DRAFT Final Report on EFP 06-03 to Develop a Halibut Excluder for the Gulf of Alaska Shoreside Cod Trawl Fishery

By

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Part 1: Development of a Gulf of Alaska halibut excluder for cod and description of how the device was tested

Background

In June of 2006, the North Pacific Fishery Management Council recommended approval of an exempted fishing permit to test a halibut bycatch reduction device designed for use in the Gulf of Alaska (GOA) cod fishery. The EFP applicant (Gauvin and Associates on behalf of the Marine Conservation Alliance Foundation) developed the test with technical assistance from Dr. Craig Rose of the Alaska Fisheries Science Center and in cooperation with trawl industry partners Alaska Groundfish Data Bank and the Alaska Draggers Association.

The objective of the excluder test was to evaluate its performance and feasibility to reduce halibut bycatch on typical “inshore” catcher vessels that target Pacific cod in the Gulf of Alaska. The performance goal for the device was to reduce the halibut bycatch by at least 40% (by weight) while minimizing loss of target catch (cod catch per hour) compared to an unmodified net. The test also sought to evaluate the functionality and handling aspects of the excluder for use on Gulf of Alaska trawl vessels which tend to be smaller than Bering Sea trawlers. While halibut excluder usage already occurs in many Bering Sea bottom trawl fisheries, Gulf trawlers represent a challenge because the rigid halibut excluder devices used in the Bering Sea were developed for large vessels with ample deck space. Use of the Bering Sea halibut excluders has been problematic in the Gulf of Alaska due to the relatively short decks and the widespread use of aft net reels on the smaller GOA vessels. Practically speaking, Gulf of Alaska trawlers need an excluder that can withstand being rolled onto a net reel. Such a device must therefore be made of flexible materials that allow it to regain its original shape and function during fishing.

Priority for the development of a halibut excluder for the Gulf trawl cod fishery

For the fall (B season) cod fisheries in 2004 and 2005 (the two years prior to the EFP application), trawl halibut bycatch rates were dramatically higher than in previous years. As a consequence, halibut mortality attributable to the GOA trawl cod fishery grossly exceeded the seasonal shallow water complex PSC bycatch allowance for those two years. Due to these overages in the halibut cap, NMFS did not open the shallow or deep water complex fisheries during the fourth quarter of 2004 and 2005. This was done to prevent exceeding the annual halibut mortality cap for the GOA.

Gulf trawlers attribute the increase in halibut bycatch in the cod fishery in recent years in part to an increase in the spatial overlap of the halibut resource with the cod fishing grounds nearest Kodiak. Another factor that fishermen have cited is that sea lion protection measures have shifted the trawl cod fishing from the traditional winter/spring months to the summer/fall period when cod are not as likely to be tightly schooled. This increases towing times and potential for catching more halibut.

To address the increase in halibut bycatch, Gulf cod trawlers and the Alaska Groundfish Databank stepped up efforts in 2006 to work with NMFS in-season managers to help track halibut bycatch to avoid halibut PSC cap overages. Additionally, the fleet requested assistance from Dr. Craig Rose of the Alaska Fisheries Science Center and John Gauvin working on behalf of the Marine Conservation Alliance Foundation. Technical help was sought to both develop concepts for and field test a gear modification to help reduce halibut bycatch in the cod fishery.

Design elements of a halibut excluder for the Gulf of Alaska

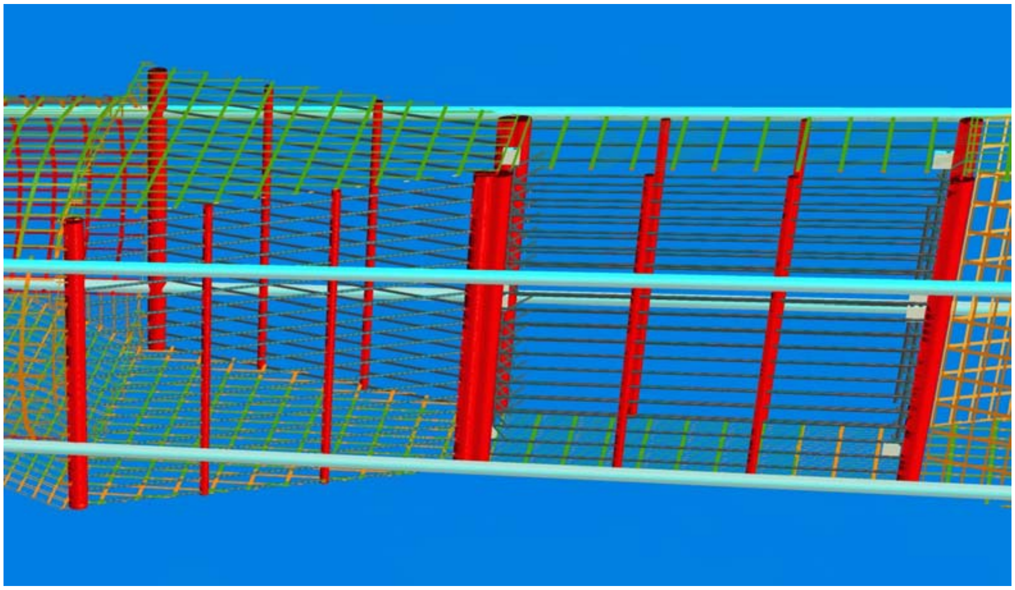
For achievement of bycatch reduction through gear modification (a.k.a. selectivity) between halibut and cod, the participants in this endeavor elected to focus on the relatively large thickness of the head of Pacific cod relative to the smaller thickness and flatter head and body shape of halibut. To evaluate the potential for selectivity based on differences in head size/body shape characteristics, head thickness measurement data collected by Dr. Rose for an earlier bycatch reduction project in the Bering Sea were examined.

