Bering Sea Salmon Excluder EFP 15-01 Final Report

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Summary:

EFP 15-01 set out to test an "over and under" (O/U) style salmon excluder in the Bering Sea Pollock fishery. The impetus to focus on this particular excluder was that it achieved 33%-54% escapement for Chinook salmon with 1-9% Pollock escapement in the Central Gulf of Alaska (GOA) EFP during trials in 2013 and 2014. With escapement portals on the top and bottom of the net, this new excluder has been largely embraced as the excluder to use by GOA Pollock captains and many feel it provides advantages over other designs in terms of adaptability into GOA Pollock nets and lower need for tuning to achieve the desired shape at normal towing speeds.

The main question for EFP 15-01 was whether the differences in towing power/speed of Bering Sea Pollock vessels or other factors would affect the escapement performance. Given that performance of other excluder designs has tended to vary by vessel size, EFP 15-01's testing was purposely divided between three classes of Bering Sea pollock vessels, a smaller class catcher vessel at under 1,800 HP, a larger class catcher vessel in the 1,800 to 3,000 HP range, and a catcher processor vessel.

The testing spanned 2015 A season, 2015 B season and 2016 A season (February 2015 – March 2016). Vessels selected were F/V Commodore (133 feet, 1,700 hp), the F/V Destination (180 feet, 3,000 hp), and the F/T Northern Jaeger (336 feet, 7,200 hp). Escapement rates of salmon and pollock were generated from video observations of fish escapes. Whereas overall pollock escapement was negligible (0.5-2.2%), salmon escapement rates ranged from 3-18% across the three vessels. Overall, salmon escapement rates were considerably lower than hoped relative to GOA EFP results and even some previous Bering Sea salmon excluder EFP's using older excluder styles (flapper versions). Even more enigmatic was the finding that performance results did not follow expectations based on horsepower and towing differences between Bering Sea vessels in the EFP as well.

Reasons for the poor performance are not obvious but could be a combination of factors including tow speed, horse power, door size and spread, bridle rigging, mesh opening, fishing behavior, excluder shape (achievement of sufficiently large pathways for salmon to move out of the flow of Pollock and move forward to escapement portals). Differences in Pollock catch rates and flow of fish through the net that may create congestion and difficulty for salmon to find/utilize the escapement pathways may also be important for explaining the differences between GOA and Bering Sea results.

Future salmon excluder research should incorporate the use of sensors to accurately monitor and record previously unmonitored variables such as speed over ground in step with actual timing of escapements, size/shape of the escapement portals and available to access them, and relative amount of "congestion" in the net over the course of a haul. Scaling the excluder that worked best in the GOA trials to the Bering Sea fishery appears to have not worked for this round of trials, but existing BSAI salmon excluder designs, most notably the flapper excluder currently used by many Bering Sea Pollock vessels took considerable time and multiple trials to develop and refine. Achievement of high rates of Chinook

escapement similar to those in the GOA may still be possible with the O/U excluder in the Bering Sea. Steps needed to definitively resolve the differences in performance are outlined in our report.

Evolution of salmon excluders leading up to EFP 15-01

EFP 15-01 is the latest in a suite of exempted fishing permits (EFP's) issued to North Pacific Fisheries Research Foundation (NPFRF) (John Gauvin as principle investigator) to explore ways to reduce salmon bycatch through gear modification. EFP 15-01 included three field testing seasons in the Bering Sea pollock fishery from January 2015 to March 2016, two occurring in winter/spring months when Chinook is normally the predominant salmon bycatch species and one in fall of 2015 when chum (non-Chinook) is the primary salmon bycatch species.

This section provides relevant information on NPFRF's work on salmon excluders to provide context for understanding the specific focus and outcomes for EFP 15-01. The information provided in this section was pulled from previous EFP final reports (these reports can be found at http://alaskafisheries.noaa.gov/ram/efp.htm and www.npfrf.org).

The development of salmon excluders started in 2003 via the NPFRF's partnership with Dr. Craig Rose of the Alaska Fisheries Science Center (AFSC), now retired, and Carwyn Hammond (AFSC, RACE Division). At each step in the development of salmon excluders, significant contributions of time and resources have been made by Dr. Rose and Carwyn Hammond, many pollock fishermen, pollock companies, and net manufacturers.

Early research with video cameras deployed in unmodified pollock nets showed significant differences in swimming ability and behavior between salmon and pollock, most notably the salmon's ability to swim forward inside the net at normal towing speeds. By comparison, pollock were most often seen dropping steadily backwards even if they can at times make short bursts forward against the flow. Taking this into consideration, the concept behind a salmon excluder was to create an area out of the main flow of pollock through the net with a little slower water speed (a lee) where salmon can rest and eventually move forward via an escapement pathway and escapement portal. This should occur with salmon escaping without any significant contact with the excluder.

Fishermen were at first concerned that modifications to pollock nets for salmon excluders, particularly large escapement portals, could not be installed without high losses of pollock and other problems with reducing water flow in the net. In fact, seeing the large size of escapement holes in the first excluder prototypes fueled considerable consternation. But the desire to look at excluders was still strong with fishermen recognizing the need for additional tools to control salmon bycatch.

The process to come up with designs for salmon excluders started with ideas from fishermen and net manufacturers discussed at workshops held by NPFRF. Vetted ideas were later transferred to formal drawings and scale models that fishermen and gear makers could examine. From this process input was solicited as to which ones were worth trying in field tests. Following that, a single season of fairly limited field trials under the first EFP was done in fall of 2003 and then a second set of workshops was held to discuss the preliminary results.

