Development and testing of halibut excluders for Alaska cod trawling

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Abstract

Having successfully developed trawl modifications to reduce halibut *(Hippoglossus stenolepis*) bycatch in some sole fisheries, Alaska trawl fishermen and their organizations worked with government scientists in a project to develop similar solutions for cod *(Gadus macrocephalus*) fisheries. This effort included work on five trawlers, operating under research or exempted fishery permits as well as in the open fishery. While a design based on the sole excluders, replacing square openings with circular, was effective for large halibut, it was necessary to add new components to exclude small halibut and prevent clogging by skates. Gulf of Alaska tests of the whole system released 80% of the halibut while retaining an average of 85% of the cod. Bering Sea tests encountered so few large halibut that only the skate and small halibut sections were needed. That excluder released 86% of the halibut while retaining and average of 89% of the cod. It also released nearly all rock sole and pollock. While all the non-cod rates were statistically significant, small catch differences and variable catches left considerable uncertainty around the estimates of cod retention.

Introduction

Pacific halibut (*Hippoglossus stenolepis*) bycatch can be a limiting factor on the Pacific cod (*Gadus macrocephalus*) fisheries of the Gulf of Alaska and Bering Sea. Halibut may not be retained in any of the Alaska trawl fisheries and annual limits are set on halibut bycatch mortality for most of the groundfish trawl fisheries (Witherell and Pautzke, 1997). Previous cooperative efforts demonstrated the effectiveness of certain excluder devices for some sole fisheries (Rose and Gauvin 2001). The excluders consisted of panels across the intermediate section of the trawl with openings large enough to accommodate the target fish, but not the larger halibut. Panels were sloped so that fish that do not pass through are herded to an escape opening. Varying features of the panels, including hole size and shape, slope, rigidity and materials, were tested to adapt to different fishing operations and to achieve a range of catch and bycatch rates.

In November of 1999, a meeting of trawl fishermen was convened by the Groundfish Forum and the Alaska Draggers Association to review sole excluder results and to generate ideas for future developments. At that meeting, it was recognized that a similar tool for cod fisheries, while technically challenging, could be very useful in reducing halibut bycatch. In early 2000 the Groundfish Forum and the At-Sea Processors Association, proposed an exempted fishery (EF) to test halibut excluders for use in trawl fisheries for cod. They asked Craig Rose of the Resource Assessment and Conservation Engineering (RACE) Division of the Alaska Fisheries Science Center (AFSC) to develop a device for testing, starting with the knowledge developed in the sole fishery project and gained from discussions with captains from the trawl fleet.

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The initial separation concept, based on morphometric differences and previous behavior observations, used a rigid grate with circular holes for the separation panel. The F/V Katie Ann (KA) conducted a brief fishing trial of a prototype excluder during the open fishery in February of 2000. Two AFSC research cruises, aboard the chartered vessels F/V Hickory Wind (HW) and F/V Hazel Lorraine (HL) in June and August 2000, made systematic tests and advanced excluder development. The excluder system developed from those two cruises was tested in the Gulf of Alaska in September 2000, during an exempted fishery aboard the F/V Legacy (LG). In April of 2001, additional tests were conducted in the Bering Sea aboard the F/V Northwest Explorer (NE). This paper describes the methods and results of those tests and the designs and performance of the resulting excluders.

Methods

During each of the cruises, the vessels used trawls and rigging which they used when commercially fishing for Pacific cod. No alterations were made to the forward part of the nets, the sweeps or the doors. Excluders were installed in or immediately ahead of the untapered intermediate section of the trawl. During the Gulf of Alaska cruises (HW, HL and LG) recapture nets were also installed to retain all fish moving out of the escape openings of the excluder. Care was taken in rigging this net to keep it from masking the escape openings, or being clearly visible from those openings, so as not to affect fish behavior. During the F/V Northwest Explorer cruise, catch comparisons were made by doing alternate tows with and without the excluder installed.

The initial tows (KA) were conducted North of Amlia Island in the Aleutians. All Gulf of Alaska (HW, HL, LG) trawling was conducted east and south of Kodiak and Afognak Islands, while Bering Sea trawl tows (NE) were located north of Unimak Island. Trawl locations were selected for likelihood of encountering Pacific cod schools with some Pacific halibut present. Towing speeds varied between 3 and 4 knots and the ship's positions, based on GPS (Global Positioning System) fixes, were recorded at one minute intervals throughout each tow, except during the exempted fishery when only starting and ending positions were recorded. Temperature, light level and depth were recorded with a data logging sensor attached to the top of the trawl.

Catches from main and recapture codends were sampled separately. Whenever feasible, the length of each halibut was measured. If it was necessary to subsample fish, a systematic sample was obtained by measuring every n^{th} fish, where n was an integer that would result in a sample of 100 or more fish. Individual halibut weights were determined from a length/weight table.

Sampling of cod was similar to that for halibut during the AFSC cruises (HW, HL), except that, for large catches, baskets were used as the sampling unit instead of individual fish. Baskets of cod were weighed to obtain the total catch weight. During the exempted fisheries (LG, NE), basket samples of the catch were taken from a conveyor belt in the ship's factory and the cod were separated from the other species. The number of baskets sampled was adjusted get a sample of at least 100 cod. Lengths of all sampled cod were measured. Samples were taken at regular intervals throughout the catch. The entire catch, before sampling, was weighed as it passed across a flow scale. Total cod weight in each haul was estimated by extrapolating sample weight to full catch weight.

Intensified CCD cameras (ICCD) with high sensitivity in the infrared range were used with infrared LED illuminators to observe fish behavior. While the rapid absorption of infrared light by water limited the range of this combination, the insensitivity of fish vision to infrared light made observation possible while providing minimal illumination for the subject fish. Batteries and a video recorder in an underwater housing were connected to fixed camera and light mountings within the net to provide power and record the video output. These systems were started when the trawl was launched and operated throughout the trawl tow. Tapes were reviewed after each tow to assess the configuration of the excluder components and to assess their effects on fish behavior.

Excluder Designs and Results

Halibut excluders developed for the sole fishery consisted of sloped panels across the intermediate section with holes (rigid squares or mesh) of a size that allowed the sole to pass through while directing the larger halibut to an escape opening at the top or bottom of the net (Figure 1). In some of the designs, there was a wide, compressed horizontal tunnel along the top (or bottom) of the net between the end of the slope and the escape opening. Large meshes between this tunnel and the main body of the net provided sole with more opportunities to remain in the catch.

The main challenge in applying this concept to cod fisheries was that cod are much more similar in size and swimming ability to halibut than are sole. Thus, a square hole or mesh large enough to allow all cod to pass would only exclude the very largest halibut. The different body shapes of these fish were considered a characteristic that could be exploited for separation. When alternate hole shapes were considered, it was noted that rigid circular holes, sized for the largest cod, had the best chance of excluding smaller halibut. Therefore, the excluders were constructed with rigid circular holes in the selection panels.

