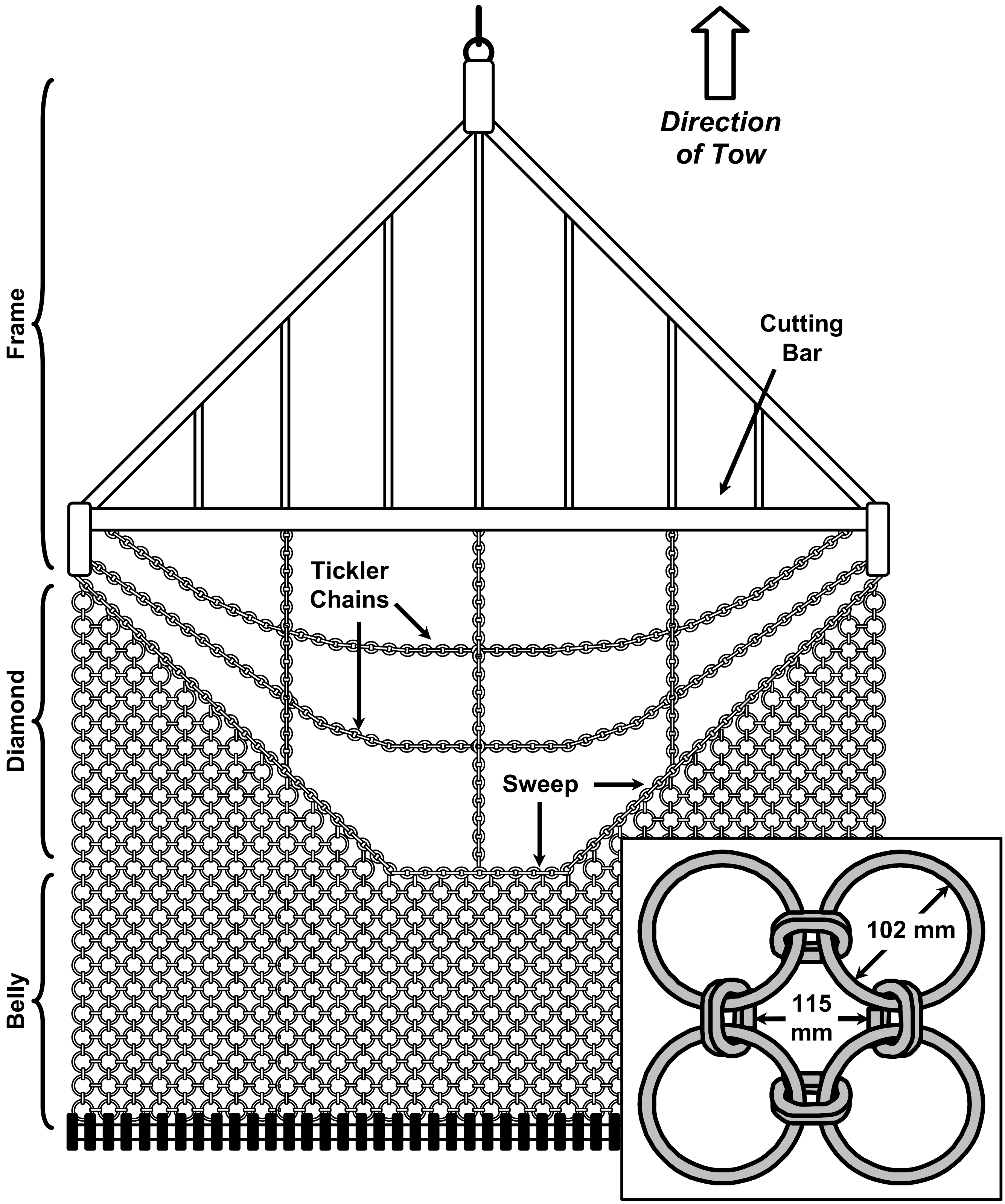


Figure C – Schematic diagram of bag with 102 mm (4”) rings. Dimensions are given in ring counts (fore-to-aft length × width across), with corresponding counts for the 89 mm (3.5”) bag in parentheses. Although ring counts differ between the two dredges, the actual lengths and widths are approximately identical. The “twine top” refers to the bag’s ceiling of crisscrossing ropes, with counts given in number of meshes, each 255 mm × 255 mm (10” × 10”, the legal minimum). The “sweep” is the heavy chain at the mouth of the bag, with counts given as the number of chain links.

