What is the Optimum Mesh Size to Harvest Groundfish on Georges Bank?

Drawing Conclusions from Cooperative Research

by Ken LaValley

New Hampshire Sea Grant
Technical Report

Cooperation and Collaboration

Following the decline in fish stocks in the Northeast in recent decades, fishermen have faced a daunting list of regulations. To overcome these limitations, many fishermen have begun to collaborate with scientists to develop innovative fishing strategies that reduce bycatch, increase selectivity and minimize gear impacts on benthic communities.

Cooperative research has been very successful in bringing together management, scientists and fishermen. By building trust between these various stakeholders and examining problems from many angles, we can continue to rebuild the fisheries and support the long-term health of the fishing industry.

As a commercial fishing technology specialist with NH Sea Grant and UNH Cooperative Extension, one of my goals is to help fishermen in the Northeast get involved with cooperative research. I've written this document to highlight a successful collaborative project between two scientists from the University of Rhode Island, Joseph DeAlteris and David Chosid, and two fishermen from New Bedford, MA, Captains Matt Stommel and Mark Theroux. I would like to thank Joseph DeAlteris and David Chosid for their time and effort assisting with the technical development of this publication, as well as for their reviews, comments and suggestions.

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by Ken LaValley
Commercial Fishing Technology Specialist
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A MANAGEMENT PERSPECTIVE

The New England groundfishing industry has witnessed dramatic change over the decades. Once bountiful historic stocks plummeted, leading to today's tightly regulated fishery. One way that modern regulators have attempted to manage fish stocks is by setting minimum codend mesh size regulations for the trawl fishery. To study the effects those regulations have had, researchers Joseph DeAlteris and David Chosid of the University of Rhode Island's Department of Fisheries and Aquaculture embarked on a cooperative research project with Matt Stommel and Mark Theroux, fishermen from New Bedford, MA. The team set out to determine how past, present and future codend mesh size regulations may affect the rebuilding of stocks of valuable Georges Bank groundfish.

The cooperative research team collected samples aboard Captain Matt Stommel's trawler, the *F/V Morue*.

The Northeast Multi-species (Groundfish) Fishery Management Plan (NMFMP) includes 15 species and 24 stocks of finfish. (Some groundfish species are treated as multiple stocks due to the multiple geographic regions they inhabit.) Twelve of the NMFMP-managed species are considered "large-mesh" species, as defined by their size and the types of gear used to harvest them. These large-mesh species include Atlantic cod, haddock, pollock, yellowtail flounder, witch flounder, winter flounder, windowpane flounder, American plaice, Atlantic halibut, redfish, ocean pout and white hake. The other three species, whiting (also called silver hake), red hake and offshore hake, are managed under a separate "small-mesh" multi-species program.

All 15 groundfish species are demersal, living on or near the bottom and feeding on benthic (bottom-dwelling) organisms. Therefore all are susceptible to the same bottom fishing gear. Of course, the various species exhibit unique behaviors, habitat preferences and body shapes. Such differences lead to complicated management strategies, as no single gear can be perfectly suited to every species in the fishery.

To rebuild stocks on Georges Bank, regulators have attempted to reduce the proportion of juvenile fish being captured. To do so, they have increased the minimum codend mesh size almost 50 percent over the last three decades, from 4.5 to 6.5 inches. But is bigger always better?

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As a result of their study, DeAlteris and Chosid concluded that a 6.5- or 7.0-inch mesh codend maximizes yield and provides adequate retention of spawning stock biomass. They also determined that no additional benefit would be realized by increasing mesh size beyond 7.0 inches. That, of course, is only the short answer. As we will see, DeAlteris and Chosid's study highlighted many complex factors involved in fisheries science and fisheries regulations.

A COLLABORATIVE EFFORT

Currently, a 6.5-inch diamond or square mesh is the minimum size required for New England's groundfish trawl codends. About a decade ago, the minimum mesh size was 5.5 inches, and at the time of the passage of the Fishery Conservation and Management Act (FCMA) in 1976, the minimum mesh size was 4.5 inches. Managers increased minimum mesh sizes in direct response to the over-fishing crisis.