To focus on the specifics of the head size/shape differences between cod and halibut for the size of fish taken in the Gulf cod fishery, fish length data for the two species was examined. These data were collected by fishery observers working in the Gulf cod fishery. When plugged into the head size/shape differential relationship developed by Dr. Rose, the estimated relationship suggested that rectangular-shaped "slots" would allow halibut to pass out of the net while retaining most of the cod. Dr. Rose's selectivity relationship indicted that the slots should be 18 inches long with a height of 2 5/8 inches (measured between the bars).

Based on findings from previous fish behavior and bycatch reduction tests in the Bering Sea and the size data from the observed fishery in the Gulf cod trawl fishery, we estimated the halibut escapement rate that such a device could achieve if a sufficient number of these rectangular escapement slots were arranged where they would be accessible to and used by halibut. The point estimate based on the selectivity curve was a reduction in halibut by weight of 40%. A similar estimate for cod escapement indicated that it would be minimal as long as the slots were made of materials that were sufficiently rigid to prevent expansion in the rectangular dimensions of the slots.

Given the potential for achieving selectivity from the head and body shape differences based on the parameters of the Gulf cod fishery, work with Gulf fishermen and gear manufacturers started in late 2005. The first step was to develop ideas on how to build a halibut excluder that would provide the escapement slots while meeting the handling/flexibility requirements so that the excluder could be rolled up onto the net reel without damage to its shape. Ideas were developed through a series of informal meetings with Gulf fishermen spearheaded by the EFP applicant. Gradually, ideas evolved on construction and materials. A catalyst in this process was a full-scale model of a halibut excluder that Dr. Rose had developed in earlier work to reduce halibut bycatch in the Bering Sea cod fishery. The previous work had shown considerable promise for the concept of the slotted halibut excluder. But the construction of the device clearly needed significant modification to meet the handling requirements of the Gulf trawl fishery. Dr. Rose's earlier excluder for the Bering Sea had been constructed of fiberglass rods which were oriented horizontally. The rods were kept in place by passing them through vertical sections of hydraulic hose to which they were affixed via twine lashing and adhesives. A schematic of Dr. Rose's Bering Sea halibut excluder model is pictured below.

Figure 1. Slotted escapement panel halibut excluder



The concept for the halibut excluders for use in the cod fishery is different from sorting grids commonly used in Bering Sea flatfish fisheries. Excluders for flatfish are installed across the intermediate and exclude halibut by diverting them up (or occasionally down) and out of the net instead of passing through the grid tied across the intermediate. For the GOA cod fishery, the concept was to induce halibut to escape out the sides of the net while retaining the cod. The sides are used in lieu of the top or bottom based on expectations of where the halibut will find the best chance of escaping. The slotted design had worked fairly well in the Bering Sea cod fishery so it made sense to utilize the same approach in the Gulf of Alaska.

But Gulf fishermen felt that the length of the excluder section should be greater than what was done in the Bering Sea. For the Bering Sea cod fishery, the section with the escapement slots had extended over a distance of approximately 4-5 meters. In considering how the device might work in the Gulf cod fishery, fishermen were interested in increasing the surface area fitted with the rectangular slots. To Gulf fishermen, this might be more workable and less problematic than pulling the sides of the net together as had been done in the Bering Sea. For the Bering Sea device, the passageway through the excluder had been narrowed to help trigger the halibut to attempt to swim out the sides. To accommodate the approach preferred by Gulf fishermen, it was decided that the length of the excluder would be nearly doubled to approximately 8 meters. This would provide nearly twice the number of slots for escapement relative to the Bering Sea version of the excluder.

Rigged to be inserted into the straight tube intermediate section, the excluder was essentially an extension to the straight tube section of the net wherein escapement slots replaced the webbing on the port and starboard sides. The webbing on the top and bottom of the net would be maintained. Sufficient strength in the net would be maintained because the riblines would continue to support the force when the net is being towed and retrieved.

Construction of a “flexible” slotted halibut excluder device

In the spring and summer of 2006, Gulf of Alaska fishermen and gear manufacturers came up with the idea of using scrap coaxial cable to form the slots for the excluder. This type of steel core wire is covered by a plastic jacket. In its normal application, “third wire” cable is used to carry an electronic signal from a net sounder or trawl sonar placed on the net headrope to a receiver located in the vessel wheelhouse. Third wire systems are used to monitor the shape of the net and the catch rate of the target species while fishing.

Third wire cable is replaced at regular intervals when it loses its ability to adequately carry the electronic signal. For this reason, scrap third wire in sufficiently good shape for use in constructing a halibut excluder was readily available in Kodiak (and other trawl vessel home ports). The challenge with third wire cable is mostly to figure out how to form semi-rigid panels of rectangular slots that maintain the desired dimension: 18 inches wide and 2 5/8 inches in height. Maintaining this consistent dimension during fishing and net retrieval is critical to achieving the halibut and cod escapement rates that are expected in the size/shape differential relationship described above.

To construct a slotted third wire halibut excluder, fishermen and a gear manufacturer in Kodiak replaced the side panels of an un-tapered intermediate extension tube with parallel lines of third wire cable oriented fore-aft. Eyes were pressed into each end of the third wire cable pieces with the excess seized down to form the eyes. Vertical spacing was set with vertical lines connected to each wire. To accomplish this, the plastic jacket was stripped away from the wire at each point where a connection was to be made to set the width of the slots (18 inches). Various methods were evaluated to connect the wires and vertical supports. These included “verticals” made of woven rope with the wire passing through and vertical twines knotted over the wires. The latter method was eventually selected because, as construction started, it was clearly easier to do and allowed for more consistent spacing. The main consideration for construction of the slots is that the spacing be consistent and fixed.

Square mesh top and bottom panels were used to make the section somewhat narrow and chain riblines on the bottom were also used to attempt to narrow the section. The goal of narrowing the section was to (hopefully) increase opportunities for halibut to escape as they passed through the excluder. Another way of creating opportunities for escapement was with steel trawl floats that were attached along the sides on lines from top to bottom inside the excluder (figure 2).

Figure 2. Bags of steel floats inside the halibut excluder.