NPFRF's first field test in the fall of 2003 showed salmon escapement rates of just over 12% with pollock loss around 3%. This was an unexpected result and when these preliminary results were reported many fishermen suspected that the pollock escapement rate would have been much higher if a recapture net had not been used in the testing (a recapture net was used to collect fish that escaped from the net so escapement could be quantified). This stemmed from their thought that as the codend of the recapture net filled, lift from the kites used to separate the recap net from the trawl intermediate was lost. The eventual result was, they suspected, that the pathway for escapement was blocked and hence pollock escapement had been underestimated. NPFRF took this possibility seriously and undertook considerable work to examine it. In the end the concern was shown to be unwarranted but a related issue fishermen flagged in this process about a recapture net affecting fish behavior (e.g. are escapement rates accurately determined if escaping fish can see a recapture net in the process of attempting to escape?) was deemed to be more important and this was fundamental in NPFRF's ultimate decision to use video cameras to track escapement in lieu of recapture nets.

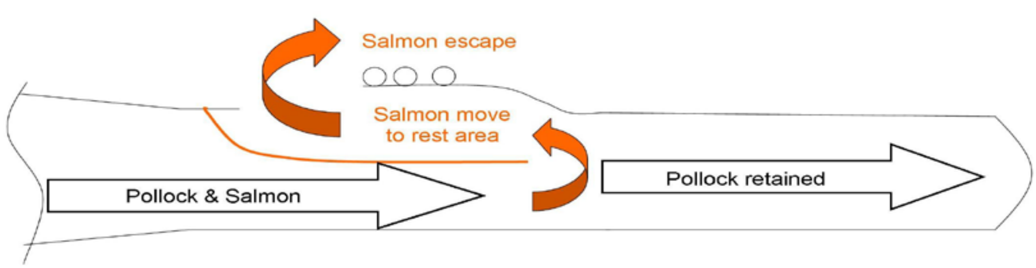
NPFRF's switch to tracking escapement with video alone, almost a decade later, was made possible by improvements in the capacity and reliability of the camera systems so that deployments could be done without putting limitations on fishing practices. The new systems were smaller, therefore creating lower drag and effects on the shape of the net where the camera(s) were installed. Also, advances in batteries and data storage capacity enabled the new systems to be operational for the duration of a normal commercial fishing haul. Improvements to salmon excluders in terms of reductions in pollock escapement with successive excluder designs were also instrumental to NPFRF's ability to switch to cameras for escapement accounting. Specifically, with relatively high pollock escapement early on, accounting with cameras would have been nearly impossible due to the sheer volume of pollock escapement and the challenges for counting individual fish escapes. Large volumes of pollock escapement also affect accounting for salmon escapes due to the increased potential that salmon escapes would be obscured by "clouds" of escaping pollock.

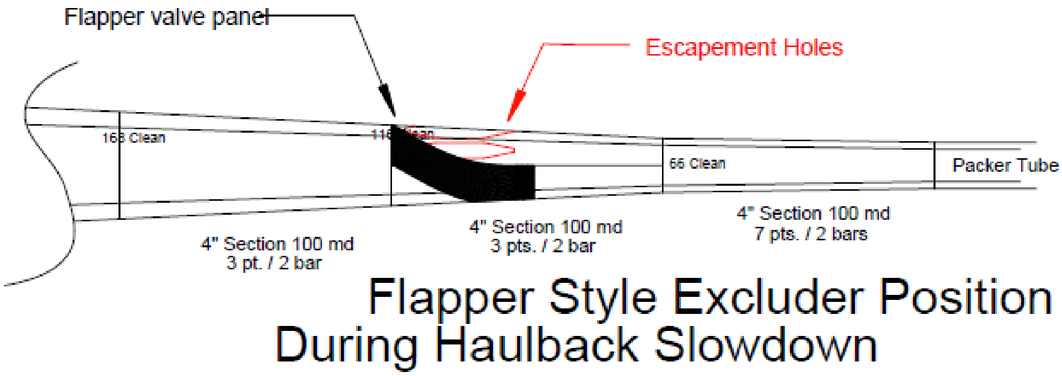
<u>Status of salmon escapement rates leading into EFP 15-01</u>

The two most relevant salmon excluder EFPs as context for EFP 15-01, were EFP 11-01 (2011/2012), the last Bering Sea EFP before 15-01, and the Gulf of Alaska EFP 13-01 (2013/2014). Progress on devices used and escapement rates in those EFP's are the most relevant baseline for understanding both the NPFRF's selection of excluder designs for this EFP and performance expectations so some details from those tests are provided here.

Bering Sea EFP 11-01 results showed mean escapement rates for Chinook salmon in the range of 12%-38%. This EFP tested the "flapper excluder" design, an excluder that uses a weighted panel to control access to a large escapement portal at the top of the net. For that design, lead line weighting on the "flapper" panel of webbing is added to the point where escapement pathway is open and sufficiently large for salmon to make use of it at the vessel's normal towing speed. When the vessel slows down to make a turn or hauls the net back, any salmon or pollock moving forward are directed up to the escapement portal because the weighted panel "ramps" fish moving forward up to the escapement area (Figure 1).

