Effectiveness of a Rigid Grate for Excluding Pacific Halibut, *Hippoglossus stenolepis*, From Groundfish Trawl Catches

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ABSTRACT—A rigid grate was installed in a groundfish trawl to test its effectiveness in excluding Pacific halibut, Hippoglossus stenolepis, *from commercial flatfish catches in the Gulf of Alaska. The grate was located ahead of the trawl codend to direct halibut toward an escape opening while allowing target species to pass through toward the codend. In an experimental fishery, the escape rate of halibut was estimated at 94%, while 72% of the Dover sole,* Microstomas pacificus, *67% of the rex sole,* Glyptocephalus zachirus, *and 79% of the flathead sole,* Hippoglossoides elassodon, *were retained.*

Introduction

Diverse fishing gear modifications have been made and tested in efforts to alleviate bycatch problems in various fisheries. These include changes in the size and orientation of trawl meshes to avoid the catch of undersized fish (MacLennan, 1992), grates to release fish from trawls that target shrimp (Jones, 1993), and turtle excluder devices (TED's) to remove endangered sea turtles from shrimp trawls (Watson et al., 1986).

Pacific halibut, *Hippoglossus stenolepis*, may not be retained in any of the Alaska trawl fisheries, and halibut bycatch quotas are established for most of the groundfish trawl fisheries (Witherell and Pautzke, 1997). It is common for these fisheries to be closed because halibut bycatch limits are reached and, as a result, substantial quantities of groundfish remain unharvested each year.

Flatfish fishermen have long been interested in developing gear modifications to reduce this bycatch and allow increases in fishing time and harvests. Some have developed their own designs for halibut excluders.[1] Most of these excluders put a size selection panel across the trawl a short distance ahead of the codend. Holes in the panel are large enough to allow smaller target species to pass but will exclude the much larger halibut, which are guided toward an escape slot. The performance of these excluders had not been scientifically evaluated. Although the ad hoc experience of these fishermen convinced some that these excluders were effective in particular fisheries, the need was seen for scientific evaluations of at least one excluder's selectivity. Costs associated with the intensive catch sampling and experimental design, which were necessary for such evaluations, were well beyond what any single fishing operation could reasonably manage during an open fishery.

In 1998, the Groundfish Forum, an organization representing groundfish trawl catcher/processors that fish in Alaska waters, obtained a National Marine Fisheries Service (NMFS) exempted fishing permit to test systematically the exclusion of halibut from flatfish trawls with a selected industry device. The work was done in cooperation with NMFS, which provided assistance in the experimental design, fieldwork, and data analysis. The experiment was designed to determine if the excluder device could reduce halibut bycatch without significantly reducing catches of target species. Data analysis included estimation of the effects of the device on species and size compositions of the catch and to determine whether the device would be practical for use in Alaska groundfish fisheries.

Methods

The Alaska trawl industry participants were invited to submit designs of halibut excluders for effectiveness testing, together with information regarding their effectiveness. Four applications were received and reviewed by a panel of NMFS scientists. A rigid grate design submitted by the owners of the F/V *Legacy* was selected, based on criteria of expected effectiveness, considering any previous ad hoc experience or testing, and the suitability of the vessel and its fishing gear.

The outer frame of the F/V *Legacy*'s excluder grate was made of 6.4 cm (2.5 in) diameter tubular aluminum bent into a 1.8 m (6 ft) diameter circle, except that the top 38 cm (15 in) of the circle was removed and replaced with a straight section of tube (Fig. 1). Inside this frame, a grid of 15 cm × 15 cm (6 in × 6 in) square holes was formed by 5 cm × 0.64 cm (2 in × 0.25 in) vertical bars and 1.9 cm (0.75 in) diameter horizontal rods, welded together at all junctions. Short sections of PVC tubing were installed over each of the horizontal rods. Because these rollers protruded above the vertical bars, large fish could slide up the grate more easily. The grate was mounted in the interme-