The benefit of larger mesh sizes seems logical. Larger meshes allow more juvenile and small mature fish to escape, and instead target the older fish that have already had a season or two to spawn. However, determining optimum mesh sizes requires balancing the economic complexities of the fishing industry with the reproductive ecology of the groundfish species in question. To determine what effect mesh size increase would have on the yield of the fishery and on the biomass of the spawning stock, DeAlteris, Chosid and their industry partners compared the selectivity of the codend mesh sizes and shapes that exist under the NMFMP with larger experimental mesh sizes. Additionally, conducting a retrospective analysis, they evaluated whether benefits have been realized from the past increases in mesh size from 5.0 to 6.5 inches. Ultimately, the researchers attempted to determine the ideal codend mesh size for the Georges Bank multi-species groundfish fishery.

Aboard the *F/V Morue,* Captain Stommel's 96-foot stern trawler, the research team conducted 15 days of alternate tow comparisons in the Great South Channel on the western flank of Georges Bank. More than 80 two-hour tows were completed within 15 days. The researchers compared the catch from 6.5-, 7.0- and 8.0-inch mesh codends, both square- and diamond-shaped, to the catch from a 3.0-inch diamond mesh codend (the control mesh). They sorted the catch by species and took weight and length measurements.

Back at the lab, DeAlteris and Chosid generated graphs of their data to determine the optimum mesh size for three individual species: winter flounder, yellowtail flounder and Atlantic cod. They also set out to determine the optimum mesh size for the multi-species complex, which was dominated in their investigation by winter flounder.

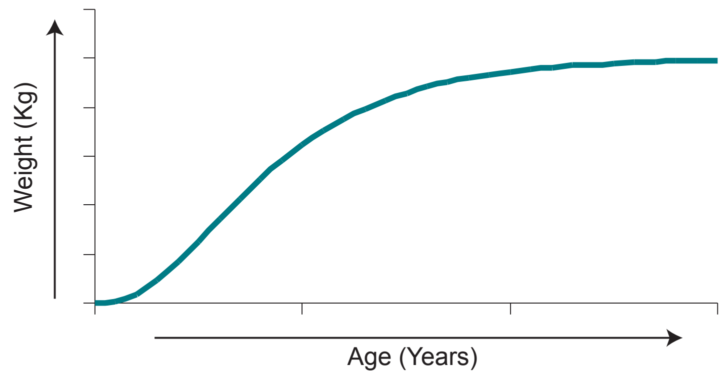
Determining optimum mesh sizes requires balancing the complex economics of the fishing industry with the reproductive ecology of the fish species in question.

PRINCIPLES OF FISH STOCK ASSESSMENT

In order to understand how DeAlteris and Chosid used their data to answer questions about ideal mesh size, we need to recognize some basic fish life history concepts and some of the principles of stock assessment models. Larger codend mesh sizes retain fewer small fish. The smaller fish that escape from a larger mesh are able, in theory, to grow bigger and possibly reproduce once or twice before being caught at a later time.

Fish grow most rapidly at younger ages (Figure 1, page 6). As a fish population ages, it shrinks due to natural mortality (Figure 2, page 7). The size of a fish stock is measured in terms of its biomass, the estimated weight of all the fish in the stock.

Figure 1: Young fish grow rapidly. As they age, their growth rate slows, finally leveling off when they reach their maximum size.



Imagine the life cycle of a single cohort, or group of fish all born in the same year. The biomass of that cohort starts out small; the cohort contains a large number of fish, but they're all very small in size. Biomass peaks midway through the life cycle of the cohort as fish grow, then drops off again as large, old fish die. This relationship is described as a "dome-shaped curve" (Figure 3, page 8).