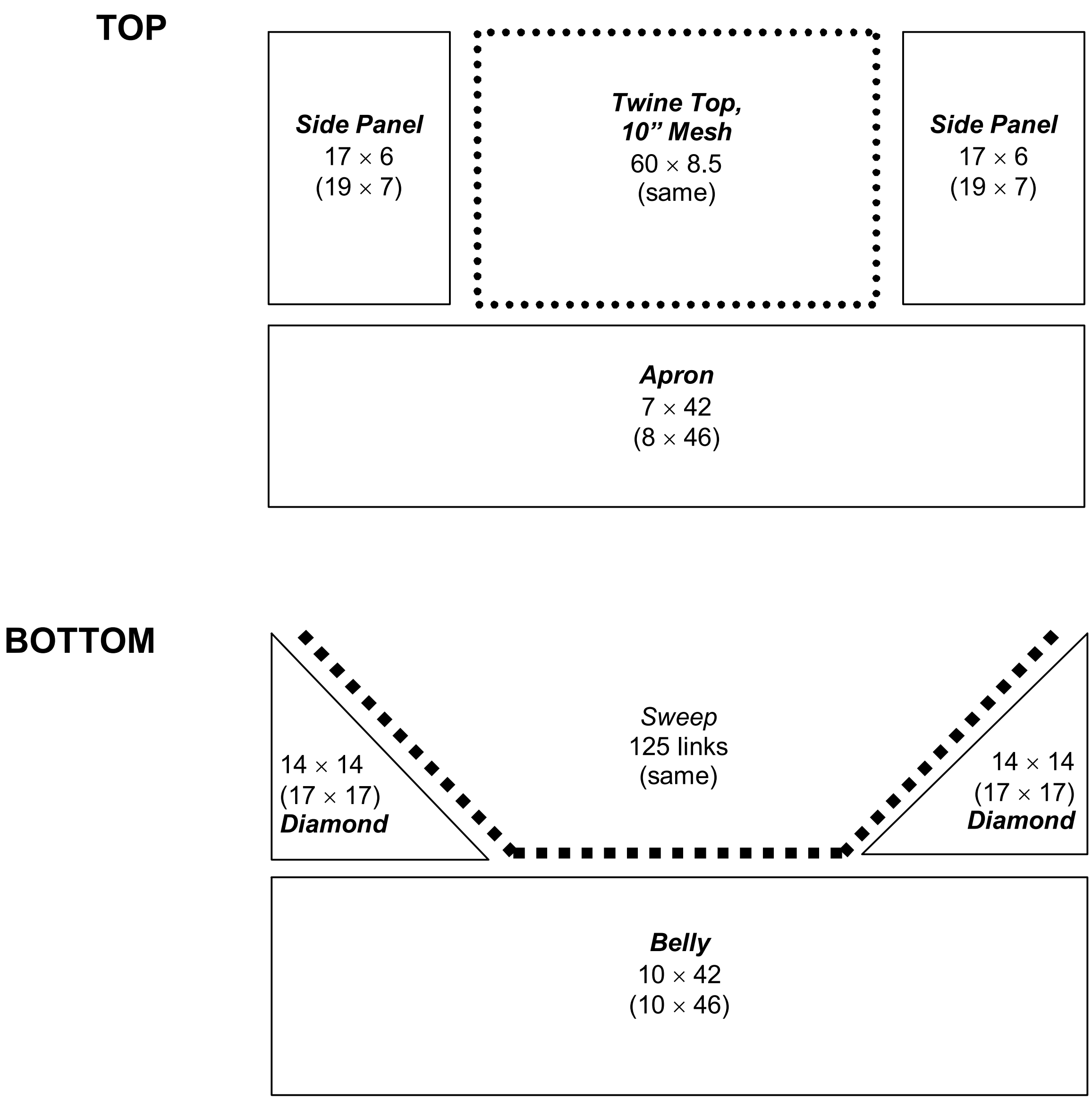