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[1] Personal commun. with owners and captains of groundfish trawlers, including Mark Kandianis, Bob Hezel, Mark "Corky" Decker, Steve Spain, Scott Bryant, Mitch Hull, and Mike Peterson.

diate section of the trawl (just ahead of the codend)(Fig. 2). This intermediate section consisted of a mesh tube made of four 36 mesh-wide, untapered panels of 14 cm (5.5 in) stretch mesh double polyethylene. Four riblines were installed at the corners where the panels joined and the grate was secured to each of these and laced to the mesh of the side and bottom panels. The attachment point on the top ribline was 71 cm (28 in, 5 meshes) aft of that on the lower riblines, creating a slope of about 28 degrees back from vertical.

Another panel of 14 cm (5.5 in) double mesh was attached to the top edge of the grate and along the top riblines, extending aft for 4 m (49 ft) where it was joined to the top panel of the intermediate. This panel and the top panel of the intermediate section formed a low tunnel through which escaping fish had to pass before exiting through a slit in the top panel.

An auxiliary grate, called the "deflector," was installed with a top-forward slant ahead of the main grate to direct fish downwards. The deflector grid had similar construction to the main grate but with 7.6 cm by 7.6 cm (3 in × 3 in) square openings. The back edge of the deflector and the main grate formed a 23 cm (9 in) wide slot through which fish had to pass to reach the escape tunnel. Sufficient flotation was installed on the top riblines to compensate for the weight of the grate and deflector.

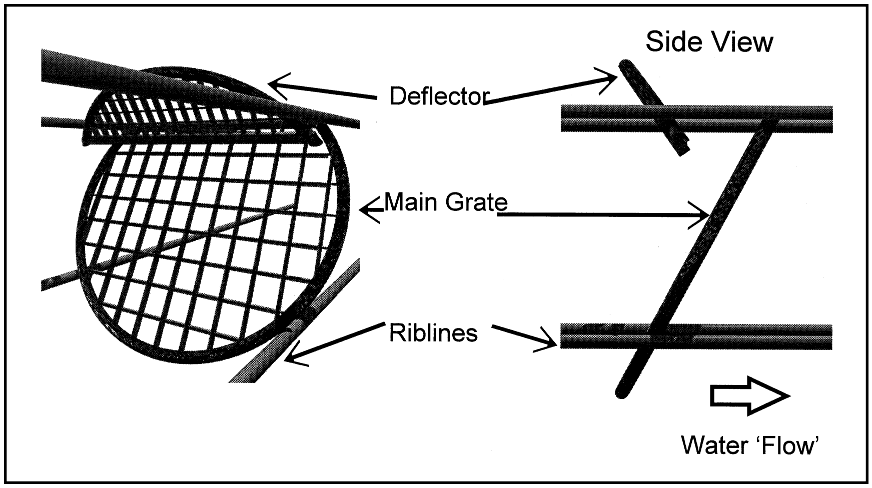

Figure 1.—Halibut excluder grate as installed in a trawl intermediate section. Mesh sides of intermediate are omitted for viewing, only riblines are represented.

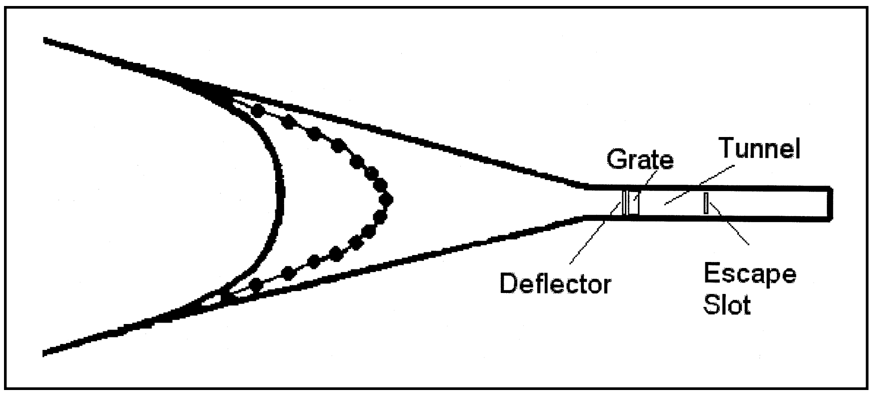

Figure 2.—Location of the excluder components in the trawl.