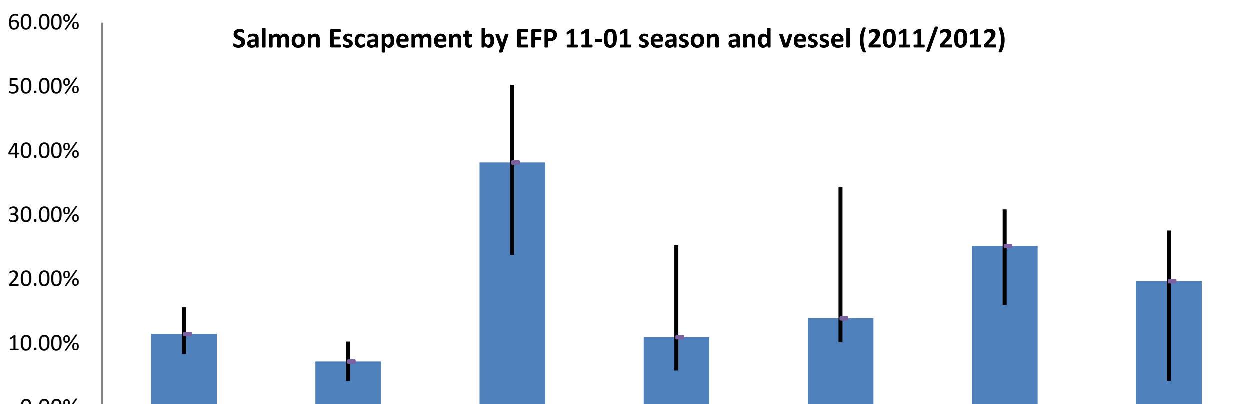
Figure 1. Bering Sea flapper style salmon excluder schematic.





While results with the flapper excluder were encouraging, a concern from tests done in EFP 11-01 was that Chinook escapement rates were quite variable on a tow-by-tow basis within individual seasonal tests. This is evident from the relatively wide confidence intervals around the mean escapement rates shown in Figure 2. This variability in performance raised questions about what factors/conditions might explain excluder performance differences between tows within a seasonal test and for trials on different vessels. An analysis of covariates was undertaken to explore this but it did not elucidate the issue to any great extent.

Figure 2. (Excerpted from EFP 11-01) Percent salmon escapement with 95% confidence by EFP field season and vessel with salmon species of interest (Chinook or chum)



	SB11BChum1	SB11BChum2	SB11BChn	SB12AChn	Dest12AChn	Dest12BSalm	Prince12BSalm
Mean	11.50%	7.20%	38.20%	11.00%	13.90%	25.20%	19.70%
Upper	15.30%	10.00%	50.00%	25.00%	34.00%	30.60%	27.30%
Lower	8.70%	4.50%	24.10%	6.10%	10.50%	16.30%	4.50%
Mean	11.50%	7.20%	38.20%	11.00%	13.90%	25.20%	19.70%

The improved escapement seen in EFP 11-01 for Chinook salmon on the Starbound (see result for SB 11B Chn) was viewed as a step forward in terms of having a workable excluder for Chinook salmon by many pollock fishermen in the Bering Sea despite the fairly large confidence interval around that result. At the same time, chum salmon escapement rates with the flapper excluder clearly trailed behind (results pertaining to chum salmon with the flapper excluder are SB 11B Chum1, SB 11 B Chum2). In that respect, the most pressing issue for the field testing seasons on the back end of EFP 11-01 was to attempt to come up something that would be more effective for chums.

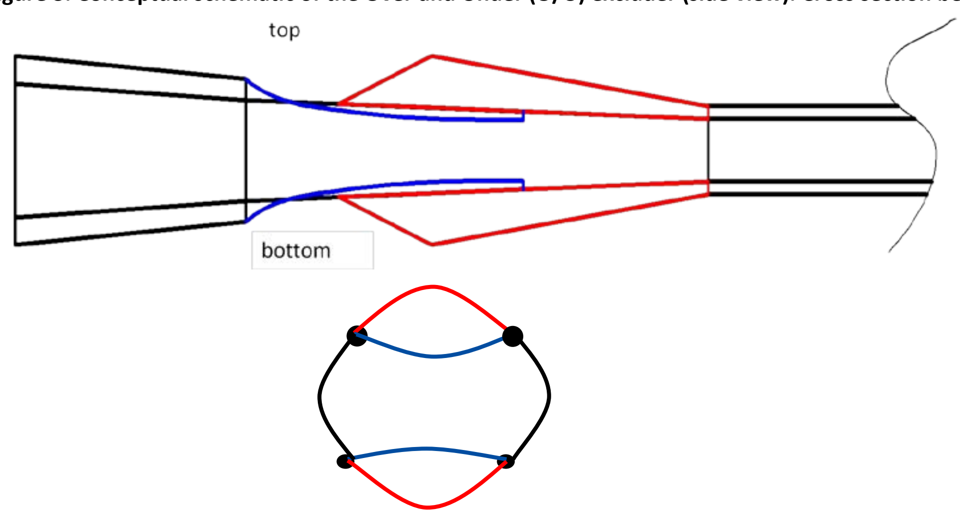
To focus on chum salmon escapement, the last phase of testing in EFP 11-01 in 2012 looked at two new approaches. The first was the use of artificial lights to increase salmon escapement. This idea came from video observations of chum salmon from earlier testing where they appeared to be attracted to camera lights and at times remained near them for extended periods of time.

Adding light to attract chums to swim out of the excluder, however, proved to be more challenging than expected. One issue was the inability to contain the light in the locations where lights were installed. In fact the illumination tended to bleed down into portions of the net intermediate ahead of the excluder where escapement was actually not possible. If chum salmon were attracted to locations where escapement is not actually possible, then adding light may actually be counter-productive. Experimentation with lighting was reassessed at this point in recognition of the complexity of evaluation its effects on escapement.