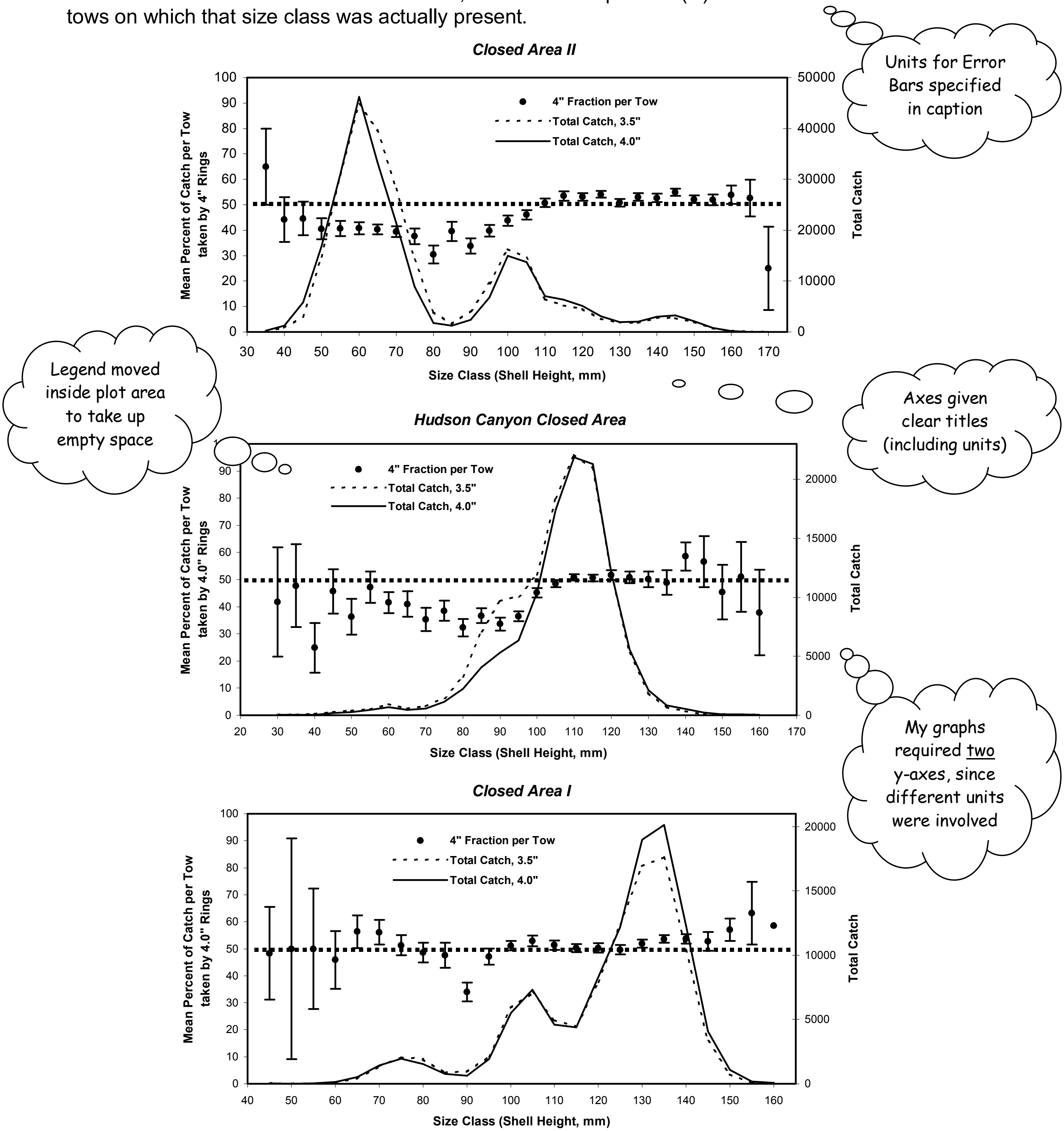