Because the experimental design required more tows than one vessel could accomplish in the time available, an additional participant, the F/V *Alliance*, was picked at random from the remaining applications. Both vessels were catcher/processors which fish in the Gulf of Alaska for deep-water flatfish species, and both used low-opening commercial bottom trawls. The F/V *Alliance*, one of the smallest Gulf catcher processors (33 m in length), provided a means of determining whether this grate system could be fished effectively from a vessel with limited deck space.

The tests were conducted in the Gulf of Alaska deep-water flatfish fishery because halibut and deep-water flatfish species are concentrated in the same areas, and exclusion of halibut could dramatically increase harvest of those target species. Also, the halibut encountered by this fishery tend to be relatively large, making exclusion more effective. Target species include rex sole, *Glyptocephalus zachirus;* Dover sole, *Microstomus pacificus;* and flathead sole, *Hippoglossoides elassodon*. Arrowtooth flounder, *Atheresthes stomias,* are an abundant but low-value species that is also taken, but it is usually not targeted.

Vessels alternated experimental and control gears to create pairs of tows (blocks) conducted under similar conditions. Pairing of tows helped to eliminate variation in catches due to location, time, and vessel effects. The gear used for the first tow of each block was randomly determined, and the vessel captain was not informed of the selection until after location and time of the tow had been decided. The second tow of each block was made on a parallel track, as close as practical in time and location to the first, matching speed and other towing parameters.

The F/V *Legacy* alternated tows with two matched nets: one with and one without the excluder. The excluder was exchanged between the nets at the midpoint of the experiment. The F/V *Alliance* used one net, exchanging intermediate sections with and without the excluder between experimental and control tows. Tow duration was allowed to vary within blocks to accommodate for the loss of catch through the excluder. Analyses were done on catch per distance fished to prevent differences in tow lengths from introducing a bias.

Catch volumes were measured from full codends or from a bin into which the catch had been dumped. These were converted to weights using a conversion factor for deep-water flatfish of 0.95 metric tons per cubic meter (t/m^3), a value used by the NMFS Observer Program for this fishery.[2]

To improve survival of discarded halibut, as many as possible were sorted out of the catch as it was transferred into a holding bin. A NMFS trained and certified fisheries observer worked with the deck crew to count and measure all halibut and return them to the sea. To ensure that the rest of the catch was available for sampling, no fish were moved out of the bin into the factory until the deck sampling was completed and the observer went down to the factory. All halibut recovered in the factory were also counted and measured.

The catch was sampled to determine species composition by filling baskets from conveyor belts as the catch passed from the holding tank to the factory. These samples, totaling at least 300 kg, were accumulated from several collections taken systematically throughout the emptying of the bin.

Bridge personnel recorded the position and time of the start and end of each tow. They also recorded the type of tow (experimental or control), depth, and towing speed.

A recording temperature-depth-light level sensor was attached to the trawls. Tow length was the distance traveled between the time the trawl depth stabilized at the beginning of the tow until the winches were started during retrieval.

To allow tests for proportional differences with additive statistical tests, a (natural) logarithmic transformation was applied to all catch rates. This also helped to normalize the catch rate distributions. The parameter which was used as a measure of the effect of the excluder (E_{EX}) was the difference between the transformed catch rate from each tow with the excluder (subscript *e*) and the comparable rate from the control tow (subscript *c*) in the same block (pair):

$$E_{EX} = Ln\left(\frac{Catch_e}{Distance_e}\right) - Ln\left(\frac{Catch_c}{Distance_c}\right). \quad (1)$$

This parameter was calculated for each block for each major species in the catch. The antilogs (exponential) of the means and confidence intervals of E_{EX} estimates were used to provide estimates of the proportion retained when the excluder was used. The E_{EX} values were analyzed with t-tests to determine whether the excluder significantly changed catch rates. Halibut size selectivity was analyzed using a similar procedure.