The second focus for increasing chum escapement was to design a completely new excluder style that would allow escapement out of both the top and bottom of the net. The idea came from talking to salmon seiners who believed that chum behavior in response to a net was to dive rather than swim up to escape. With this information, John Gruver, NPFRF's excluder designer, came up with a new design called the "over and under" or O/U. The O/U uses a weighted panel on the top and a floated panel on the bottom to "corral" fish into the center of the net as they move through the intermediate. This creates a lee behind each panel of the excluder and an area for salmon to get out of the flow of pollock. This set up is designed to give salmon an opportunity to use one of two escapement pathways built into the net; one on the bottom with a weighted scoop and one at th

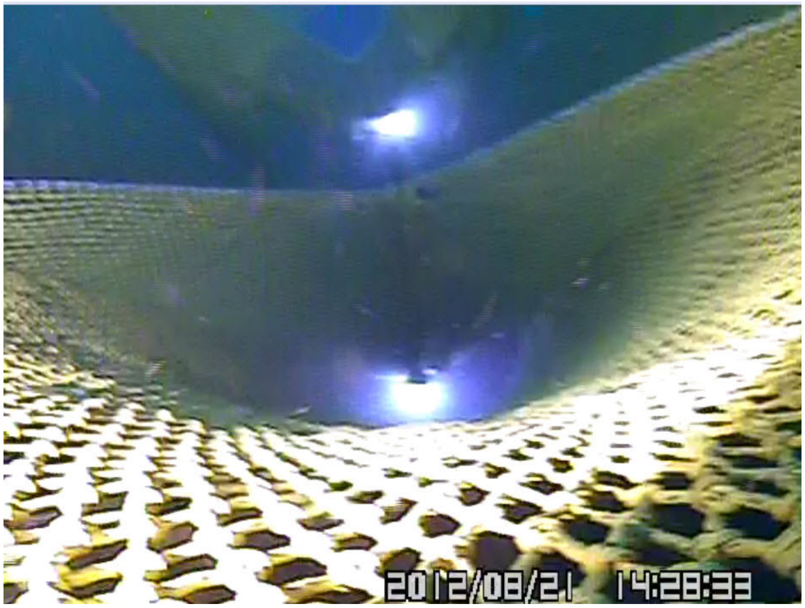
e top with a floated hood (Figure 3).

Figure 3. Conceptual schematic of the Over and Under (O/U) excluder (side view). Cross section below.



The final field season of EFP 11-01 in fall of 2012 focused on a Beta version of the O/U excluder installed on two of the Bering Sea test vessels. Fortuitously, pre-EFP tows showed the early version of the O/U closely achieved the desired shape with minimal adjustment needed. Under full towing speed with a closed codend during the EFP fishing, however, the degree to which the weight and floatation corralled fish into the center was less than desired amount of clearance, particularly at the bottom escapement portals (Figure 4). Despite this, the fall 2012 trials of the O/U did show that chum salmon escapement rates improved relative to previous trials. Those specific results are labeled in Figure 2 for chum as "Dest12B Salmon" and "Prince 12 B Salmon".

Figure 4. Beta version of the O/U excluder, Pacific Prince 2012 B season. View is from aft of the excluder looking forward.



Once again, however, relatively high variability in escapement rates from tow to tow meant that performance was not very consistent. Also, mean chum salmon escapement still lagged well behind what was achieved for Chinook salmon with the flapper excluder.

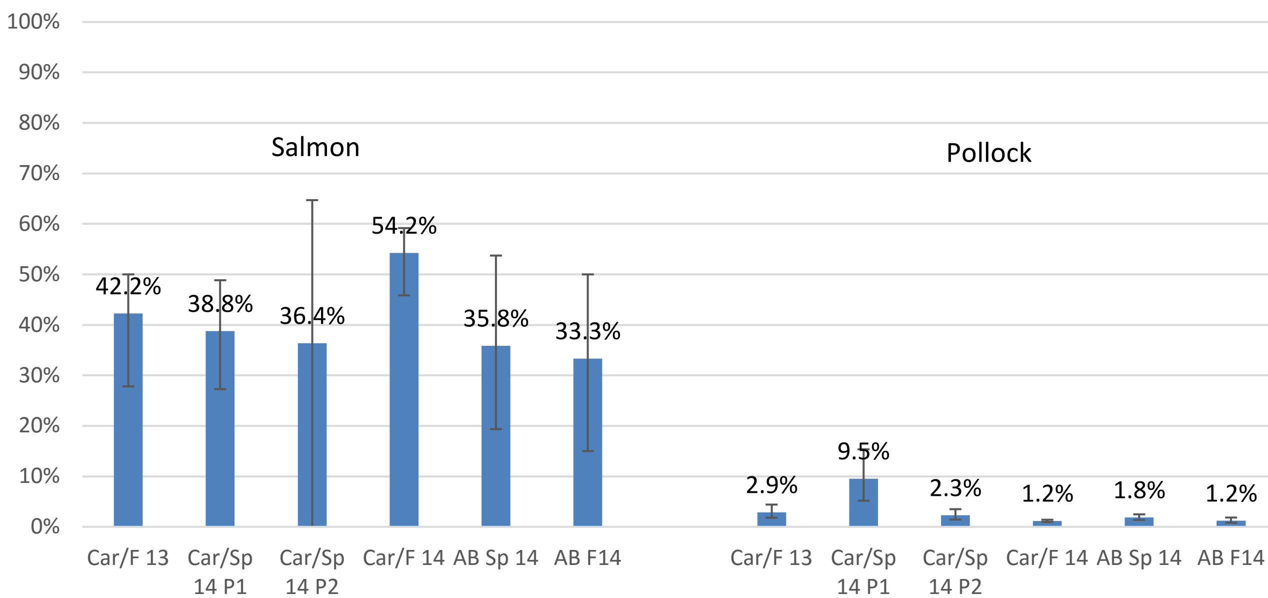
Following EFP 11-01, NPFRF's attention shifted to salmon bycatch in the Gulf of Alaska given the recently implemented Chinook salmon bycatch caps in that management area. Initial work in the GOA started with a trial of the flapper excluder adapted to the size/scale of central GOA pollock boats. But after the initial trials of a flapper in the GOA showed poor performance, work soon shifted to an O/U style excluder. The main challenge with flappers in the GOA was achieving the correct shape at towing speeds on lower horsepower vessels.