As will be explained below, this addition was done after some preliminary testing in the fall of 2006. Video from those early trials showed that additional measures were needed to entice halibut to swim out the slots built into the sides of the excluder section. The floats were used to interrupt fish moving aft, encouraging escape attempts. The addition of floats was also installed to create lees that might help halibut to orient themselves for escape. The photographs below were taken in a Kodiak net shed. They show an excluder under construction (figure 3) and the finished excluder in 2006 (figure 4).

Figure 3. Halibut excluder under construction.

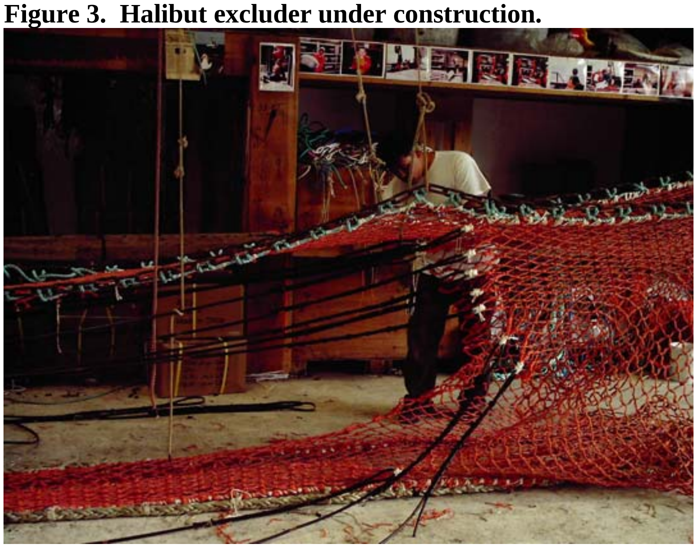


Figure 4. EFP crew and fishermen adding final touches to excluder.

Field testing

The method selected for testing the third wire halibut excluder was to evaluate its performance relative to an unmodified net in side by side trials. This involved pairs of vessels (one with the excluder and one without) fishing simultaneously and side by side.

Some conservation engineering development work in Alaska has successfully utilized recapture nets to collect escaping fish whereby the fraction of the species of interest that escapes can be evaluated relative to the overall catch. While appealing in terms of the potential for statistical power, the recapture net approach was deemed infeasible for evaluation of the halibut excluder device. A recapture approach was not practical due to the large surface area of the slotted escapement portals and the fact that a very large recapture net would be required to cover all of the escapement area. Such a large recapture net might create problems for the tow vessel due to its additional drag or might distort the shape of the net and change the water flow around the excluder.

For this reason, pairs of side by side tows by vessels of like horsepower were preferred. To address potential for vessel-specific effects, the testing incorporated a requirement to switch the device between the vessels working as a pair for the test. It was decided that excluder rotations would be done after each trip during the EFP test. The rotations were expected to provide for approximately four to five changes of the excluder between vessels. This would help to reduce any tendency for vessel effects to bias the performance estimates.

Based on the paired comparison approach, a statistical power analysis was developed using differences between log transformed catches of halibut between the pairs of tows selected from observer data for the trawl cod fishery. These data were used to calculate a standard deviation within pairs (1.37) which was used to account for the ambient variability in the catch rate of the species of interest for the power analysis. The standard deviation for the power analysis was calculated from observed tows in the last two regular fall cod fisheries (2004 and 2005) which were paired *post hoc* using a pairing routine to select pairs based on minimization of location differences of the haulback positions as well as minimization of the time difference of recorded net retrieval time.

The power analysis for halibut escapement was constructed around the expectation of a 40% reduction in halibut catch due to the excluder, corresponding to an effect of ln(.6) = 0.51. The desired power for the test was 0.80 and the Alpha value selected for the test was 0.10. These parameters plugged into the power analysis generated a target of at least 46 pairs as the number of pairs (replicates) needed for the experiment. A similar exercise was done to determine the number of replicates needed to measure effects of the excluder on cod escapement. The replicates needed for evaluating the effects on cod could essentially be done simultaneously because the data collected would allow for the effects on both halibut and cod to be measured at the same time.

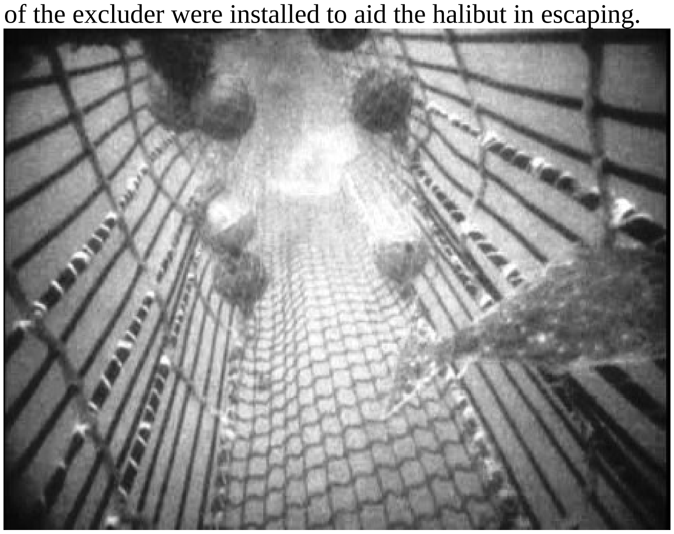
Given the large number of pairs of tows needed for the test, a decision was made to utilize two pairs of vessels for the test. While potentially introducing additional "vessel effect" on the test, two pairs of vessels was selected for pragmatic reasons. Using two sets of paired vessels (four vessels overall) reduced the time needed to conduct the test. This avoided some of the potential of introducing additional ambient variability from changes in environmental conditions during the testing period. For instance, both the density of cod schools and the overlap of halibut and cod on the cod grounds can change seasonally. If this is changing seasonally during the experiment, this could affect the performance of the excluder and our ability to measure that performance. Additional information on the testing methods can be found in the EFP application (available from the North Pacific Fishery Management Council).