F/V Katie Ann

The main component of the excluder used on the Katie Anne was a rectangular, welded aluminum frame with a 6 by 7 array of circular rings with an 8.5 inch diameter. This was installed in an untapered intermediate section with the wider side across the net and the top edge offset forward to create a downward slope. A mesh panel was installed over the bottom panel of the intermediate. Six rubber loops connected the aft edge of this panel to the excluder grate along the top of the lowest rank of rings. This prevented fish from directly entering the escape tunnel below the grate, forcing them to encounter the grate's rings. No additional rings were used aft of the sloped grate and the escape hole was close behind it's lower edge.

The excluder was only used on a few tows aboard the Katie Anne. Ship's personnel reported reduced cod catch and little or no halibut exclusion. Most of the halibut encountered during the tests were small, with very few large enough to be blocked by the selection grate.

F/V Hickory Wind (Cruise No. 2000-1)

The excluders used on the Hickory Wind had sloped ring panels followed by horizontal panels in the top of a tunnel section. Five panels for the slope and the inside wall of the tunnel were constructed of welded stainless steel rings (0.64 cm (0.25 inch) diameter stock) linked by welded wire (0.32 cm (0.125 inch)) loops (Figure 2). The 21.5 cm (8.5 inch) inside-diameter (ID) rings were linked in a hexagonal array, with rows of 7 rings alternated with offset rows of six rings. These linked rings were secured inside 107 cm (42 inch) long by 163 cm (64 inch) wide

fiberglass frames (1.3 cm (0.5 inch) diameter solid rods) to prevent tangling and facilitate attachment to the net. Two similar panels of 19 cm (7.5 inch) ID rings, alternating rows of 8 and 7, were also constructed. Finally, a rigid aluminum frame, with a rectangular array of 8 by 9 circular holes (20 cm diameter) was also available for testing. To make this frame more comparable to the flexible frames, 19 cm steel rings were affixed inside of each of these holes.

The 21.5 cm rings were tested first, installed with 3 panels forming a constant slope from the top to the bottom of the intermediate section and two panels forming the top of a tunnel against the bottom panel of the net. Three tows were made in that configuration, followed by two tows with the horizontal tunnel eliminated.

While all of the tows with 21.5 cm rings retained more than 95% of the cod, they retained a similar percentage of the halibut (Figure 3). On only one tow was a significant proportion of halibut excluded (47%). That tow was unique in that half of the halibut encountered were longer than 80 cm. On all other tows, fish of that size made up less than 1% of the halibut. The relatively small halibut (averaging 1.6 kg) captured with the cod (averaging 3.1 kg) made separation with this ring size ineffective.

The remaining tows were made with 19 cm rings, six with the flexible grates forming the slope and four with the rigid grate. No tunnel rings were used with either. None of these tows achieved useful selection. The general pattern was that more cod and halibut were excluded with the smaller rings, but that both species were excluded at similar rates (Figure 3).

Underwater video observations of fish encountering the holes showed that even though many fish did not pass through at the first encounter, both cod and halibut could pass the grates at relatively high rates. Skates which encountered the grates would usually become entrained, blocking a portion of the grate for the remainder of the tow. On the final tow, a combination of skates and a very high catch rate of cod resulted in the rigid grate becoming completely blocked, with the subsequent catch accumulating ahead of it.

The principal conclusions from the Hickory Wind cruise were: 1) while this type of excluder could be effective for larger halibut (>80 cm in length), it would not be useful when most of the halibut were smaller (< 70 cm). Alternative methods would have to be developed for smaller halibut; and 2) a method for preventing skates from blocking the grates could result in better operation.

F/V Hazel Lorraine (Cruise No. 2000-1)

To address problems related to skates and small halibut, two devices were added to the trawl for the next cruise. A large mesh (20 by 20 cm) panel, was installed ahead of the ring excluder to deflect skates before they reached the ring slope (Figure 4). This panel was cut as square mesh, 40 bars long and 12 bars across the front edge, tapering to 10 bars across the aft edge. The front edge of the panel was installed between the center of the side panels of the intermediate and the sides were secured to a descending bar of those panels until it reached the lower ribline. From that point aft, the skate panel was affixed to the edges of the bottom panel. Thus, approximately half of the skate panel formed a descending slope that blocked the lower half of the net, while the aft portion and the bottom of the net formed a narrow tunnel that was closed off where the aft edge of the skate panel was secured to the bottom panel of the net. A slot in the bottom panel, secured shut during towing, allowed the fish that accumulated in that bag to be released as the net was brought aboard.

To allow the escape of small halibut, the difference in body shapes between cod and halibut was again exploited. Because of their wide flat body shape, it was expected that even

medium size halibut could pass through a horizontal slot that would accommodate only the smallest cod. Estimates based on published cod girth data, with an assumption of circular cross-section, and a few measurements of halibut thickness indicated that a slot height of 9.2 cm (3.6 inches) would allow halibut up to 90 cm through, while retaining cod less than 50 cm long. Four panels, each with a 3 by 14 array of 9.2 by 36 cm horizontal slots, were constructed of fiberglass rods inserted through crosspieces of rubber hosing (Figure 5). These were installed in an open section (no intermediate mesh) behind the ring excluder so that fish passing through the slots escaped and those that did not pass through were guided to the codend. The slot panels were installed vertically on the sides of the net. The front two panels angled toward each other from the spread of the riblines to a spacing of 51 cm (20 inches) apart (Figure 5). The aft two panels formed a 51 cm wide channel, leading back toward the codend. The aft opening of this channel was obstructed by an aluminum frame, supporting flexible, plastic 'fingers', which fish had to bend to pass. Mesh was installed between the top and bottom edges of the slot panels to prevent escape upward or downward.

The combination of skate, ring and slot excluders (Figure 6) achieved a better selection between species, retaining approximately 70% of the cod, but only 20-25% of the halibut (Figure 7). After several tows, the frame with the flexible fingers was damaged and replaced with a broad grid of stretch cords ('bungees'). This resulted in a decrease in cod retention and an increase in variability, for cod and halibut. The escape of cod was notably greater in an area (Bungee (E) in Figure 7) where the cod were mostly smaller. For the final tows, the ring excluder was removed. This resulted in an increase in the retention of halibut to 40-65%, with little apparent improvement in cod retention.