The Gulf EFP results for the O/U design showed high Chinook escapement (33-54%), the main salmon species of concern for bycatch in the GOA pollock fishery. Figure 5 shows the mean escapement rates and associated confidence intervals for Chinook salmon and pollock in GOA field trials using the O/U excluder in 2013 and 2014.

Each stage of testing looked at slightly different versions of the O/U style excluders on each GOA pollock vessels (one in the 800 HP, one at 1,300 HP categories). Each adjustment was tailored to bringing the shape of the excluder closer to where the floated and weighted panels come fairly close together in the center at normal towing speeds. This maximized the room salmon would have to move out of the flow of pollock so they could make use of the escapement pathways on the top and bottom of the O/U excluder.

As can be seen from Figure 5, average rates of escapement with the O/U were generally higher than rates seen in the Bering Sea (for Chinook and chum). For fall 2014 the trial on the F/V Caravelle in particular, the escapement rate was 54% and not only was Chinook escapement at an all-time high but performance was consistent over the course of the tests so confidence intervals were relatively tight. This success set a whole new expectation for what was achievable with salmon excluders. The Caravelle's fall 2014 results were also notable because a relatively high number of salmon were encountered in the test. This helped the GOA captains to believe in the result. Finally, the rather low loss rate for pollock, a little over one percent, was also very encouraging.

Figure 5. Salmon and pollock escape rates using the over/under style salmon excluder: by EFP leg/vessel with 95% CI boundaries. P1 = Phase I, P2 = Phase II. (Excerpted from EFP 13-01 final report)



The GOA results constituted a major performance milestone relative to what had been achieved in the past. Due to the time needed to establish results from video review and the lead time needed to get an EFP application through the NMFS approval process, results from the final season of the GOA EFP actually came to light after the application for a new Bering Sea (EFP 15-01) had been submitted to the NMFS Alaska Region. With the Caravelle's fall 2014 results, however, it became clear to NPFRF that a course correction was merited in the selection of an excluder for the next stage of testing in the Bering Sea. Further work with adding light to the excluder was not as important as seeing if the O/U could reduce Chinook bycatch by similar amounts in the BSAI. The new plan was to test an excluder that mirrored the one tested in the fall of 2014 on the Caravelle but scaled to the nets/vessels of the Bering Sea pollock fishery.

Objectives of EFP 15-01

When originally proposed, EFP 15-01 set out to refocus on the relatively lower escapement rates for chum salmon bycatch in the Bering Sea seen in the last Bering Sea EFP (11-01). This would be done through adding lighting and further design changes to the flapper or version one of the O/U excluder tested in the Bering Sea in 2012. To focus on chum salmon, the original application requested that two of the three field seasons (fall of 2014 and 2015) occur when chum bycatch would be expected to be the predominant bycatch species.

As it turned out, agency consultations concerning marine mammals in the EFP review process took longer than expected and the original application for 15-01 was still under review during the fall of 2014 when the results from the final GOA salmon excluder trials became available. This prompted NPFRF to request the opportunity to make changes to the application. The new plan was to have two field seasons focusing on Chinook salmon in winter/spring (2015 and 2016) and one fall season focusing on chum salmon escapement, also using an O/U.

In looking back at NPFRF's discussions prior to EFP 15-01 it is clear that NPFRF was realistic about the chances of duplicating the Caravelle's GOA performance from fall 2014 in the Bering Sea. This is because getting the floated and weighted panels of the excluder to come together as they did in the GOA was recognized as a challenge. Specifically, horsepower ratings for the GOA vessels were 800 and 1,300 HP and towing speeds in the range of 2.5 to 3.0 knots in the GOA pollock fishery. This is different from Bering Sea pollock vessels that tow at speeds ranging from 3.0 to 4.2 knots, with average speeds closer to four knots than three. Also, net spread is greater in the Bering Sea with more efficient trawl doors and larger horsepower boats. This affects the degree that trawl net meshes open, the size of the intermediate portion of the net, and the flow of water through the net. Overall, NPFRF was aware that adapting the O/U excluder to the Bering Sea vessels would be challenging but at the same time certainly worth all the effort if that excluder could achieve results similar to the GOA trials on Caravelle.

EFP 15-01 RFP and Methods

Recognizing that EFP tests have consistently shown significant differences in performance of excluders by vessel size classes, there was every reason to believe that this would be the case with the O/U excluder. For this reason, NPFRF's testing plan included a representation of the main vessel sizes/horsepower classes for Bering Sea pollock fishery including a catcher vessel with around 1,800 HP (the smaller vessel class for the Bering Sea), a larger catcher vessel with horsepower of between 1,800 and 3,000 HP, and a pollock catcher processor in the 3,000 HP to 7,000 HP range. To do this, NPFRF drafted a request for proposals (RFP) soliciting applications to participate in the EFP in each of the three vessel classes.

The EFP allowed for a total of 7,500 metric tons of groundfish harvest over the three testing seasons from January 2015 through April 2016. The seasonal guideline amount of 2,500 mt of groundfish was divided into 900, 900, and 700 mt for the CP, large CV and smaller CV vessel categories respectively. Average tow amounts for the three vessel categories was used to establish these divisions with an objective of getting at least 10 test tows per testing season per vessel class category.

EFP 15-01 requested salmon allowances for the EFP based on catch rates in the regular pollock fishery in areas with relatively high bycatch rates. The rates used for the EFP application pertained to 2012-2014, the most recent years at the time the EFP application was drafted. NPFRF recognized , however that annual variability in salmon bycatch rates occurs and therefore there was no way to guarantee that the requested EFP allowances for Chinook and chum would be adequate to allow the EFP testing to consistently occur in areas of relatively high abundance of salmon. The stated objective for selecting testing locations during the EFP was areas with representative (average) pollock catch rates and relatively high salmon bycatch rates to help ensure the results were meaningful.