Field testing commenced in August of 2006 with Gulf cod trawl vessels F/V Pacific Star, F/V Caravelle, F/V Topaz, and F/V New Life selected by a NMFS AFSC application review board for the field test for their ability to serve as matched pairs. As was mentioned above, after considerable effort to locate sufficient schools of cod to ensure that the testing could make a valid assessment of the effects of the excluder on cod and halibut, the testing had to be suspended in mid-August with the achievement of only a few pairs of tows. Hence the first attempt of the experiment was not able to provide an estimate of the effect of the excluder on halibut and cod catch rates. One accomplishment of the 2006 work, however, was that underwater video footage taken during the trials in August and October 2006 did reveal that modifications to the excluder were needed. The video revealed that while a large portion of the halibut passing through the excluder were of a size that could swim through slotted escapement portals, most halibut appeared to drop back through the net without attempting an escape.

To attempt to address the problem seen in the 2006 trials, a decision was made to modify the excluder and repeat the experiment in the spring of 2007. The modification was the addition of two sets of trawl floats that would be attached to the sides of the excluder across from each other. This was done to create a gantlet of sorts to trigger escapement. Another purpose for the trawl floats was to slow the flow of water in that section of the excluder with the hope that halibut resting there might make use of the escapement opportunity. A picture of the trawl floats tied into the third wire halibut excluder for the testing that occurred in the spring of 2007 is shown below (figure 5). This picture is a still image from the spring 2007 video showing a halibut escaping through the slots just ahead of the floats in the picture.

Conducting the second round of tests inside the pre-spawning time window was preferred in terms of how representative the test would be of the cod fishery. Additionally, we also wanted to avoid a repeat of the outcome of the previous year's experiment when sufficient cod fishing opportunities were not available for the test.

Figure 5. Underwater photo showing a halibut escaping through the excluder. The steel floats on the sides of the excluder were installed to aid the halibut in escaping.



In March of 2007, testing was conducted with the same four vessels that were used for the 2006 trials. Cod fishing conditions were notably better during this second year. Halibut were also in sufficient abundance to evaluate the performance of the device from conditions approximating the regular cod fishery in recent years.

The experiment took nearly the entire month of March to complete (even with the four vessels used to conduct the test). The longer than expected time needed for the test resulted from unavoidable interruptions while the vessels awaited safe weather conditions between trips. A total of 59 pairs of tows were completed in the experiment although six of these pairs had to be dropped from the analysis because one or both of the vessels encountered problems and could not complete the tows comprising the pairs. Examples of typical problems were things such as picking up a crab pot or failing to complete a tow by one of the vessels in the pair due to mechanical issues. The table below details the catches from all the tows done in the spring 2007 experiment in comparison to the catch limits placed on the experiment under the exempted fishing permit granted to the permit holder by NMFS and the NPFMC.

Table 1: Catches from the Spring 2007 third wire halibut excluder EFP test.

EFP limits	mt	Quantity used in EFP (mt)	Remaining (mt):
Halibut mortality	**90**	**72.21**	**17.79**
Halibut catch	**147.54**	**118.37**	**29.17**
Total Groundfish	**1300**	**1254.38**	**45.62**

As might be expected from a successful cod fishery, the groundfish catch during the trials in March was dominated by Pacific cod (73%) with rock sole being the next most common species in the catch by weight. Overall, the objective of testing the device in the cod target fishery was achieved following the difficulties experienced in 2006.

Data collected to measure the effect of the excluder on catches

Catch performance data during the experiment were collected by sea samplers hired specifically for the EFP test. Sea samplers were NMFS-certified fishery observers who were provided additional training to meet the specific data collection needs of this project. The background information on the objectives of the project provided to the sea samplers included objectives of the EFP, the methods employed for the test, the specific data collection methods, and the importance of standardized data collection procedures for the experiment. The additional work placed on sea samplers was mitigated by a requirement that each of the participating vessels hire an additional deck crew member to assist the sea sampler during the EFP with getting lengths for each halibut and tracking catches on a haul by haul basis.

The key focus for data collection was the catch rate of halibut, Pacific cod, and flatfish species. Data to track halibut catch per tow were collected on a tow by tow basis as the crew sorted halibut from groundfish catches each time the net was brought on board. Once this was completed, the remainder of the catch from each tow was dumped into the RSW holding tanks on each vessel and the nets on each vessel were reset. To get overall weight of halibut per tow (the key index of performance), halibut length measurements were collected by the sea samplers. This was done by placing each halibut on a length strip and recording a length on the strip before returning the halibut to the water. The standard IPHC length-to-weight conversions were later used to convert individual halibut lengths into weights.

The effects of the excluder on catch rates for cod and flatfish (other than halibut) were assessed on a trip by trip rather than tow by tow basis. This was done because there was no practical way to collect catch information to assess the effect of the excluder on cod and flatfish catch rates on a tow by tow basis. Our trip by trip assessment of catch per hour of towing of groundfish catch overall and for cod and flatfish specifically was designed to be based on catch amounts of these species per trip once the weight of each species was determined at shoreside processing plants. To allow for shoreside accounting for these species, catches of all groundfish were required to be retained during the experiment. The seas samplers were responsible for oversight of the collection of cod and flatfish weights per trip for each vessel at the shoreside plants to ensure that trip catches between vessels were not mixed.

The catch data collected by shoreside processing plants participating in the EFP included weights of cod catches by size for each separate vessel trip. These data were based on weights of cod grouped into relevant market size categories for cod (small, large). This provided information on the effects of the excluder on cod of different sizes. This information is desirable for assessment of the effects of the excluder on the economics of cod trawling. The effect of the excluder on retention of cod by size is important because escapement of smaller cod was less problematic from a vessel revenue perspective due to lower prices paid for small cod. Our expectation for the test was that smaller cod would escape at a higher rate than larger market-size cod.