Video observations of the slot section showed why more cod were escaping than had been expected. When cod encountered the slots in an upright position, only very small cod would pass through. However, when crowding caused vigorous attempts to pass through the slots, cod turned on their sides and compressed their heads between the bars. In this way, much larger cod were able to pass through the slots. It was clear that smaller slots would have to be used to reduce cod loss. To estimate a more effective slot width, compressed head width measurements were made for both cod and halibut.

The skate excluder was effective at preventing large skates from reaching and blocking the selection panels. Large skates were retained between the aft edge of the panels and the bottom of the intermediate.

F/V Legacy (Exempted Fishery)

The excluder system tested during the exempted fishery was identical to that used during the Hazel Lorraine cruise, except that:

1. the slots in the slot excluder were reduced to 7 cm (2.75 inches) in width (20 slots across instead of 14),
2. the flexible fingers were installed at both the forward and aft ends of the narrow portion of the slot excluder. (Instead of being mounted within and aluminum frame, these fingers were affixed outward from fiberglass rods that were installed vertically down the center of the opening.)
3. The forward portion of the ring panel was mounted within a 229 cm (90 inch) diameter aluminum ring, instead of just being tied to the sides of the intermediate. (This frame was one that the Legacy used for its halibut excluders in sole fisheries.)

The initial tows resulted in halibut retentions of approximately 20%, about half of the cod were also escaping (Figure 8). Cod size data indicated that even large fish were escaping, so an adjustment was made to the ring excluder. To make it harder for fish to pass through the tunnel to the escape opening, a fiberglass rod was installed under the bottom panel of the intermediate in the tunnel section. This closed the tunnel down to a thin slot between this rod and the rods of the ring frames. While this modification did not affect halibut retention, it did improve cod retention.

A second constricting rod was then installed aft of the first to further hamper escape and encourage fish to pass upward through the tunnel's rings. This resulted in cod retention values between 75 and 86% with halibut retention still around 20%.

The final tows were made with the ring excluder removed, to see how the slot excluder performed alone. While the cod retention was excellent (97-99%), halibut retention rose considerably.

Examination of selectivity by length class (Figure 9) indicated that only cod smaller than 56 cm escaped through the slots, while 10 - 15% of the larger fish were escaping through the rings. With the slots alone, the percentage of halibut escaping declined steadily from about 40% at 52 cm to 90% at 90 cm. With the ring excluder added, escape rates were relatively constant from 50 to 70 cm and then increased until all of the halibut larger than 87 cm were excluded.

F/V Northwest Explorer (Exempted Fishery)

In early April 2001, the excluder system from the Legacy fishery was tested in the southeast Bering Sea aboard the F/V Northwest Explorer. In contrast to the studies above, no recapture net was used and tows with matched nets were alternated with and without the excluder. This allowed testing under actual commercial fishing conditions. Other differences included:

1. codend meshes (176 mm stretch square mesh) used by the fishery,
2. larger meshes in the intermediate section containing the ring excluder (195 mm diamond),
3. the size composition of halibut (see below),
4. the 'flexible fingers' were replaced by a series of 4", square mesh panels that divided the space between the aft slot panels into 12 (2 across by 6 high), 10 inch by 10 inch tunnels, and
5. due to the construction of the trawls, the excluders had to be moved aft so that the skate excluder was in an untapered section and the slot section connected directly to the codend.

While the original excluder included skate, ring and slot sections, the ring section was removed after 3 excluder tows because:

1. Very few halibut < 60 cm were encountered, most were in the 30-40 cm range,
2. Apparent significant loss of all sizes of cod was occurring, and the large meshes in the ring section were considered a likely site of such escapes, and
3. Minor damage was occurring to fiberglass rods in the ring section.

Seven excluder tows were completed using the skate and slot excluders as well as seven control tows. Comparisons of the catch per hour from those tows showed that: the average cod catch with the excluders was 11% lower than the control tows, while decreases of halibut, pollock and rock sole were 86%, 97% and 99%, respectively (Figure 10). Only the cod difference was not statistically significant. Preliminary analysis of the length data indicate that cod escapes were mostly fish smaller than 55 cm (Figure 11).

Timing of the setting and recovery of the trawl indicated that the presence of the excluders did not significantly increase handling time. The skate and slot excluders were not damaged by normal fishing operations. The fiberglass frames of the ring section were prone to breakage without extra care taken in handling.

Conclusions

Through this series of experiments, an excluder system which retains cod while excluding halibut was developed and demonstrated. This system includes a mesh panel to exclude skates, an excluder based on rigid rings to exclude large halibut and an excluder based on rigid slots to exclude small halibut. The effectiveness of these elements were dependant on the size of the cod and halibut entering the net relative to the size of the escape openings. Selective adjustments of the configuration and dimensions of excluder openings improved selectivity.

Optimum selectivity for specific fishing situations should be obtained by selecting opening sizes and which sections to include, based on the size and species encountered. For example, in areas where mostly small halibut are present, the ring section, which primarily excludes larger halibut, can be omitted. If only large cod are present or marketable, the slot widths might be increased to achieve more halibut escapes. Further testing in a range of areas and seasons should improve the ability to accurately make such decisions.

This flexibility and the need to adjust to different mixes of fish would make it counterproductive to try to find and define a single excluder configuration for Alaska cod fisheries. They will also require some maintenance and would be easy to disable. Thus, these excluders are not a good candidate for a gear regulation at this time. However, they will be very valuable tools where individual trawlers are motivated to reduce their halibut bycatch.

References

Rose, C. S. & J. Gauvin 2001.Effectiveness of a rigid grate for excluding Pacific halibut (*Hippoglossus stenolepis*) from groundfish trawl catches. Marine Fisheries Review (In Press).

Witherell, D. and C. Pautzke. 1997. A brief history of bycatch management measures for eastern Bering Sea groundfish fisheries. Mar. Fish. Rev. 59(4):15-22.