The seasonal salmon limits were divided pro-rata among the EFP vessels based on the vessel's groundfish allowances for the EFP: 600, 250, and 600 Chinook salmon were allocated for 2015 A season, 2015 B Season , and 2016 A Season respectively so these limits were divided pro rata among the vessels. For chum salmon, the limits across the same seasons were 250, 2,500, and 250 respectively.

To engage interested pollock vessel owners to apply to participate in the EFP and inform them of EFP responsibilities and catch opportunities, NPFRF's RFP described amounts of groundfish available to EFP participant and seasonal limits on salmon bycatch. The RFP also included an explanation of the objectives of the EFP, and a description of the testing protocol that participants would need to follow, and other pertinent details. The RFP was sent out to different sectors of the pollock fishery in October of 2014.

A panel of experts from the Alaska Fishery Science Center's Resource Assessment and Conservation Engineering division reviewed the applications received in response to the RFP. The panel possessed decades of experience with selection of vessels for NMFS' charters and previous EFPs for the salmon excluder and other EFPs dealing with tests of gear modifications.

Nine applications were received, two in the CP category and five applications split between the catcher vessel categories with some applications on the cusp between vessel categories. RACE's application review panel conducted their review in December of 2014 and ranked the applications. The top-ranked application in the lower horsepower category for catcher vessels was the F/V Commodore, at 133 ft and 1,700 hp. For the larger catcher vessel, the 180 ft and 3,000 HP Destination was selected. For the catcher processor, the 336 ft and 7,200 HP F/T Northern Jaeger was the top ranked vessel. With the selections in hand, NPFRF started to work with the top-ranked applicants to arrange for how to get the excluder built and shipped up to Dutch Harbor as well timing for NPFRF's project manager and the sea samplers to board and disembark each vessel during the first testing season.

In the process of making these arrangements, the CP Northern Jaeger flagged an interest in conducting the excluder test over an entire trip (approximately 25 tows) instead of just the 10 or so that the EFP groundfish allotment would provide. Their rationale for this was that it would make the test more robust. From the Northern Jaeger's perspective there were benefits in terms of cost savings from avoiding the fuel costs and down time needed to bring the EFP personnel back to the Dutch Harbor in the middle of a fishing trip when the EFP fish had been caught. An allowance to incorporate the EFP into a regular American Fisheries Act (AFA) trip was made in the permit for catch-processor vessels because they have a certified flow scale, two full time fishery observers, and a catch accounting system that does final catch accounting at sea. According to the permit, this would have to be done without mixing EFP and AFA catches in the same calendar day to simplify catch accounting. Abiding by that rule was not a problem for the Northern Jaeger. This combined EFP/AFA testing regime took place in the B season 2015 and A season 2016 (no AFA fishing A season 2015).

For each of the three 15-01 EFP vessels, the plan was for NPFRF to provide an O/U excluder for the test based on the one tested in fall of 2014 on Caravelle in the GOA. Each excluder would be scaled and custom built to the EFP vessel's relative horsepower and net size. The photo below (Figure 6) taken during the fall of 2014 testing on Caravelle, shows the excluder shape during normal towing speed. Note how the floated and weighted panels in the excluder come close together in the center, maximizing the area used for escapement. A salmon in the process of moving forward to escape is shown in the photo.

Figure 6. O/U Salmon excluder at depth on the Caravelle, GOA EFP 13-01. The camera is looking forward towards the mouth of the net and a salmon is seen swimming forward to escape out of one of the escape portals.

At the start of each Bering Sea EFP 15-01 test, a set of pre-test tows in mid-water (not in fish sign) were made to examine how well the shape achieved the desired parameters. Adjustments (e.g. adding floatation or leadline) were made as needed to allow the upper and lower excluder panels to come together as closely as possible at the vessel's normal towing speeds. Once the shaping was confirmed, the vessel commenced with the EFP tows.

Prior to setting the net into fish sign at the start of EFP fishing, cameras were placed in selected locations close to the egress point in the excluders scoop or hood. This was the optimal location for recording escapements of salmon and pollock. With the O/U excluder, there are two escapement locations to monitor, one at the top and one at the bottom. Whenever possible, two cameras would be placed at <u>each</u> escapement portal. This would help avoid missed data if one camera failed to record or if one of the camera views became blocked by pollock or other matter (jellyfish, kelp). While two cameras per escapement location was the desired plan, based on experience in previous EFPs we knew that camera breakdowns might force us at times to rely on a single camera per location even if each NPFRF project manager had a back-up system. For each tow, NPFRF personnel installed fresh batteries before the net was reset. In between tows, NPFRF personnel would do a quick review of the video to ensure that the cameras were placed and recording properly.

The data collection plan to account for the salmon and pollock in the net (what did not escape) was fairly standard relative to accounting for salmon catches on a tow by tow basis is used in normal AFA sector. For the two EFP vessels with flow scales, catch from each haul was weighed on the vessel's scale as it entered the processing area. Sea samplers working for the EFP would conduct species composition sampling which would be used to estimate the fraction of pollock in the overall weight of allocated species per haul. All salmon that did not escape were accounted for by crew as per normal AFA accounting procedures.   Sea samplers measured all salmon and a sample of pollock to allow sufficient data to characterize pollock escapement on a per-haul or daily basis. Sea samplers also collected genetic samples from salmon under a data collection protocol designed specifically for the EFP by Dr. Jeff Guyon of the Auke Bay Laboratory of the AFSC. Genetic sampling of salmon was an add-on project for the EFP and all samples were forwarded to Dr. Guyon.