In other words, early in the life history of a long-lived fish, growth exceeds natural mortality, building biomass; late in the life history, natural mortality exceeds growth, reducing biomass. Natural mortality is assumed to be constant over the life of the fish. Fishing mortality, on the other hand, is not constant. It is managed by a combination of effort limitations and technological controls. Technological restrictions on gear, such as minimum mesh sizes, are used along with the appropriate minimum fish size regulations to control the age of entry of a particular fish species into the fishery.

The likelihood that a codend will retain a fish of a particular size is known as trawl mesh size selectivity. Size selection in trawl codends is based on a physical sieving process as fish enter the codend of a trawl. The smallest fish pass through the mesh and escape (zero percent probability of retention), while the largest fish are all retained (100 percent probability of retention). Fish in between those sizes have probabilities of retention ranging between those extremes. Therefore, if we increase the size of the codend mesh being used, we would expect fewer fish of every size to be caught (except the largest fish that have 100 percent retention by the larger codend).

In order to evaluate how age of entry into the fishery and fishing mortality rate affect the yield (catch) from a potential cohort of fish, scientists establish a yield-per-recruit (YPR) curve. Taking the maturity rate of the fish species into consideration, scientists perform a spawning stock biomass-per-recruit (SSBPR) analysis. This analysis is used to determine what proportion of the spawning stock biomass remains, given a specified fishing mortality rate and age of entry into the fishery.

Mesh size determines the size (and therefore the age) at which a fish enters the fishery. Modelers use YPR and SSBPR analyses to predict the age of entry and fishing mortality rate that will maximize yield, yet leave enough mature spawning stock biomass for a sustainable fishery. The management objective is to slowly harvest the fish in a given cohort just before the peak in the unfished biomass curve (Figure 3, page 8). That

Figure 2: As a cohort (year class) of fish ages, it shrinks in number as older fish die off.

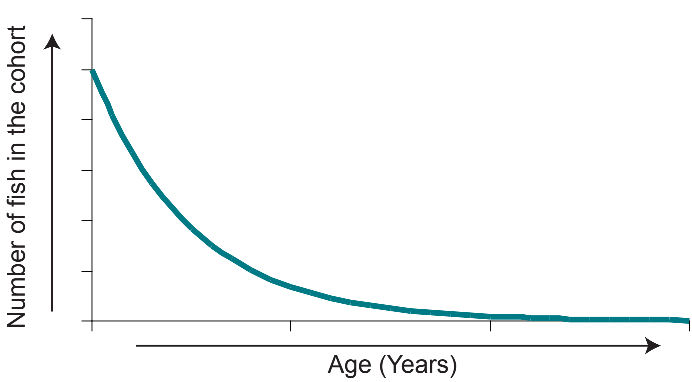
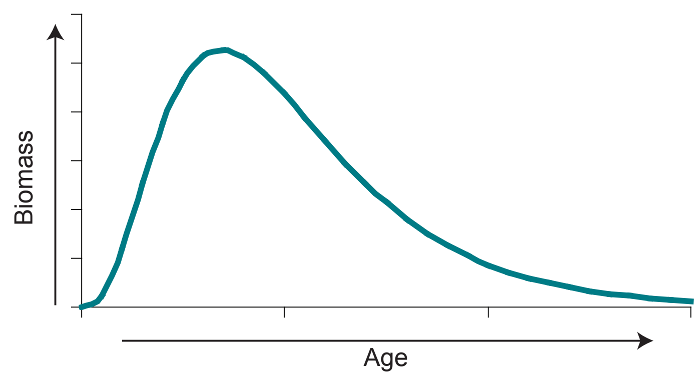


Figure 3: The biomass, or weight, of a cohort of fish starts out small. As fish age and grow in size, biomass increases. The cohort's total biomass drops again as large, old fish die off.



practice will maximize the biomass available for catch and still allow the cohort to maximize its reproductive capacity.

The YPR curve can be used to determine optimum conditions for maximizing the yield from a fishery. It can also address the potential profitability of a fishery. Revenue is proportional to yield or catch weight. Fishing mortality is proportional to fishing effort, and production cost is proportional to effort. Therefore higher profits might be achieved at lower levels of fishing effort. A set of YPR curves can be instructive when evaluating the profitability of a harvesting strategy, mesh size and level of fishing effort for a potential cohort of fish.