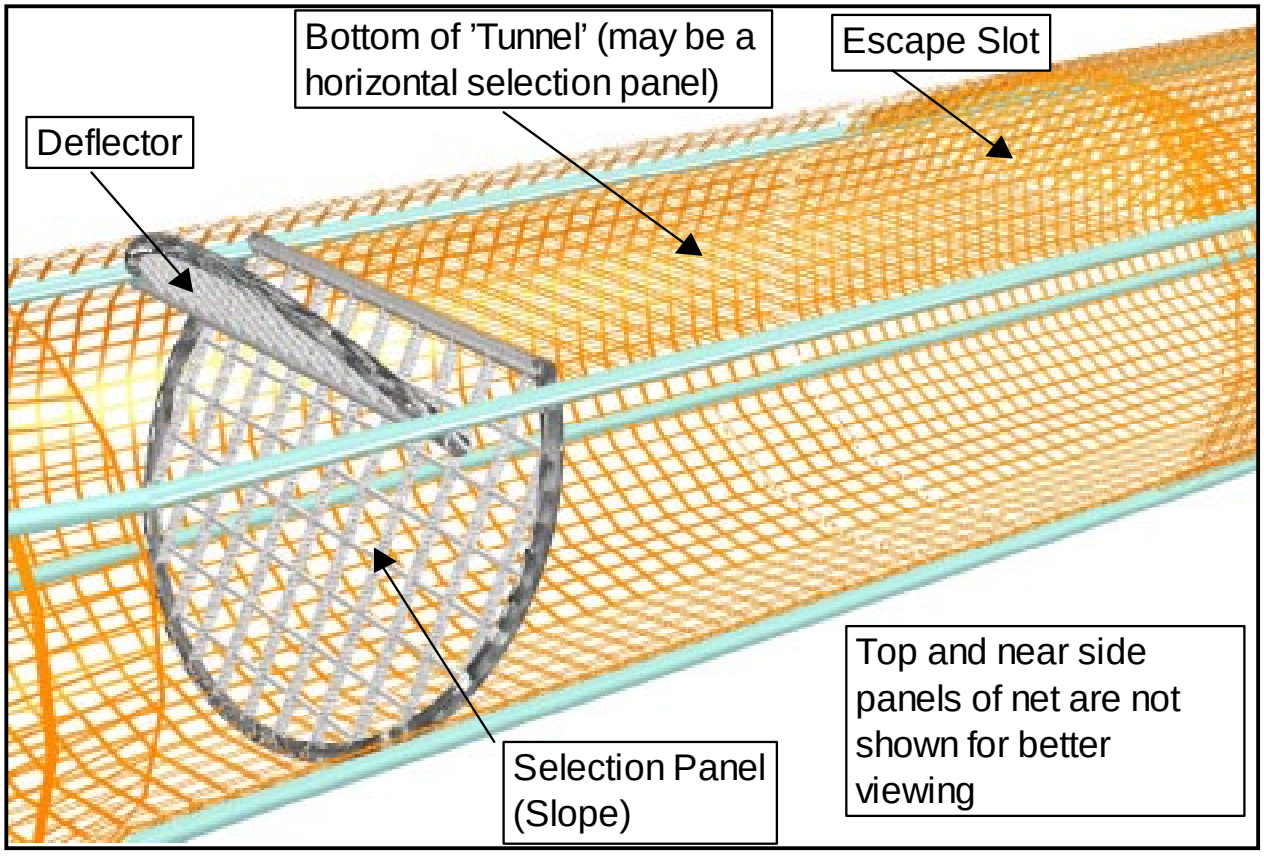

Figure 1. Configuration of a rigid halibut excluder for use in sole fisheries.

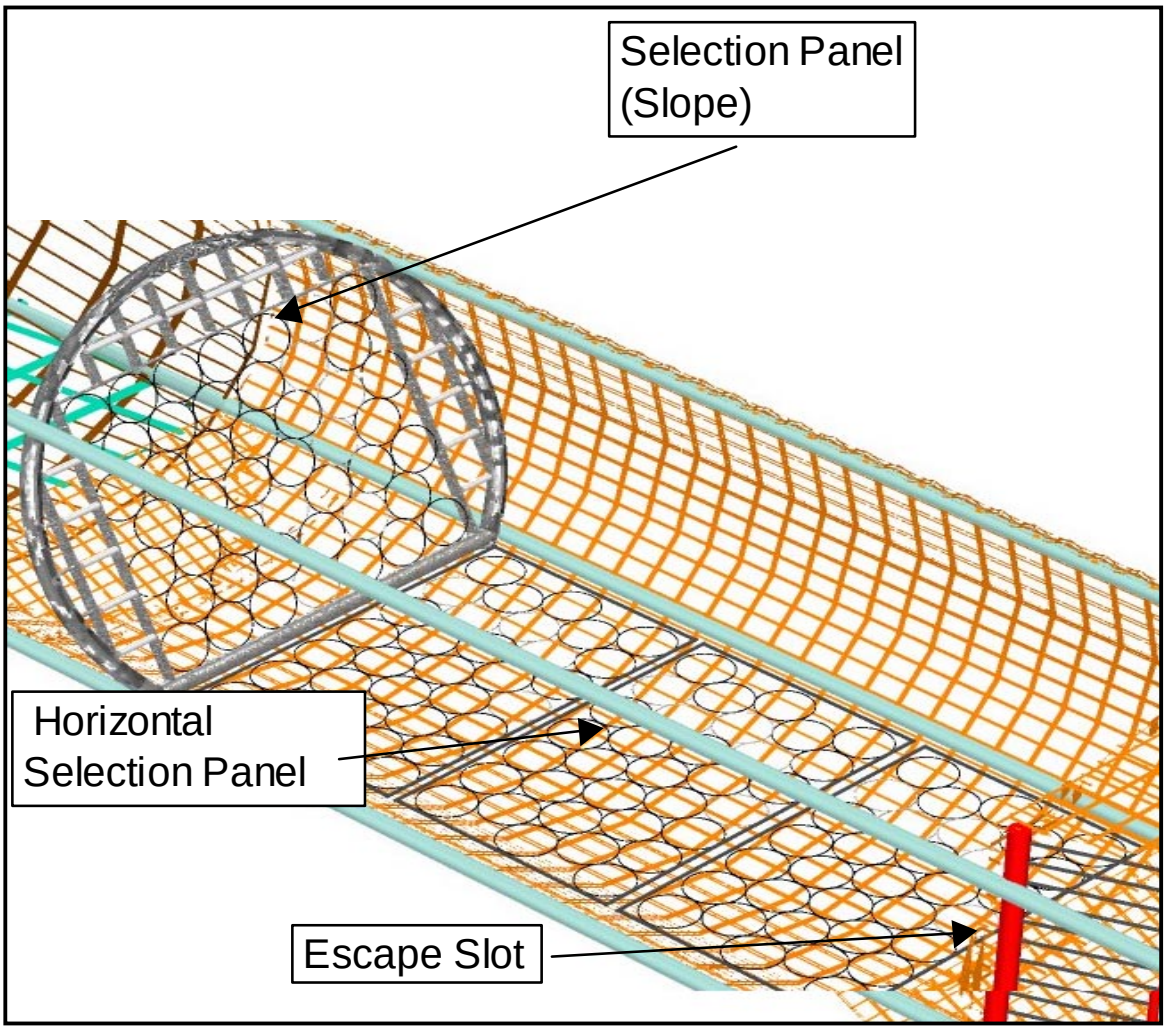

Figure 2. Configuration of the 'ring' excluder to allow escape of large halibut.