Because the catcher vessel Commodore, the vessel in the lower horsepower category, did not have a motion compensated flow scale, catch of groundfish per haul were estimated through a "dump box" bin accounting approach. Commonly used in the Gulf of Alaska, this process involves running the contents of each codend onto a conveyor belt that fills a bin of known weight to a designated fill line. The weight for the bin at the fill line was established at the processing plant prior to starting EFP fishing. The number of filled bins was tallied to estimate the weight of groundfish catch per haul.

Data collected by the sea samplers were monitored by the EFP project manager to ensure that the area selected for testing (normally a designated hot-spot under the rolling hotspot system used in the pollock fishery during the regular fishery) in fact possessed relatively high numbers of salmon per ton of groundfish. In addition to checking the number of salmon in the haul based on the codend count, a quick review of the video by the project manager was also done to provide an indication of whether there was sufficient salmon in the area. This was necessary because when an excluder is working well, the number of salmon in the codend may not be a good indicator of salmon encounter rates.

Upon completion of the testing, the video was reviewed by the NPFRF project managers. In cases where very large numbers of video hours were collected, and particularly for the case of an entire trip on the CP vessel, it was recognized that review of the data would likely take months. In this case, the project manager hired and trained auxiliary video reviewers to assist in the review to avoid long delays in getting the results.

One final detail of importance for understanding the testing plan was that it was recognized at the outset that small adjustments to the excluders would be necessary during the second and third seasons of the EFP. Readers interested in the specifics of these adjustments should refer to the NPFRF field project managers' reports for each season of the EFP (http://www.npfrf.org).

Recognizing that nets are not in a static state, the NPRFRF started each testing season with test tows to verify that the excluder was taking the desired shape. If not, then modifications were made to add or subtract weight and/or floatation to get the excluder panels back to the desired positions. In the context of controlled scientific testing, one might expect a protocol that no changes would be made to a device during testing or at least there would be a systematic and calibrated way to detect small changes to the device and corrections could be confirmed systematically. This kind of controlled testing and metrics to establish it is actually not currently possible with excluder testing even if systematic protocols are followed (discussed later). This is important because small changes in nets typically occur gradually just through normal fishing. Recognizing these subtle changes (drift) from the desired construction parameters and shape over time is subjective and difficult at present. This would only be possible from video observations and because the camera angles are affected by the dynamic environment of the net, changes to the shape affect the degree to which a camera view can actually be useful for detection of the changes.

Because fishermen would normally make adjustments to gear if it were not performing as desired, NPFRF's testing incorporated the approach of making adjustments to the excluder to re-establish the desired shape at the start of each testing season to the extent possible. Adjustments during a test would only be done if for some reason the excluder became damaged. These adjustments were for obvious things such as when floats on the lower panel were lost or damaged or lead lines became detached during the testing.

Results:

Testing on the Commodore took place February 17-28th in 2015 (13 tows); August 25-September 7th 2015 (12 tows); and March 2-15th 2016 (11 tows). For the Destination, the larger catcher vessel, testing occurred February 18-24th 2015 (12 tows), August 25 to September 2, 2015 (12 tows); and February 28th

to March 9th, 2016 (14 tows). For the CP vessel Northern Jaeger testing dates were February 28 to March 3rd 2015 (9 tows); September 8 –September 23, 2015 (full trip 29 tows); and February 14 through February 26th (full trip 25 tows).

For the most part, the testing went as planned but a few problems did occur. Table 1 below details the EFP allowances and harvests (groundfish, Chinook salmon, non-Chinook salmon) by season and vessel (see appendix at the end of this report for detailed catch by species): 7,319 mt were harvested of the 7,500 mt EFP groundfish allowance; 813 Chinook were landed compared to the 1,450 Chinook salmon EFP limit; and 2,666 non-Chinook salmon were landed compared to the 3,000 non-Chinook salmon EFP limit. A total of 1.2 mt of halibut PSC mortality were taken (EFP limit = 36 mt). As can be seen in Table 1, one overage (for chum salmon) did occur in winter of 2015. After consultation with NMFS' Alaska Regional Office, this resulted in needing to stop testing on F/T Northern Jaeger during the winter/spring 2015 A season before all EFP tows were completed.

Table 1. EFP 15-01 groundfish and salmon limits and harvests by season and vessel.

Seasonal targets and overall limit for EFP metric tons (groundfish not allocated by season)								
	2015 A target	Catch	2015 B target	Catch	2016 A target	Catch	Total Catch	EFP limit
Northern Jaeger	900	744	900	1,075	900	845	2,664	
Destination	900	887	900	922	900	917	2,726	
Commodore	700	637	700	647	700	645	1,929	
Total	2,500	2,268	2,500	2,644	2,500	2,407	7,319	7,500
Target per vessel, catches, and seasonal and total limits for Chinook (numbers)								
	2015 A limit	Catch	2015 B limit	Catch	2016 A limit	Catch	Total Catch	EFP limit
Northern Jaeger	216	273	90	6	216	187	466	522
Destination	216	98	90	13	216	115	226	522
Commodore	168	78	70	3	168	50	131	406
Total	600	439	250	22	600	352	813	1450
Per vessel targets, catches, and seasonal and total limits for Non-Chinook (numbers)								
	2015 A limit*	Catch	2015 B limit	Catch	2016 A limit	Catch	Total Catch	EFP limit
Northern Jaeger	90	188	900	89	90	56	333	
Destination	90	113	900	721	90	3	837	
Commodore	70	32	700	1461	70	3	1496	
Total	250	333	2500	2271	250	62	2666	3000
*Note: Red indicates overage and requirement to cease EFP operations for that year; NMFS later agreed to modify permit manage non-Chinook catches to overall EFP limit								