Data on cod size was collected in the following manner. At the time of each vessel delivery to the participating processing plants in Kodiak, plant workers sorted the catch to species. The vessel's sea sampler was present during each offload and directed plant workers to randomly divert a sample of the cod of approximately ¾ of a ton (or one standard tote) before the cod were sorted by size. This sample represented approximately one to two percent of the cod catch per vessel delivery during the EFP. The cod were then sorted into the relevant market size categories: small (less than or equal to 21 inches) and large (greater than 21 inches). The cod from the sample in the two market size categories were then weighed separately. In this manner, the proportion by weight of cod in each size category could be compared for vessel pairs for trips with and without the excluder. This allowed us to estimate the loss of cod due to the excluder in terms of the proportional difference relative to the vessel without the excluder.

The effects of the excluder on flatfish catch rates, such as rock sole, was also of interest for several reasons. One reason was that some fishermen pursue cod and flatfish jointly, delivering their catches to processing plants that provide markets for both species. The effects of the excluder on rock sole are therefore a consideration for the economics of fishing for some fishermen. For the most part, however, Gulf of Alaska fishermen target cod as a single species and their cod fishing decisions (where to fish, mesh size) are not likely to be affected by catch rates for rock sole or other flatfish. From an experimental design approach, tracking rock sole catch rates was of interest for evaluating the manner in which the excluder performed. This is because rock sole are considerably smaller relative to the size of halibut typically taken in the cod fishery. For this reason, our expectation was that a very high fraction of rock sole would be able to escape, probably a higher fraction than for halibut escapement. So an additional reason to track the comparative flatfish catch rate effects was done as a check to help evaluate excluder performance against the expectation described above.

Like the effect on cod catch rates, data to track the effect of the excluder on flatfish catches was collected on a trip by trip basis. Size categories for flatfish catches were not tracked because given the relatively small size of flatfish relative to the size of the escapement slots, we expected that even large rock sole would make use of the excluder to escape.

Assessment of handling issues for the excluder

In lieu of a quantitative approach to evaluate the excluder, our assessment of handling issues of the excluder was qualitative and focused on the captain's opinion of such things as how well the device can be rolled onto the net reel. To get this information, a meeting with the four EFP vessels was conducted at the conclusion of the EFP test. The format for the meeting was informal and all four captains were interviewed at the same time. Each was asked to give his personal assessment of the excluder's performance and potential. To help solicit key information, each captain was asked about how putting the excluder on the net reel worked, the resilience of the excluder during the test, an assessment of whether the excluder created handling problems on deck for the crew, and finally whether the excluder was ready for deployment in the regular fishery. If captains reported that the excluder required additional development, the interview was designed to solicit their input on the highest priorities for improvement. Following the informal interviews, captains were then provided the general results from our preliminary analysis of the data on the performance.

Part 2: Results

Catch and bycatch reduction performance results for the EFP test

As was detailed above, the experimental design required data from at least 46 usable pairs of tows to enable our assessment of differences in catch from fishing with and without the excluder to be scientifically rigorous. Recognizing that the experimental design is built around 46 usable pairs of tows, it is important to remember that the experiment was designed to produce statistically significant results only for the pooled data encompassing experimentally paired tows from both sets of vessels. In the tables and analysis below, however, we do look at subsets of the data, (e.g. looking at escapement of halibut for one of the pairs of vessels on trip by trip basis). Examination of subsets of the data is, however, primarily for the purpose of seeing how consistent subsets of the data are with the overall result. This is useful for helping to confirm the results as well as for the eventual development of hypotheses to test in any future research on the excluder.

The first row ("Combined") of Table 2 below reports average performance across the entire data set (both sets of pairs). These results do not include pairs that were dropped due to problems with particular tows (e.g. picking up a lost crab pot). The correct interpretation for the effect of the excluder on halibut catch is that tows with the excluder had 57% less halibut by weight on average than tows without the excluder. At the same time, the overall catch of groundfish measured by the groundfish trip weights delivered to the plant was 39% lower on average for vessel trips with the excluder compared to those without. Because the catch during the EFP was made up primarily of cod, one would expect that most of the escapement is comprised of cod and the data collected at the trip level for catches of cod shows that the trips for vessels with the excluder had 35% less cod (by weight) on average than trips that fished with the unmodified net. Finally, catch of rock sole, the principal flatfish component of the groundfish, by vessels with the excluder had an average of 83% less rock sole by weight than trips that fished without the excluder. This confirms the expectation that rocksole escapement would occur at the highest rate given its smaller size and its flat body shape.

The observed escapement for halibut and rock sole serves to increase our confidence that the expected effect of the excluder was validated in the test. The high level of escapement for cod, however, falls outside of our expectation, as will be discussed below.

Table 2: Escapement rates by species group for the two vessel pairs and combined pairs.

	Halibut	Groundfish Overall (including cod and rocksole)	Cod	Rocksole
Combined	57%	39%	35%	83%
NLTZ*	48%	29%	22%	85%
PSCV**	65%	53%	53%	80%

*New Life/Topaz pair
** Pacific Star/Carvelle pair

To evaluate the consistency of general results for the logical subsets of the data from the experiment, Table 2 also reports vessel-pair specific results for the two pairs of EFP vessels (NLTZ= New Life/ Topaz and PSCV = Pacific Star/ Caravelle). At this level, the data suggest that the same general result for halibut escapement likely occurred for each pair (recalling that these results are not statistically significant). Specifically, the data show that a higher rate of escapement occurred for halibut than the escapement rate for groundfish overall (groundfish overall includes cod, rock sole, and all other groundfish catch that was not halibut). Likewise, for each pair of vessels, it appears that the escapement rate for cod was lower than the escapement rate for halibut.