Table 1.—Operational and environmental averages of two vessels participating in tests of a halibut excluder.

Vessel	Speed (knots)	Distance fished (n.mi.)	Catch rate (t/n.mi.)	Depth (m)	Light level (microE/m^2 – s)	Temperature (°C)
F/V *Alliance*	2.5	6.3	0.34	226	9×10^{-7}	6.0
F/V *Legacy*	3.1	4.1	1.22	217	5×10^{-7}	5.8

Results

The experiment to test the excluder was conducted from 18 to 28 September 1998. The F/V *Legacy* completed 31 blocks, and the F/V *Alliance* completed 30. The crews of both vessels developed effective procedures for setting, retrieving, changing, and storing the selection grate. The F/V *Alliance* demonstrated that this rigid grate system could be used on a vessel with a small deck and an aft net reel. They were able to complete these tows in the alloted time, even with the experimental requirement of approximately 15 changes between configurations with and without the grate.

Both vessels started towing west of Kayak Island in the central Gulf of Alaska (Fig. 3). After completing five blocks, the F/V *Legacy* moved to the northern and western edges of Portlock Bank where it completed the rest of its tows. The F/V *Alliance* remained near Kayak Island for the duration of the experiment. Most tows were made between 200 and 250 m depth, with a few blocks by both vessels in the 100–200 m range, and a few by the F/V *Legacy* were made between 250 and 325 m. Flathead sole made up less than 1% of all catches on Portlock Bank, so those blocks were excluded from the analysis for that species. In addition, there were two blocks where both Dover sole and rex sole made up less than 1% of the catches in both control and experimental tows. Those blocks were excluded from the analysis for those species, because the experiment explicitly sought to measure the performance of the excluder in the deep-water flatfish fishery.

The F/V *Legacy* towed for shorter distances and at higher speed than the F/V *Alliance* and achieved higher average catch rates (Table 1). Average depth, light level, and temperature were similar for the two vessels.

With the data from both vessels combined, the excluder retained only 6% of the halibut while keeping 62% of the aggregated deep-water flatfish species (Fig. 4). The retention rates for the individual deep-water flatfish species varied from 48% for arrowtooth flounder to 79% for flathead sole. Dover and rex sole retention rates were 72% and 67%, respectively. All of these values, except that for flathead sole, were significantly different from the null hypothesis of no effect at the $p< 0.01$ level with a Bonferroni adjustment for multiple tests.

The retention rates were significantly different between the vessels only for rex sole ($p<0.03$) and halibut ($p<0.001$) (Fig. 5). For both species, the F/V *Legacy* allowed more fish to escape than the F/V *Alliance*. This was also the direction of the nonsignificant differences for the other species.

Because the length of each captured halibut was measured, the size composition and selectivity data were abundant for that species. Fish in the 5–10 kg (75–93 cm length) size class made up 45% of the weight of halibut caught in the control net. The grate excluded all but 2% of the halibut weight in this and larger size classes (Fig. 6). The only size class of halibut passing through the grate

[2] Sarah Gaichas, NMFS Alaska Fisheries Science Center, Seattle, Wash. Personal commun.