Slowly harvesting the fish in a cohort just before its biomass peaks will maximize yield while still allowing the cohort to maximize its reproductive capacity.

Typically, when mesh-size selection studies are done in single-species fisheries, the result is a selection curve for a particular mesh size and shape that relates the length of the fish to its probability of retention. Fishery managers typically try to determine a mesh size that will retain fish of a size at which it's likely that 50 percent have reached maturity and spawned at least once. But this mesh size will not necessarily maximize the yield per recruit for that species, or maintain the sufficient spawning stock biomass to meet recruitment over-fishing reference points.

In the last two decades, fishery resource managers, responding to the dramatic decline in groundfish stocks, attempted to reduce fishing mortality on juvenile groundfish by increasing the minimum mesh size in the codend and reducing effort by decreasing the number of fishing days at sea. Management decisions are complicated in mixed-species fisheries, since not all species have similar growth, maturity, natural mortality and catchability characteristics. For example, cod are bigger than yellowtail flounder. A mesh size that will catch mature yellowtail flounder may also catch juvenile cod.

Some research has been done on modifying fishing gear to increase target species selectivity while minimizing the bycatch of over-exploited stocks or protected species. The approach has realized some success. A device called the Nordmore grate releases juvenile groundfish while retaining northern shrimp in the Gulf of Maine. Turtle excluder devices, commonly known as TEDs, have effectively reduced the bycatch of sea turtles while minimally affecting catch in the southeast and Gulf of Mexico shrimp trawl fisheries.

The Nordmore grate is designed to retain shrimp while allowing juvenile groundfish to escape.

Codend mesh size selection studies have been done in the northeast to support previous mesh size increase regulations. In the late 1980s, NMFS-sponsored mesh selection investigations demonstrated that essentially all groundfish size selection occurs in the codend of the trawl, not in the mouth or body of the trawl. This research supported the decision to establish regulations that specified minimum codend mesh sizes.

More recent mesh selection studies have been conducted for selected species using mesh sizes from 5.0 to 6.0 inches in square and diamond shapes. Yet little data exist on the current 6.5-inch minimum mesh size or larger mesh sizes, nor has there been an analysis of the relationship between the minimum legal fish size and the selection characteristics of the current minimum mesh size. And, of course, there is the question of the optimal mesh size to harvest a multi-species complex.

EXPERIMENT RESULTS

Based on their data and analyses, DeAlteris and Chosid were able to generate selection curves to determine the optimum mesh size for winter flounder, Atlantic cod and yellowtail flounder. (Figures 4-6, page 11-12.) As expected, larger mesh sizes retained fewer small fish. Next the researchers conducted single-species YPR and SSBPR analyses to determine the effect of mesh size on yield and spawning stock for each individual species of fish in the trawl fishery. Again as expected, the YPR curves varied considerably between the different species.

> Analysis of a multi-species fishery is driven by the dominant species – in this case, the winter flounder.

During DeAlteris and Chosid's investigation (conducted in 2002), winter flounder dominated the catch, accounting for about 75 percent of the fish retained in the 3.0-inch small-mesh codend. For both Atlantic cod and winter flounder, the YPRs for 6.5- and 7.0-inch meshes were similar at low levels of fishing mortality, and were 15-18 percent higher than the predicted YPR for the 5.0-inch codend mesh. For the 8.0-inch diamond mesh the YPR was dramatically reduced for winter flounder, as few large fish of this species remain in the population to be retained by a mesh this size and shape. For yellowtail flounder, YPR was maximized by the 6.5- or 7.0-inch square mesh codend at low levels of fishing mortality, and this YPR was about 10 percent higher than that predicted for the 5.0-inch square or diamond codends. YPR decreased as mesh size increased from 6.5 to 8.0 inches for both square and diamond meshes at moderate to high levels of fishing mortality.