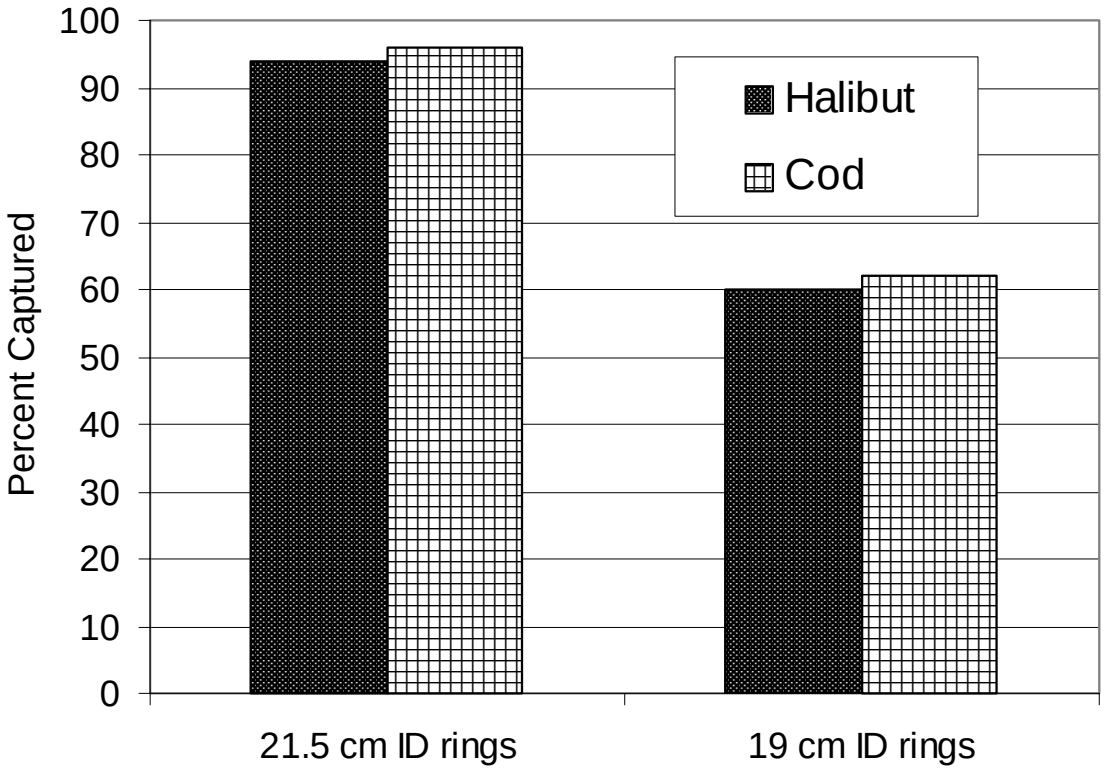

Figure 3. Species selectivity of a halibut excluder system during tests aboard the F/V Hickory Wind (ring section only).

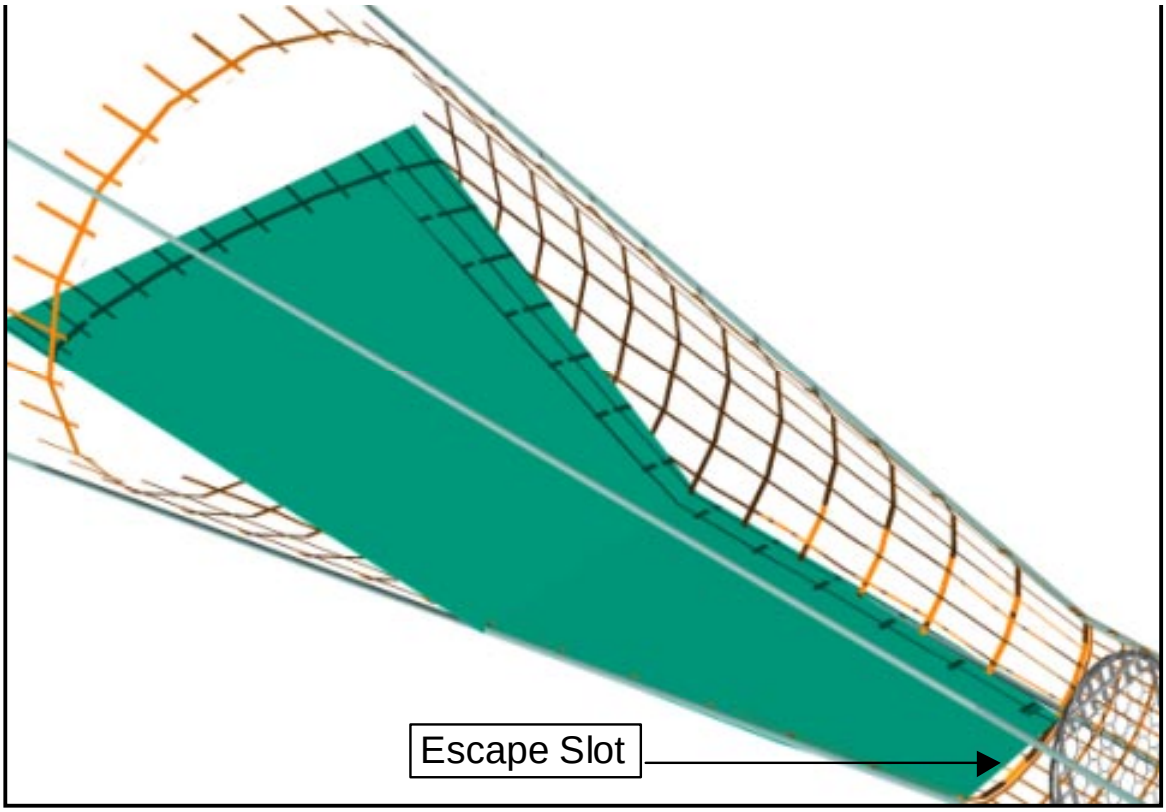

Figure 4. Location and configuration of a panel to exclude skates and other large fish. The meshes of the panel are in a square mesh orientation with openings 20 x 20 cm (40 cm stretch measure).