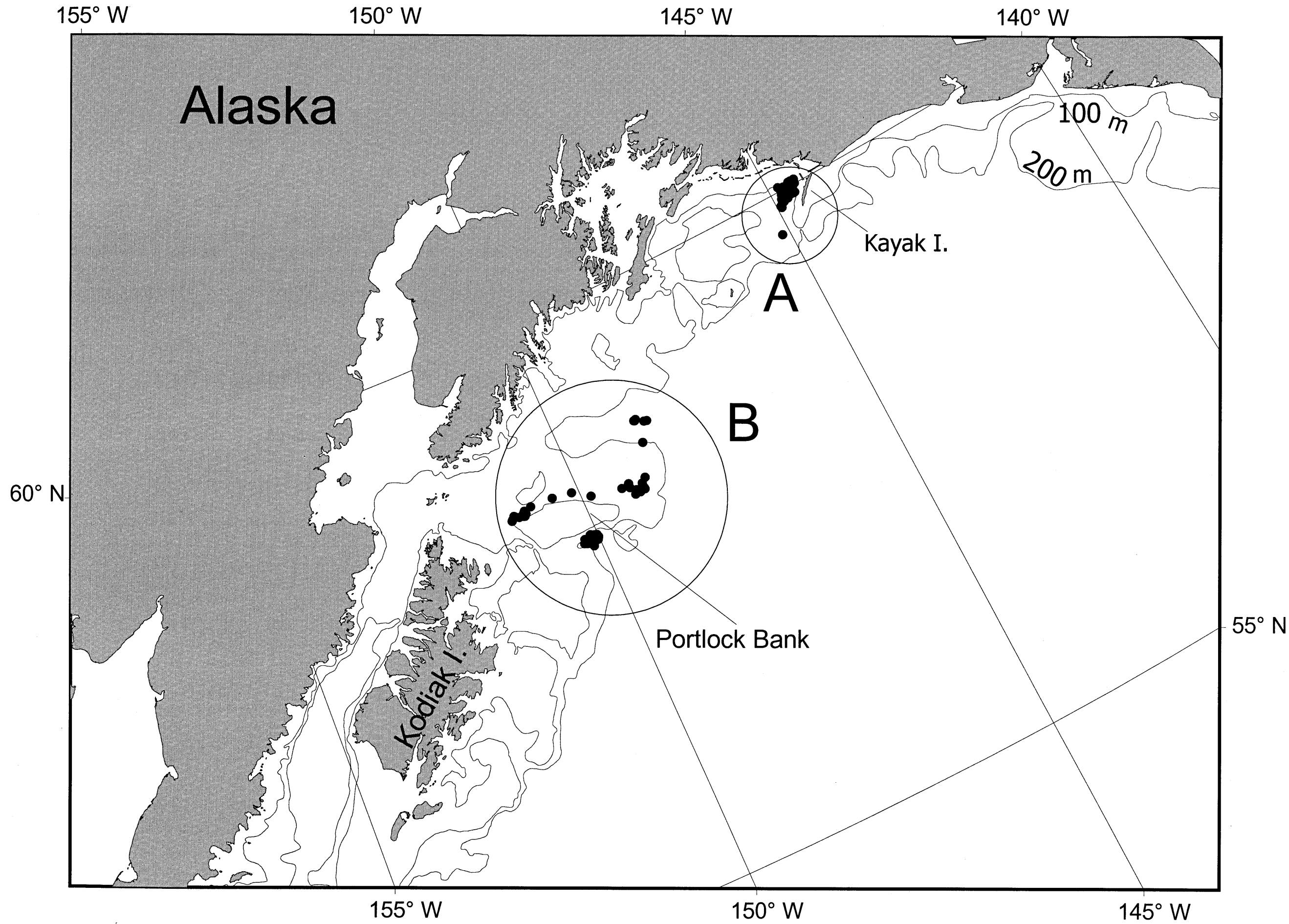

Figure 3.—Locations of experimental trawl tows. Area A—All Alliance blocks and Legacy blocks 1–5, Area B—Legacy blocks 6–31.