The magnitude of selectivity ratio, however, appears to be quite different between the pairs. Specifically, the ratio of halibut to cod escapement for the first pair is more than 2 to 1. For the second pair, however, we do not find this same suggestive evidence of fairly promising selectivity. For the second pair, the ratio of halibut to cod escapement is just slightly above 1 to 1. Finally, the rock sole escapement rate appears to be consistent between pairs and nearly the same magnitude for each pair. Once again, this is suggestive evidence that the experimental data are robust and that the experiment seems to have produced a general result that is fairly consistent at the pair-specific level. The one notable difference here is that the halibut to cod escapement ratio appears to differ significantly between the pairs. The selectivity implications of this potential difference will be discussed below.

Effects of the excluder on cod size of the delivered catch

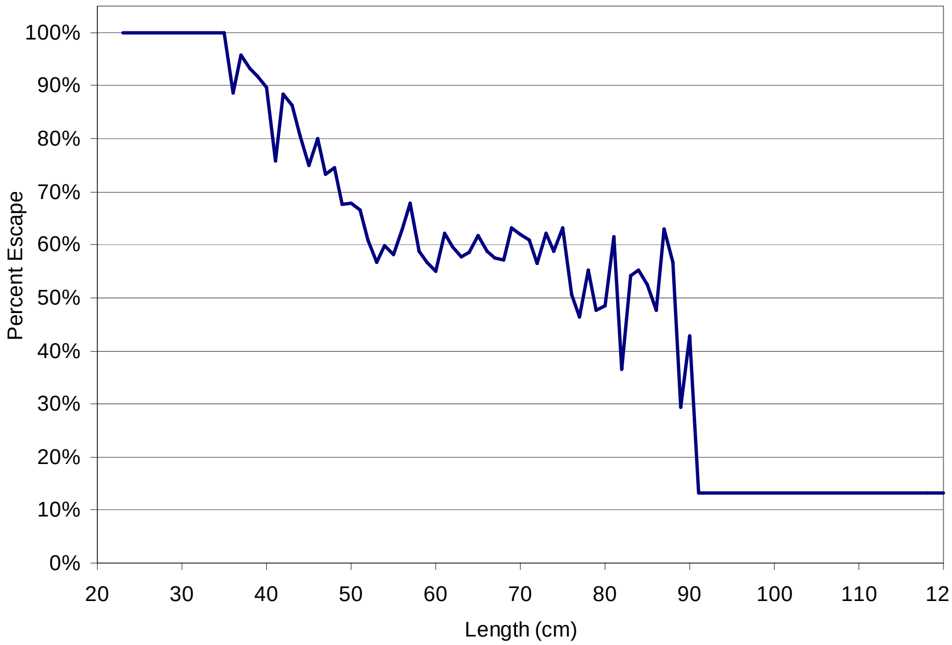
An important question regarding the higher-than-expected cod loss as a result of the excluder is whether a higher proportion of the escaping cod were cod that fall into the small cod market size category (less than 21 inches overall). This is important for two reasons. The revenue effects of the loss of cod would be proportionally lower if cod loss is comprised mostly of small cod. This is because the processors were paying an average of 25% less for small cod compared to large at the time of the experiment. Additionally, the result helps to confirm the validity of the experiment in terms of our initial expectation that if there were cod escapement it would be comprised mostly of small cod. If cod loss was made up mostly of small cod this would help to confirm the soundness of the experimental methods to measure effects that make intuitive sense.

Cod size samples were successfully taken for all but two vessel pair deliveries during the EFP. The occasions where vessel pair deliveries were not sampled for cod size occurred because all the cod had been sorted by the time the plant manager and sea sampler were able to ensure that plant workers collected the cod for size sampling. For the deliveries where sampling did occur, the cod size data do show that cod escapement was primarily of smaller cod. The weight of small cod averaged 63% lower for vessel trips with the excluder relative to vessel trips without. For large cod, vessel trips with the excluder averaged 24% lower weight than trips without the excluder. Considering that the overall weight of cod catch averaged 35% lower for trips with the excluder (combined data result above), the size data indicate that cod escapement was dominated by smaller, less valuable (25% less) cod. But some escapement of cod in the large category apparently did occur and this is puzzling given the large head size of large cod relative to the 2 5/8 height between the slots of the excluder.

Effects of the excluder on halibut size

Halibut length samples were compiled to examine whether halibut escapes were size selective. Figure 6 below indicates that, like cod, smaller halibut escaped at higher rates than larger halibut. Nearly all of those less than 50 cm in length escaped and nearly all of the halibut greater than 90 cm in length were captured (relatively few fish were of that size). Most of the halibut were between these extremes, with escape rates around 50% to 60%, consistent with the overall escape rate.

Figure 6. Halibut escapement rates by length.



Findings from the interview of the captains following the EFP

This section will focus on the result of the interviews on the handling aspects of the gear. Captains were also asked in the interviews if they believed that the excluder was ready for use in the regular fishery and that subject generated a considerable amount of discussion. The captains' responses to the overall performance question will not be reported here but will be discussed in the overall discussion of the findings below.

For the handling issues and resiliency aspects of the excluder, the four captains reported that using the excluder did not create any significant handling problems for their crews. Captains reported that they were able to wind the excluder onto the net reel with no particular difficulty and no safety concerns for their crews. Captains also thought that the construction of the excluder was sufficiently durable overall to make the gear useful for the duration of the regular cod fishing seasons. On this subject, the EFP test was actually of a similar duration to recent spring cod fishing seasons in recent years given the compressed nature of the regular fishery due to the number of boats competing for catches and other factors that drive the pace of the fishery.

One handling/resiliency issue that was raised about the excluder was that some of the vertical lashings between rows of third wire did apparently start to loosen over the course of the experiment. Captains reported this to the project manager during the experiment and it was decided that the test was designed to evaluate the performance of the excluder as it was intended to function, not how well the excluder functioned in "as is" condition throughout the test. For this reason, repairs were made to the excluder during the test as soon as it appeared that some of the slots had changed shape and were allowing considerably more vertical escapement room than the original 2 5/8 inches height and 18 inches length.