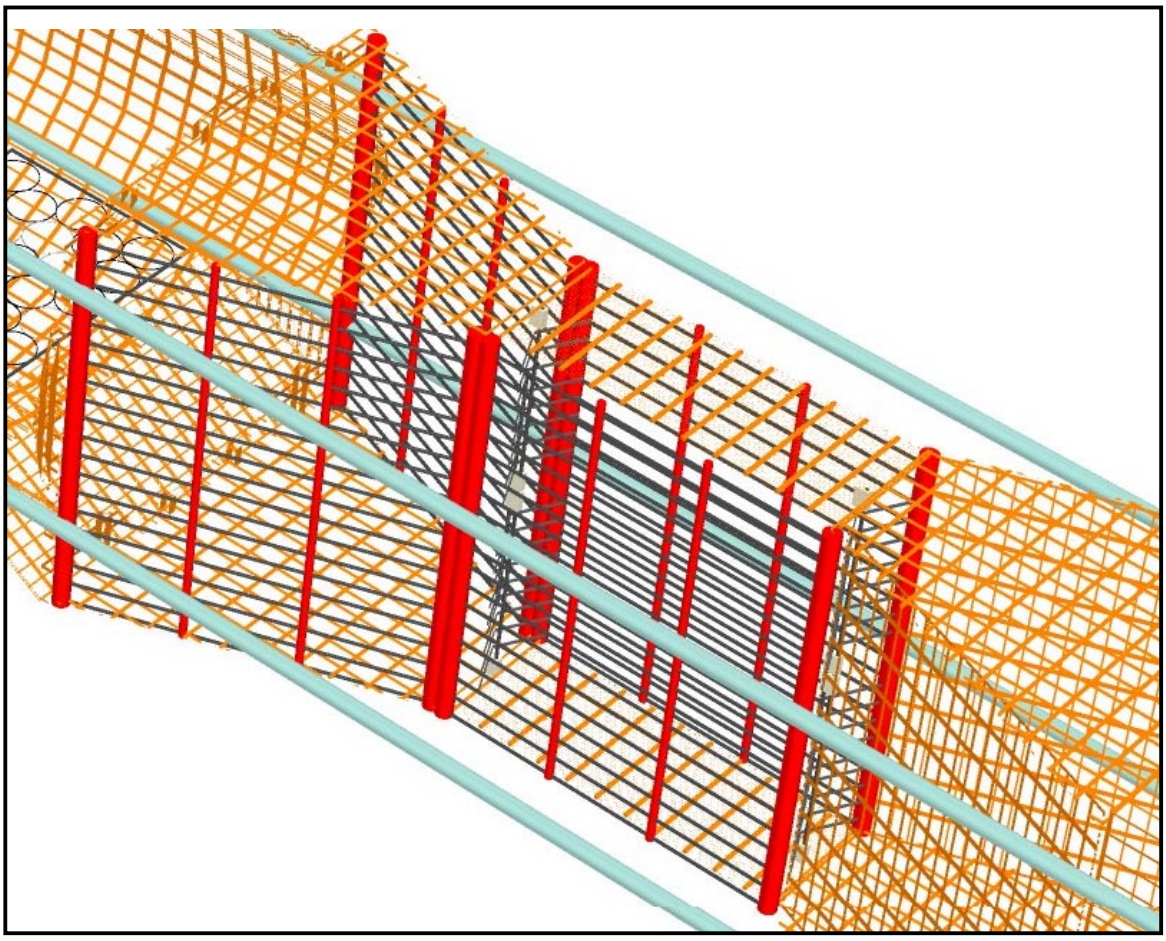

Figure 5. Configuration of the ’slot’ excluder to allow escape of small halibut.

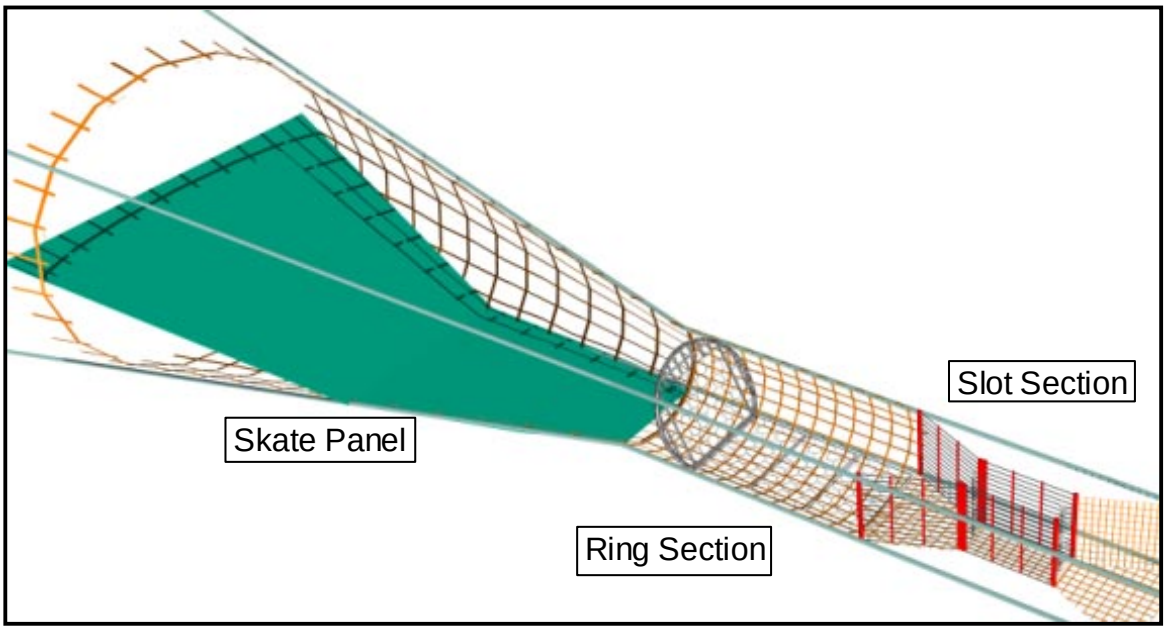

Figure 6. Configuration of the entire halibut excluder system as tested on the F/V's Hazel Lorraine and Legacy, including skate, ring and slot components.