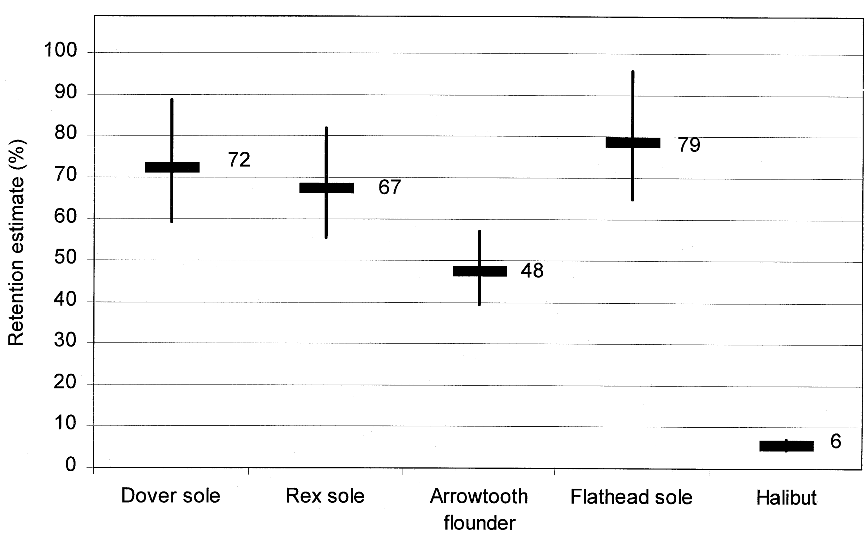

Figure 4.—Percent (mean and 95% confidence intervals) of deep-water flatfish species retained by a trawl equipped with a halibut excluder when compared with catches from a trawl of the same design without the excluder.

in large proportions included fish weighing less than 3 kg (64 cm), of which 46% (by weight) was retained. The retention difference between size classes was statistically significant ($p<0.0001$). While some size composition samples were collected for the target species, these were insufficient to effectively analyze size selectivity.

A problem recognized early in the field work was that some debris and fish would remain ahead of the grate when the trawl was retrieved. This was particularly true of large skates (Rajidae). To allow some assessment of whether an accumulation in front of the grate was affecting its sorting ability, the weight of fish ahead of the grate was estimated for each F/V *Legacy* experimental tow. This weight varied from 0 to 0.9 t with an average of 0.3 t. Linear regressions of each species' retention percentage with this weight showed no useful relationship for any species. The best correlation was for rex sole where the regression explained only 10% of the variation.

Summary and Conclusions

The experiment demonstrated that the halibut excluder grate system dramatically reduced the catch of halibut. However, there were also moderate reductions in catches of rex sole, Dover sole, and flathead sole. The halibut exclusion was size selective, with 46% of the halibut weighing less than 3 kg retained, while nearly all of the halibut larger than 5 kg escaped. The size sampling of the target species was insufficient to detect selectivity differences by size groups. As a result, questions regarding the escapement of larger flatfish were not resolved. Both vessels developed procedures for handling their nets, with the excluder installed, in ways that did not significantly impede normal fishing operations. This was particularly important for the F/V *Alliance*, which had restricted deck space and only a single aft net reel.

The deep-water flatfish fishery has been prevented from catching a large proportion of its allowable catches in the past, because halibut bycatch limits have led to closures each year since the halibut caps have been in place. Reductions in halibut bycatch rates by using excluders would thus present an opportunity to harvest a greater percentage of the target flatfish quotas. However, decreases in catch rates of target species when using the excluder were important and could affect the economic viability of the fishery. Fishermen may not be able to justify the operating costs of fishing if revenue per day is too low due to the reduction of catch rates of target species. Uncertainty regarding size selectivity leaves the possibility that a more severe loss of larger, more valuable, rex sole would further reduce catch values.

While the grate excluder system was effective in reducing halibut bycatch, some avenues are open for further improvement. A way to prevent the accumulation of large fish, particularly skates, and debris ahead of the grate would likely improve the effectiveness of the device. Procedures should be sought to improve the retention of target species, especially larger individuals. Even if this causes some additional retention of halibut, it would provide a greater range of choices with which to achieve management and fishery goals. Even though the F/V *Alliance* was able to use the rigid grate efficiently, it may be worthwhile to explore excluders that are more easily handled on smaller vessels. In this regard, mesh excluders have been tried by several vessels and, though they were not selected for this study, their further testing and development are warranted.