In general, the results of the single-species SSBPR analyses for winter flounder and Atlantic cod indicated that at all levels of fishing mor-

Figure 4: A mesh-size selection curve for winter flounder, comparing square (S) and diamond (D) mesh codends of various sizes.

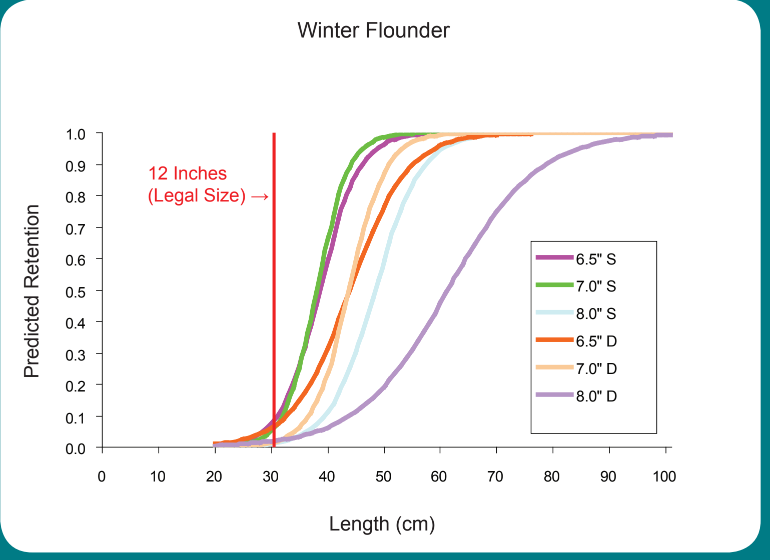


Figure 5: A mesh-size selection curve for Atlantic cod, comparing square (S) and diamond (D) mesh codends of various sizes.

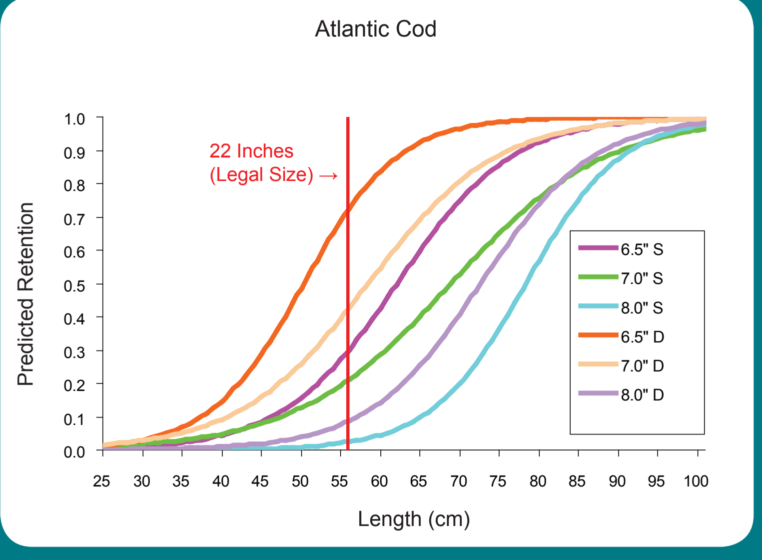
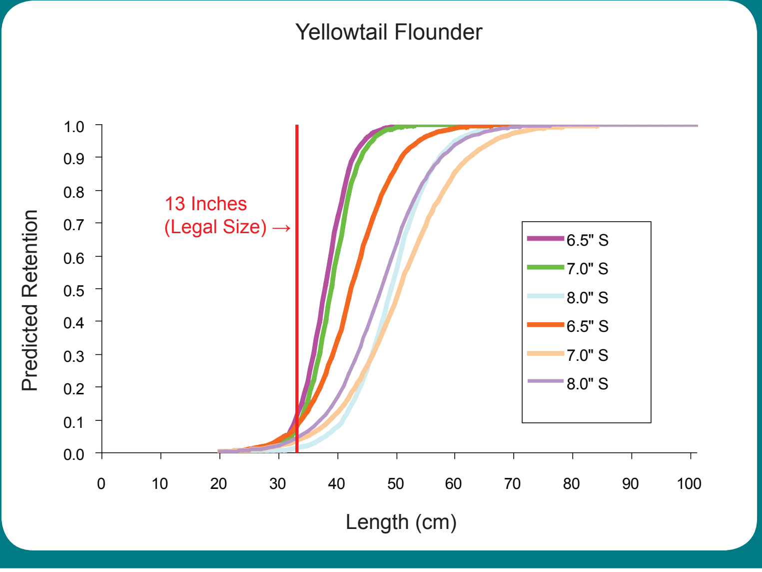