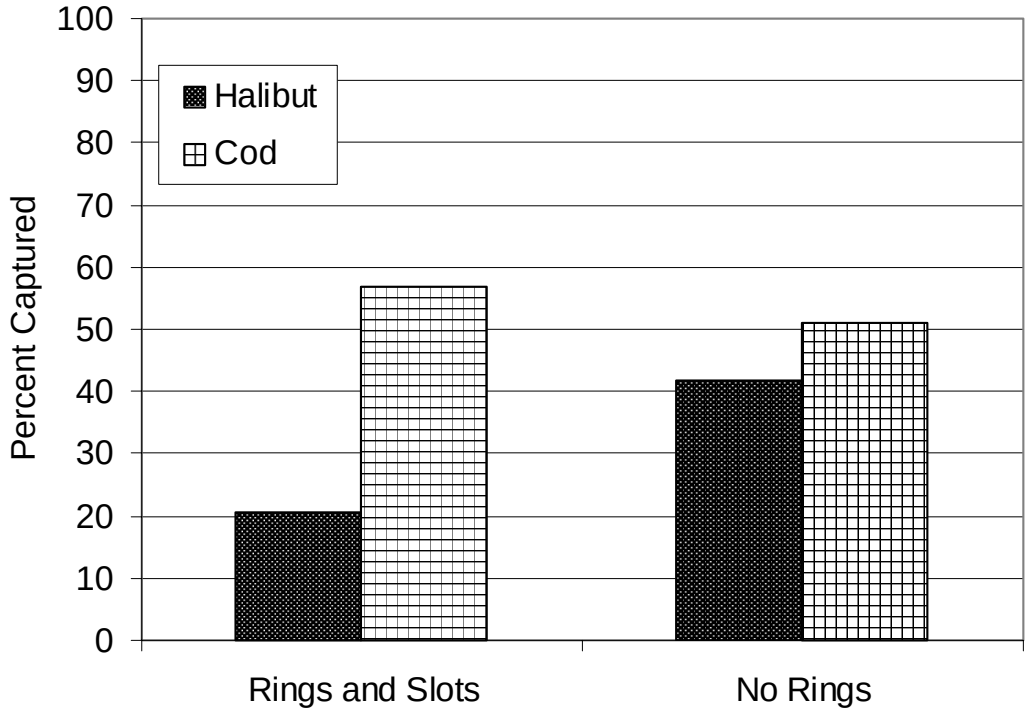

Figure 7. Species selectivity of a halibut excluder system during tests aboard the F/V Hazel Lorraine (skate, ring and slot sections).

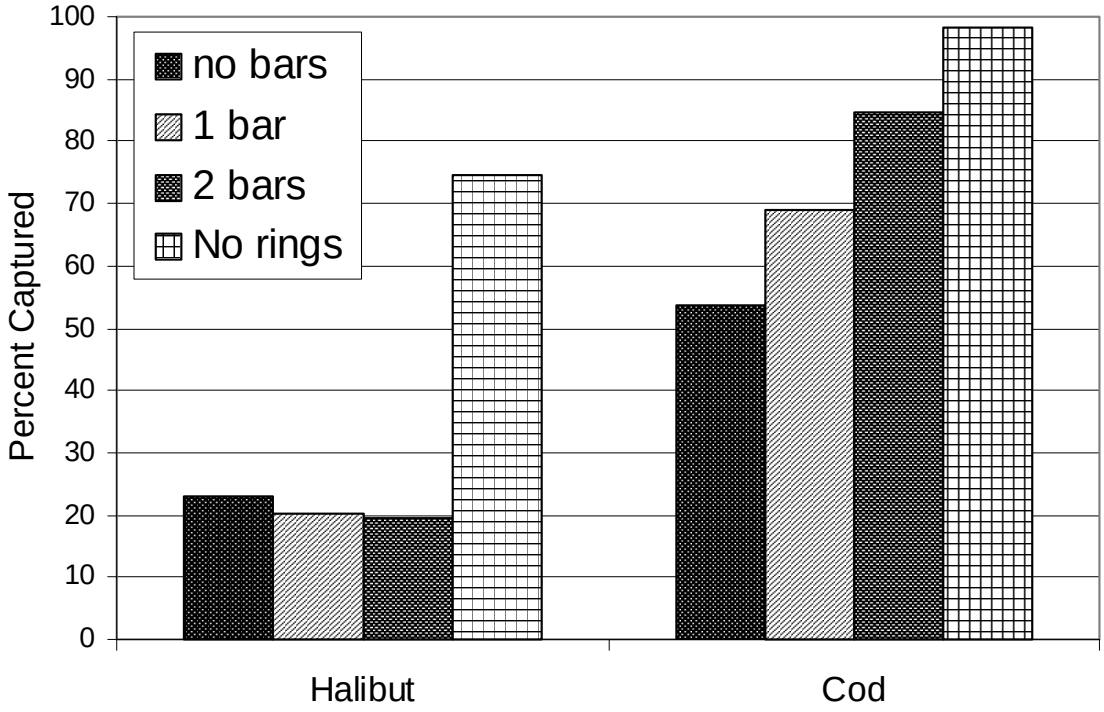

Figure 8. Species selectivity of a halibut excluder system during tests aboard the F/V Legacy (skate, ring and slot sections).

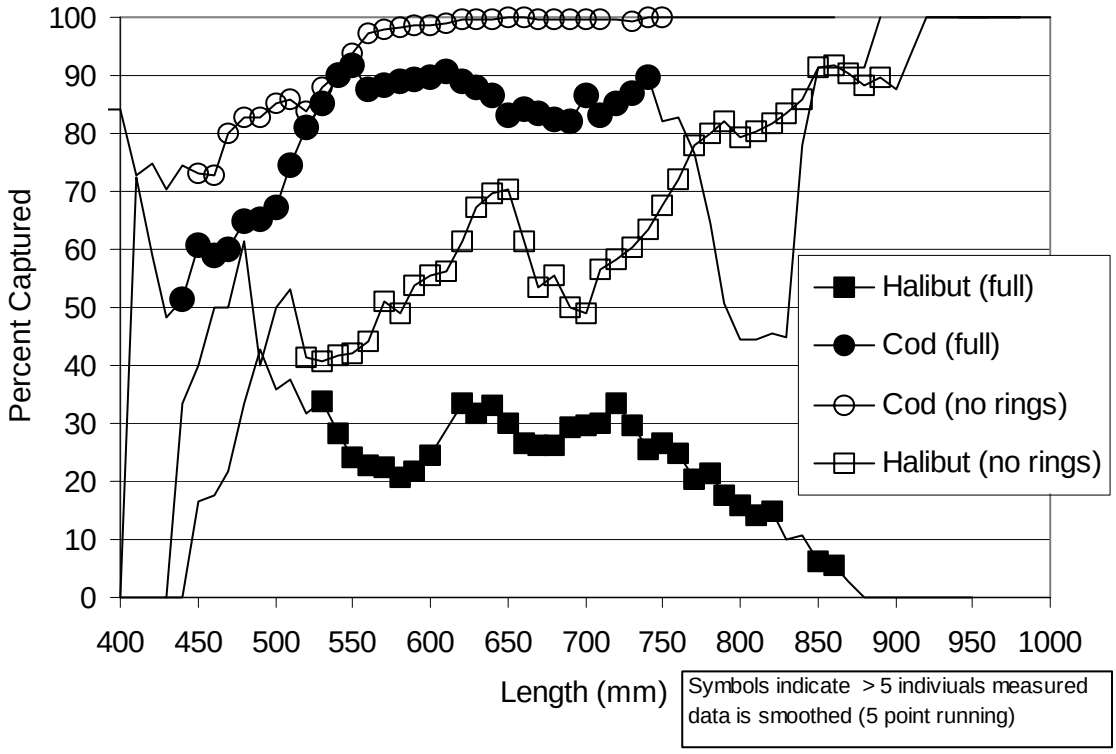

Figure 9. Size selectivity of a full halibut excluder system (skate, ring and slot sections) and a system without the ring section, as tested aboard the F/V Legacy.