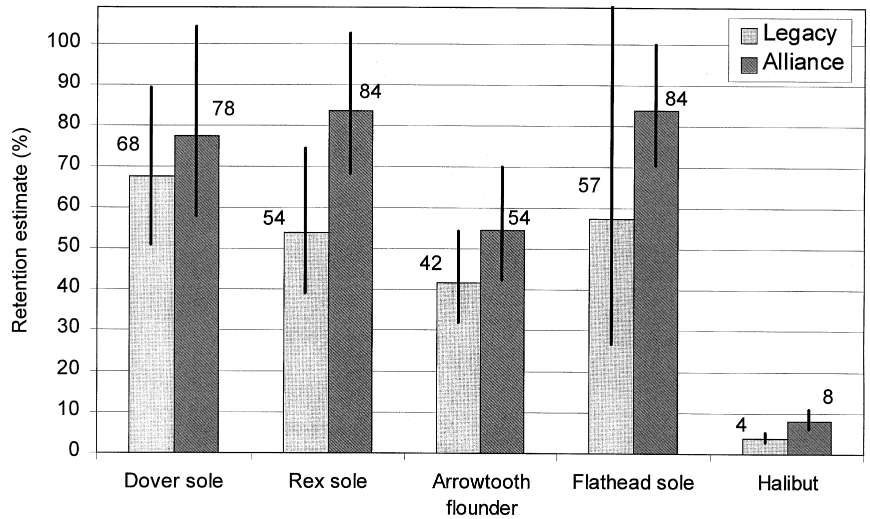

Figure 5.—Comparison between vessels of the percent (mean and 95% confidence intervals) of deep-water flatfish species retained by a trawl equipped with a halibut excluder when compared with catches from a trawl of the same design without the excluder.

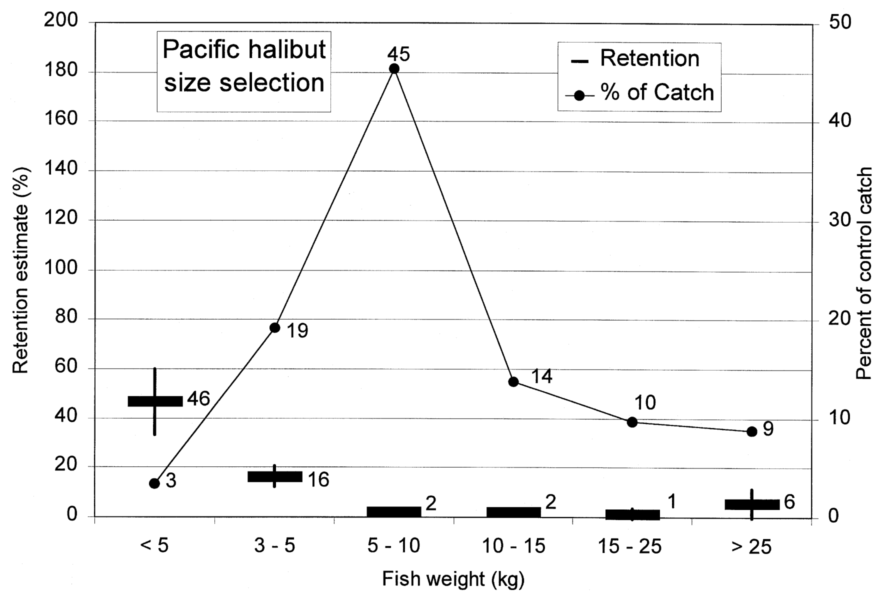

Figure 6.—Comparison between size classes of the percent (mean and 95% confidence intervals) of halibut retained by a trawl equipped with a halibut excluder when compared with catches from a trawl of the same design without the excluder.

Acknowledgments

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