Figure 6: A mesh-size selection curve for yellowtail flounder, comparing square (S) and diamond (D) mesh codends of various sizes.



tality, larger mesh sizes retain a higher percentage of the virgin spawning stock biomass. More spawning stock biomass is retained at moderate and high levels of fishing mortality than at low levels. For yellowtail flounder, larger mesh sizes have an even more pronounced effect on preserving spawning stock biomass. Because of the yellowtail flounder's smaller size, though, a given mesh size retains a higher percentage of the virgin spawning stock biomass at moderate levels of fishing mortality.

The multi-species analysis is driven by the dominant species – in this fishery, the winter flounder. Therefore, results of the multi-species YPR and SSBPR analyses approximate the results of the single-species analysis for winter flounder. At low levels of fishing effort, the multi-species yield is similar for 6.5- and 7.0-inch mesh sizes. Yield decreases for the 8-inch mesh at low levels of fishing effort. At moderate levels of fishing effort, yield is similar for all mesh sizes. At high levels of fishing effort, yield is reduced for 6.5- and 7.0-inch mesh sizes, as compared to 8.0-inch mesh. (Figures 7-8, page 13.)

Figure 7: A yield-per-recruit analysis for the multi-species groundfish complex on Georges Bank, comparing square (S) and diamond (D) meshes of various sizes.

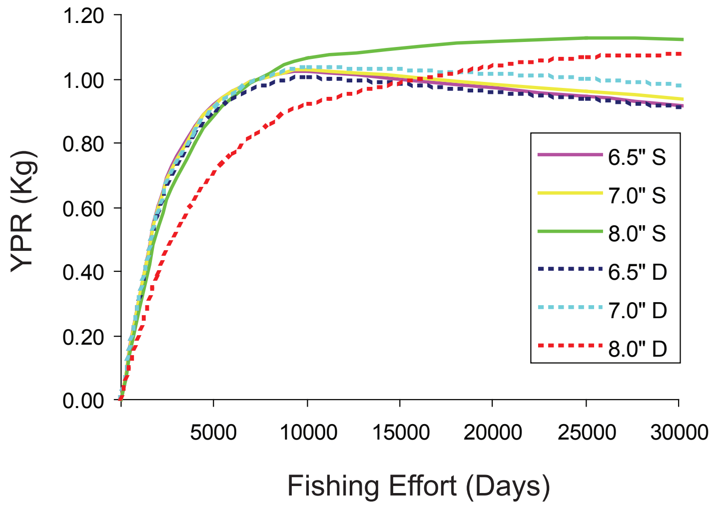
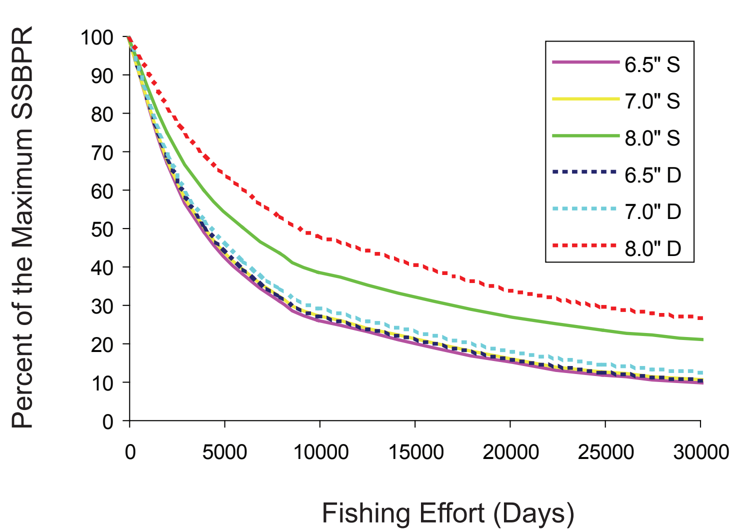