Figure D – Comparisons of both Total Catch and Mean Catch Per Tow by 4” versus 3.5” rings. The 4” Fraction per Tow data points reflect the percent of each size class that was *on average* taken by the 4” rings on any given tow. Values below 50% indicate lower catch rates by the 4” rings compared to the 3.5” rings, which in most cases reflects superior escapement. Values above 50% indicate higher catch rates by the 4” rings relative to the 3.5” rings, which in most cases reflects superior harvest efficiency. Each error bar indicates the Standard Error, where the sample size (N) was taken to be the number of tows on which that size class was actually present.



Notice Tables are lettered separately from Figures

Do NOT include gobs of raw data in your paper! What the reader really wants is sums, means, and maybe standard deviations or standard errors

Table A – Improvement in Harvest Efficiency by 4" Rings by scallops defined as "Optimal" (115+ mm, age 6+).

	Number of Tows Sampled	Optimal Scallops, Total 3.5"	Optimal Scallops, Total 4.0"	Percent Increase with 4.0"	Mean Difference per Tow	p-value (paired t-test)
Closed Area II	**101**	**24,247**	**27,825**	**14.8%**	**35.8****	**0**
Hudson Canyon	**58**	**41,507**	**42,796**	**3.1%**	$\mathbf{22.2^{ns}}$	**0.24**
Closed Area I	**33**	**73,872**	**81,608**	**10.5%**	**234.4***	**0.014**

Use of superscripts to denote statistical significance. By convention, one asterisk indicates a "statistically significant" difference ($p < .05$), two asterisks means the difference is "very significant" ($p < .01$), and "ns" means not statistically significant ($p > .05$).

Table B – Improvement in Escapement by scallops defined as "Pre-Optimal" (<115 mm) using 4" rings.

	Number of Tows Sampled	Pre-optimal Scallops, Total 3.5"	Pre-optimal Scallops, Total 4.0"	Percent Reduction with 4.0"	Mean Difference per Tow	p-value (paired t-test)
Closed Area II	**101**	**233,137**	**212,824**	**8.7%**	$\mathbf{-203.1^{ns}}$	**0.07**
Hudson Canyon	**58**	**87,771**	**71,498**	**18.5%**	**-280.6****	**0**
Closed Area I	**33**	**27,791**	**26,384**	**5.1%**	$\mathbf{-42.7^{ns}}$	**0.19**

Table C – Reductions in Dredge Time on Bottom needed to catch a fixed amount of harvestable scallops. Volumes are given in the one-and-a-half bushel baskets commonly used in the fishery.

	Towing Time	Baskets, 3.5"	Baskets, 4.0"	Time on Bottom per Basket, 3.5"	Time on Bottom per Basket, 4.0"	Reduction in Time on Bottom
Closed Area II	**18,713 minutes**	**1,605**	**1,776**	**11.7 min**	**10.5 min**	***9.6%***
Hudson Canyon	**11,856 minutes**	**1,920**	**1,949**	**6.17**	**6.08**	***1.5%***
Closed Area I	**448 minutes**	**1,952**	**2,115**	**0.23**	**0.21**	***7.7%***

Table D – Trash (debris and invertebrate bycatch) brought on deck by 4" rings relative to 3.5" rings. Baskets are one-and-a-half bushels each.

Trip	Mean Trash per Tow Retained by 3.5" Rings (baskets)	Mean Trash per Tow Retained by 4.0" Rings (baskets)	Mean Difference per Tow	p - value (paired t test)	Mean Percent Reduction in Trash
Closed Area II	**8.22**	**5.69**	**2.53****	**0**	***30.8%***
Hudson Canyon	**6.46**	**4.72**	**1.74****	**0**	***26.9%***
Closed Area I	**4.87**	**4.08**	**0.79****	**0.002**	***16.2%***

Table E – Finfish bycatch for all trips combined.

	Catch by 3.5" Rings	Catch by 4.0" Rings	Relative Catch
Yellowtail Flounder	**3047**	**3048**	**0.0%**
Yellowtail <30 cm	**316**	**142**	**-55.1%**
Witch Flounder (Gray Sole)	**151**	**151**	**0.0%**
Witch <35 cm	**18**	**7**	**-61.1%**
American Plaice	**84**	**83**	**+1.2%**
Plaice <35 cm	**38**	**26**	**-31.6%**
Winter Flounder (Blackback)	**86**	**81**	**-5.8%**
Monkfish (Goosefish)	**971**	**992**	**+2.2%**
Red Hake	**479**	**395**	**-17.5%**
Silver Hake	**1119**	**944**	**-15.6%**
Windowpane	**275**	**288**	**+4.7%**
Fourspot Flounder	**1259**	**921**	**-26.8%**
Sculpin	**753**	**459**	**-39.0%**
Sea Raven	**84**	**62**	**-26.2%**
Skates	**11971**	**11525**	**-3.7%**