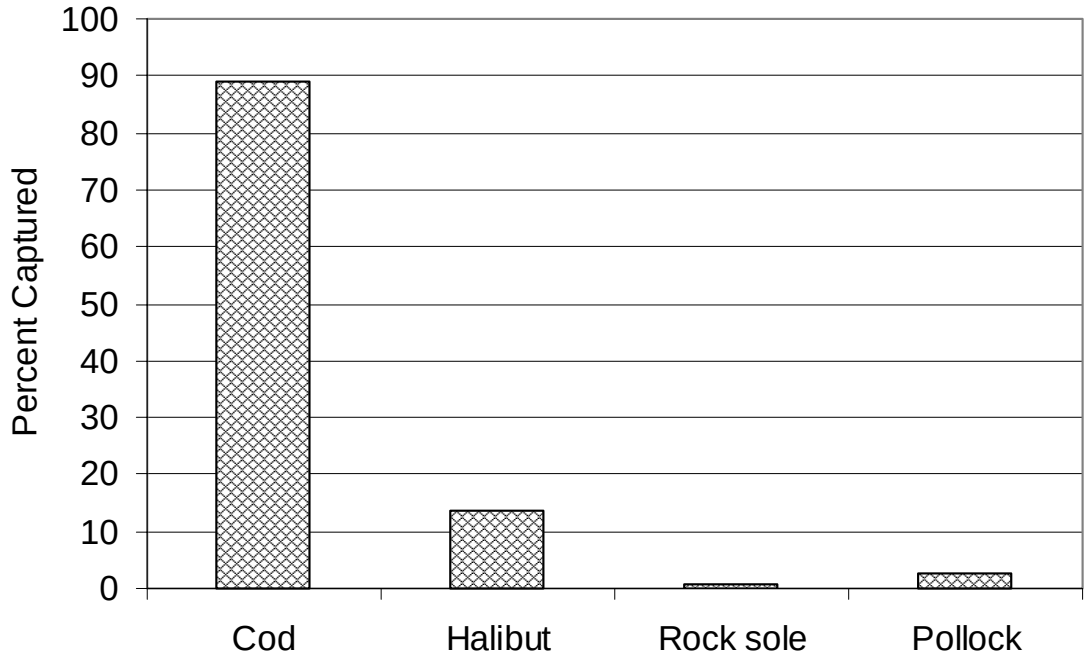

Figure 10. Species selectivity of a halibut excluder system (skate and slot sections) during tests aboard the F/V Northwest Explorer.

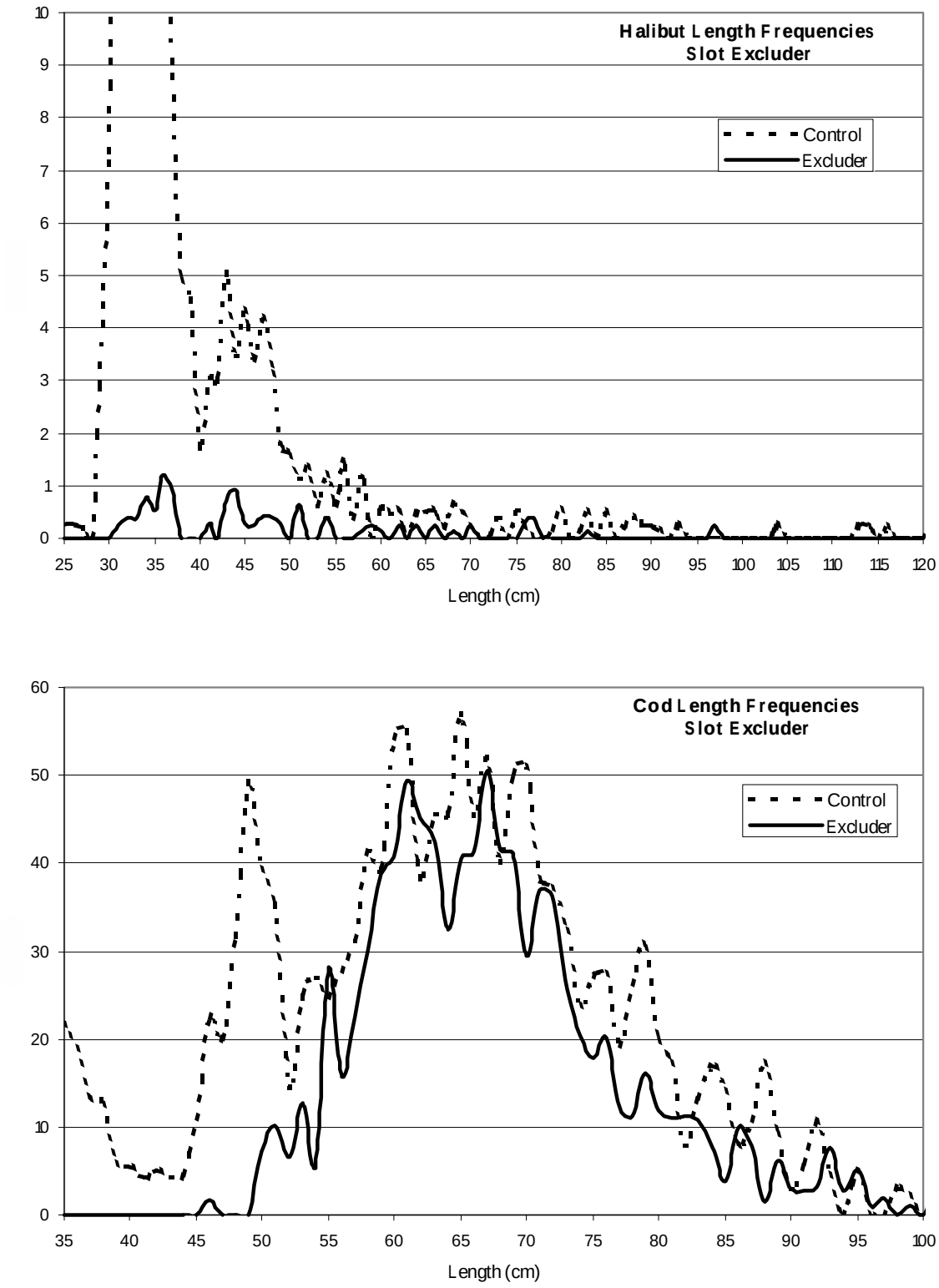

Figure 10. Size selectivity for halibut (top) and cod (bottom) of a halibut excluder system (skate and slot sections) during tests aboard the F/V Northwest Explorer.