Figure 8: A spawning stock biomass-per-recruit analysis for the multi-species groundfish complex on Georges Bank, comparing square (S) and diamond (D) mesh codends of various sizes.



DRAWING CONCLUSIONS

Based on the selectivity and YPR/SSBPR analyses, DeAlteris and Chosid were able to make recommendations about the optimum mesh size for the multi-species complex as a whole.

When fishing at high levels of effort, it is better to use a larger mesh to allow fish to grow to larger sizes. Yield will increase due to increased fish weight.

Looking at the single-species selection curves generated from the study, they came to several conclusions. The curves confirmed many of the observations the team had made at sea. They found that an 8.0-inch mesh codend retains very few fish given the current size range of fish on the west boundary of Georges Bank.

Based on their findings, the researchers concluded that the minimum legal lengths for winter and yellowtail flounder are too small. DeAlteris believes that this may provide an incentive for some fishermen to use a small-mesh liner in the codend, which would allow them to land a great number of fish that are legally sized yet not retained by the current minimum mesh size. Liners, however, can be problematic. "Small mesh liners have the potential to dramatically increase discard mortality of sub-legal target and non-target species," Chosid explained.

He and DeAlteris recommend that the minimum legal size should

DeAlteris and Chosid recommend that the minimum legal size for winter flounder (the dominant species in the fishery) be increased from 12 to 14 inches.

be increased from 12 inches to 14 inches for winter flounder and from 13 inches to 14 inches for yellowtail flounder. This increase would decrease the attractiveness of using a small mesh liner, they argue.

As for Atlantic cod, DeAlteris and Chosid found a good match between the current minimum fish size (22 inches) and the length at which 50 percent of the fish are retained in the codend (a value known as L50). Furthermore, they found that the current minimum mesh size does not retain large numbers of sub-legal cod. However, they warn, the potential use of small mesh liners to maximize flounder retention may increase cod discard mortality.

The researchers conclude that if fishing at high levels of effort, it's better to use a larger mesh size to allow fish to grow to a larger size, providing more yield due to increased fish weight (rather than increased fish numbers). The results of the multi-species SSBPR analysis indicate that at all levels of fishing effort, larger mesh sizes retain a higher percentage of the potential virgin spawning stock biomass. At moderate and high levels of fishing effort, even more spawners are retained than at low levels.

Based on the winter flounder-dominated Georges Bank groundfish fishery in 2002, these findings suggest that at low levels of fishing effort (levels that maximize profitability), a 6.5- or 7.0-inch mesh codend maximizes yield and adequately preserves spawning stock biomass. A 7.0-inch codend preserves slightly more spawning stock biomass, which could, ideally, contribute to an increased future yield.

At low levels of fishing effort, a 6.5- or 7-inch mesh codend maximizes yield yet preserves sufficient spawning stock biomass.

DeAlteris and Chosid determined that increasing mesh size beyond 7.0 inches would have no benefit. However, a large year-class of haddock is expected to be recruiting to the fishery soon. DeAlteris and Chosid did not include haddock in their analysis, because the fish were not available in adequate numbers at the time of their study. In the future, haddock may come to dominate the catch. Still, given the life history characteristics of haddock, DeAlteris speculates that the findings would not change substantially if haddock overtook winter flounder as the dominant species. DeAlteris and Chosid conclude that a 7.0-inch mesh codend would remain the optimum compromise. ❖

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