In the interviews, the discussion of resiliency focused on how well the slots held their shape and how much maintenance might be required with the third wire excluder as constructed for the test. On this matter, fishermen generally agreed that to make the gear more practical for use in the regular fishery, adjustments in its construction might be needed. This was also the case for the manner in which the two vertical columns of steel trawl floats were tied into the mid section of the excluder. The mesh bags that were used to keep the floats in place required considerable maintenance throughout the experiment. This was reported to be particularly problematic when the net picked up a crab pot or when large skates passed through the narrowed area with the trawl floats.

One captain felt the trawl floats were generally problematic and not necessary to the intended function of the excluder. Testing was not designed to evaluate the escapement with and without the trawl floats. In retrospect, it might have been useful to confirm how much performance may have been affected by the trawl floats as deployed in the experiment. While such a test could not be included in this study, it may be a useful topic for optimizing excluder performance. In any case, some of the underwater video collected during the experiment does appear to indicate that halibut escapement was positively affected by the floats. Video recordings were collected to observe differences in fish behavior in the excluder and the cameras were only placed in the section of the excluder with the floats. The video observations were therefore not designed to evaluate the effect of the trawl floats per se.

One final observation from the interviews at the end of the experiment was that the captains did feel that halibut escapement was significant (without access to the findings from the data). They also noted, however that cod escapement was high enough to be a concern for the practicality of the device.

Of particular interest was a comment by the captain who was clearly the most concerned about the loss of cod. This captain revealed that in his estimation, the cod escapement may not have been attributable to the relative size of the escapement slots or a loosening of the vertical lashings that may have allowed some slots to exceed the specified dimensions before the loosening was observed and maintenance was performed. This captain felt that the loss of cod was actually a reduction in the catch of larger-sized cod. Interestingly, he felt that this escapement of cod was occurring at the mouth of the trawl and his theory here was that the slotted excluder section reduced water flow such that larger cod were able to swim forward in the trawl and out the mouth.

Video collected during the experiment did show some escapement of small cod through the slots of the excluder. Video cameras were used opportunistically during the EFP and thus did not allow us to make any definitive assessment of cod escapement rates of even the size of cod that escaped. But it is interesting that the limited video available from the test does not show any escapement of large cod. Of particular note here is that the limited video observations we have do not appear to show a cod escapement rate that would be commensurate with the cod escapement indicated by catch comparisons. This creates some what of an enigma for how the cod escapement may have occurred.

Video collected during the experiment does show some cod moving forward for at least short bursts in the excluder section. With limited visibility, the camera deployments allowed for observations of only small sections of the excluder. Without video from sections forward of the excluder and with only a limited amount of video overall, we cannot evaluate the likelihood of cod escapement occurring via cod swimming forward in the manner that the captain speculated it had occurred.

Part 3. Discussion of Results and Conclusions:

Overall, the results from the experiment make sense intuitively in terms of the proportional effects of the excluder on fish of different size based on the expectations from the outset. Additionally, the results for each vessel pair, in terms of the general selectivity effects of the excluder (flatfish escapement highest, halibut escapement higher than cod and groundfish overall), were proportionally consistent with our expectations for each set of pairs.

Despite some variability in the results for the different subsets of the data that were examined above, the overall result appears to make intuitive sense and seems to be relatively consistent. This result and the captains' assessment of how well they were able to conduct the paired towing protocol for the EFP suggest that the test was successful in measuring the effects of the excluder on halibut, cod and flatfish catches.

In terms of interpreting how well the excluder creates useful selectivity for the Gulf of Alaska trawl cod fishery, the test data show a much greater escapement rate for cod than was the expectation based on the application of fish size/shape parameters to design the dimensions of the slotted escapement portals built into the excluder. It is also worth noting that halibut escapement for the overall result was considerably higher (57% compared to an expectation of 40%) than the theoretical expectation. Possible explanations for the higher than expected escapement rates could include:

1) Head size/shape relationship used to size the escape openings was incorrect for the fish encountered,
2) Cod and halibut encountered during this study included more small fish than the distributions based on observer data from the two years prior to the experiment, or
3) The rectangular slots of the excluder did not retain the designed dimensions while fishing. Distortion here could be due to water flow given the flexible materials used for construction or possibly due to slippage over time that was not addressed by the repairs that were undertaken by crew members (repairs undertaken when slippage was sufficiently detectable). The flexible materials could also have allowed fish that attempted to escape to spread the cables wider apart than the spacing set at each end of

the openings. Based on the calculations used to select the slot height, the observed escape rates correspond to a slot height about 9% (0.25 inches) larger.

Prior to undertaking any further field trials with the third wire excluder, additional analysis is needed to evaluate some of the above possible explanations for the differences in performance from our expectation. To examine whether the average lengths of halibut and cod were different from the observer data plugged into the selectivity curve, we can explore the data from the control fishing in the experiment. Halibut length data on a tow by tow basis are available for trips where the excluder was not used (controls within the pairs). These can be examined to see if the halibut encountered in the test were of the size that was expected. Data to examine whether the experiment encountered cod of a size that were expected based on the fishery data used to design are more limited. The cod size data from the "control" trips is coarser than what we have for halibut. This is because our sample size for cod (approximately one percent) is much smaller than for halibut and the size data for cod are really only an estimated proportion of cod that are above and below 21 inches (size break for small and large cod). The observer data from the fishery would have to be evaluated as a proportion falling into these two size categories and then compared to the proportion from the EFP. The potential for any of these comparisons of fish size between fishery and EFP data to shed light on this issue would also have to take into account the fact that observer fish length sampling, designed to estimate the size composition of the annual catch, may be much less accurate when applied to a given fishery at a particular time of year.

Data from the experiment are not available to explore whether the excluder held its shape sufficiently well to limit the escapement opportunity to a 2 5/8 by 18 inch slots over the 8 meter surface on both sides of the excluder. This is because we did not take periodic measurements over the course of the experiment of the vertical and horizontal distance between the third wire tied together to form the slots. Doing this might have allowed us to gauge whether changes of some sort (slippage and stretching) occurred during the course of the test. Sampling of slots to measure would have, however, been exceedingly difficult given that the size distortions that were detected by crew (and repaired) tended to be large in some areas and non-evident in others. A sampling design for detecting slippage would have been challenging because areas with visually detectable size distortions were few and far between and there were hundreds of slots in each excluder. In any case, testing of the excluders built for the EFP could be done retroactively if this is deemed to be of sufficient priority. Fishermen are likely willing to make more tows with the excluder during the regular cod fishery, assuming a plan to sample for and monitor size changes for the slots can be devised. There may be automated technology available to test for slippage and distortion as well.

The parameters of the selectivity curve can be examined to see if they still apply. The logical expectation is that the selectivity curve is correct given that the same selectivity curve was used for other work on rigid cod excluders in the Bering Sea and the results from those tests showed the expected halibut escapement and cod escapement in the range of what was expected. This nonetheless is a logical area of focus for solving the mystery of the cod loss. Additionally, there is some evidence from the IPHC research of a change in size at age for halibut in the Gulf of Alaska. This suggests that our length to thickness relationship could benefit from updating because the collection of fish for measuring the relationships occurred in the mid 1990s.

The possibility that the flexible materials from which the excluder was constructed allowed for higher cod (and halibut) escapement than was expected seems to be a plausible explanation for the overall escapement results from the test. The video obtained during the test does show the third wire slots expanding in the center as cod push up against the slots. Video observations were collected on the different EFP vessels as the EFP field project manager rotated between vessels fishing with the excluder. A thorough examination of all the video obtained during the test does not, however, show any large quantities of cod escaping. But the video from the test only covers a small portion of the fishing. This is because there was a single person in the field deploying the camera, the camera was only deployed when visibility was expected to be high enough to collect useful footage, and not every deployment was successful in terms of the operation of the camera. Overall, approximately 4 hours of useful video was obtained during the EFP and this is a relatively small fraction of the total of approximately 180 fishing hours for the vessels using the excluder (2 percent).

Additionally, the tows where the video allows for a reasonable assessment of escapement are daytime tows in the 40-60 fathoms depth zone in areas with good visibility. It is plausible that cod escapement under those conditions may have differed from times when fishing occurred under poor video conditions. Recall that the video was designed to learn about fish behavior and possibly supplement our understanding of the data from the experiment - the video was not intended to measure escapement rates.

Regarding the overall utility of the third wire excluder exactly as it was tested in the EFP, the cod escapement rate (35% overall) likely makes the device impractical for use in the regular fishery. This assumption is consistent with the opinions expressed by the captains at the conclusion of the experiment before they learned of our actual experimental results. Interestingly, two of the four captains were willing to hazard a guess at the halibut and cod escapement rates and their guesses were on the high side relative to the escapement rate we found for halibut and on the low side for the escapement rate we found for cod. That their estimate of cod escapement was low may have resulted from their viewing the effect in terms of the cod revenues per trip. The lower price for small cod and the proportionally larger loss of small cod may have mitigated the perceived effect of the excluder on cod catches.

Looking at the suggestive evidence from the pair-specific data from the test, the case for possible differences in overall selectivity between the pairs of vessels merits further consideration. While not definitive, the breakout between the first pair of vessels and the second suggests that the overall selectivity might have been considerably better on the first pair compared to the second. Specifically, if cod escapement was in fact as high as 53% for the second pair (PS/CV), then this suggests that the excluder may be a long way from being practical even with the presumed higher relative rate of escapement of halibut (65%) for that pair. For the NL/TZ pair, however, the rate of halibut escapement was estimated to be more than twice the rate of cod escapement. This is at least suggestive evidence that effective selectivity occurred for that pair. At the same time, the cod loss rate (22%) that the data suggests may have occurred for the NL/TZ pair is still fairly high but at least closer to the range of loss rates of target species found in other studies of bycatch reduction devices that have been made to work in other fisheries. Once again, these suggestive performance differences between pairs of vessels are not statistically significant but are interesting for future tests that may be designed to look at vessel-specific performance differences or identification of covariates that explain differences in performance.

The available evidence of a difference in selectivity between the two pairs of vessels also brings into question the leading explanation that the flexible materials used to construct the excluder allowed for higher escapement rates than were expected, especially for cod. This is because the excluders used by each pair of vessels were built from the same flexible materials and the dimensions and construction were the same. So one could expect that cod escapement would be similar between the two pairs of EFP vessels. But once again, the test was not designed to provide comparisons in escapement rates between the pairs so the difference in average selectivity performance may not be real. Also, the pairs of vessels did, at times, fish in different areas. This was done because cod fishing was not consistent over the EFP test and, at times, there was insufficient cod fishing in an area to sustain four vessels fishing on what amounted to a small school of cod.

While the overall performance of the excluder as measured in the test was disappointing in terms cod loss rate, if the cod loss was due to the flexibility of the third wire slotted excluder, then there may be ways to address this issue. Because rigid excluders cannot be rolled up onto net reels without damage, a workable solution may be to use materials that are more rigid than the third wire used for the test but still flexible enough to allow for the handling constraints on Gulf of Alaska cod trawlers. One approach may be to explore the new set of rubberized plastic grates or even rubberized frames used to make slots with third wire cable for stiffer slot pieces for the side panel grates. Another possibility may be to look into the availability of coaxial (third wire) cable of a larger diameter than the standard third wire cable used for headrope sounders. The costs associated with these two approaches are not known but would be expected to be higher than those associated with the use of scrap third wire from net sounders.

Examples of grates constructed of pliable plastics mounted inside rubberized frames are available from some gear manufacturers. These were constructed outside the United States and the costs of such grates may be prohibitive assuming a similar surface area requirement. Existing examples of flexible plastic grates also do not correspond to the dimensions of the slots used for this test so a custom manufacturing run would likely be needed. Cost saving might be obtained, however, if several fishermen ordered plastic grates at the same time.

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