Attainment of the seasonal limit for chum salmon during the 2015 A season was unexpected because pollock vessels seldom encounter chums at that time of year. In winter of 2015, however, the AFA pollock fishery encountered relatively high chum salmon catches and the rate of encounters increased throughout that season. Recognizing this, the plan was to keep a close eye on chum catch rates in the EFP and take steps to avoid areas with high chum encounters to the degree possible without compromising the objectives of the EFP. This proved to be problematic for Northern Jaeger because they started the EFP on February 28, 2015, about ten days after the other two test vessels started and by then the two EFP catcher vessels had accumulated considerable catches of chums. This left little potential for a rollover of unused chum salmon from the other two EFP vessels. Given this, NPFRF carefully monitored daily catches of chums against the 250 chum limit but unfortunately with two high-catch-rate tows by Northern Jaeger occurring before accounting caught up with the catches and the seasonal limit of 250 chums was exceeded. When NPFRF reported the overage, Northern Jaeger had only completed approximately 65% of the testing slated to occur on the vessel for A season 2015.

Upon learning of the overage, the Alaska Region of NMFS decided the EFP would have to be terminated for that season but suggested that they might grant a modification to the permit (later granted in July of 2015) to alleviate this unforeseen problem. The permit modification was to manage the EFP to the overall number of chums allowed for the permit instead of three separate seasonal limits. The process to request and approve this modification would require time, however, so the first testing season came up short in terms of testing objectives of the EFP for this reason.

The second problem related to the reliance on camera systems as the only means to track escapement for this EFP. In making the move to use cameras alone, NPFRF understood that it might have to accept gaps in escapement data from mechanical failures and deployment errors even if its project managers had considerable experience with underwater cameras systems. Based on past experience with cameras used opportunistically to understand fish behavior, the types of mechanical problems included DVRs that did not record, failures in the switches used to power the cameras, malfunctions in battery chargers, and other technical glitches. Another issue for this project was the potential for loss of effective monitoring of escapement at times when cameras become obscured temporarily. This occurs when pollock become pinned on or in front of the lens.

To help prevent loss of EFP data through technical failures, NPFRF supplied each field project manager with a sufficient number of camera systems to have two cameras deployed at both the lower and the upper escapement portals of the O/U excluder, plus a minimum of one back-up system (minimum of five systems per project manager per deployment). While two cameras in each escapement location would create redundant video when cameras worked perfectly, in the event that one camera failed or its view became temporarily blocked, this would help prevent loss of escapement data.

For the first testing season when NPFRF's camera systems were relatively new having two cameras per escapement location proved to be mostly redundant. But at times this did prevent small losses of data at times, mostly from views blocked temporarily by fish. In the latter two testing seasons when camera equipment failure rates increased, despite full maintenance of cameras between seasons, even with the second camera there were some losses of video data. Typically this was only for a relatively short portion of time on a few tows, and only at one of the escapement locations. But at times data loss was more than minimal. Towards the end of the second and throughout the third testing season, some cameras ceased to function completely or for part of a testing season even if repairs done between seasons were expected to correct for earlier issues. This meant that even with the back-up camera in use, some hauls were limited to only one camera placement in one or both of the escapement portals. If there were three working cameras, the bottom escapement portal was preferred for the single camera installation because the volume of escapement over time there is generally lower there. Reliance on a single camera in the upper escapement portal obviously increased the chances for data loss when a fish blocked the view or an insufficient battery charge led to incomplete coverage.

Table 2 below reports the percentage of time that camera deployments per vessel and season were successful (either with one or two cameras) for fully tracking escapement rates. For cases where performance was less than 100%, there was at least one escapement location that had a temporary camera problem resulting in some loss of video coverage of escapement. Equipment performance was particularly poor for F/V Destination in its final testing season with a 15% loss of video hours.

Table 2. Percent complete video hours per season and vessel.

Percentage of testing hours with complete video per vessel per testing season			
	A 2015	B 2015	A 2016
CV Commodore	100%	95%	95%
CV Destination	90%	96%	85%
CP N. Jaeger	97%	96%	100%

Given the incomplete video coverage, NPFRF decided to report the results in Table 3 below based on tows with 100% video coverage in both escapement locations. Complete video coverage means that at least one camera per escapement location worked without failure throughout the tow. This excludes very brief periods of time when a fish may have blocked the view but where project managers felt this did not meaningfully impact assessment of escapement.

Based on using on the data for complete video tows, salmon escapement ranged from 3.4% on the Commodore to 18.1% on the Northern Jaeger. Pollock escapement was low, ranging from 0.6%-2.2% across all EFP legs.

For the results table below, specific EFP seasons are indicated with an "A" (pollock A season) for winter/spring months when Chinook are the usually the principal species encountered in the testing. Seasons indicated with a "B" are for fall seasons when most of the salmon encountered are chum salmon.

Table 3. EFP salmon and pollock escapement rates by vessel and season, 2015-2016. Only tows with complete video are included. Also noted is the percent salmon escapement from the top portal

EFP 15-01 Escapement rate results for salmon and pollock								
vessel	year/season	salmon escapes	codend salmon	salmon escape rate	% escapes from top	pollock escape tons	codend	pollock escape rate
Commodore	A 15	6	83	6.8%	50%	8.7	388.4	2.2%
	B 15	51	1461	3.4%	84%	3.3	642.9	0.5%
	A16	9	53	14.5%	67%	15.9	461.2	3.4%
Destination	A 15	23	211	9.8%	47%	10.1	875.1	1.1%
	B 15	56	734	7.1%	56%	5.7	914	0.6%
	A16	18	118	13.2%	53%	18.6	909.1	2.0%
N. Jaeger	A 15	102	461	18.1%	55%	12.3	730.3	1.7%
	B 15	41	240	14.6%	70%	42.7	3818.2**	1.1%
	A16	32	328	8.9%*	n/a	38.2	2651.4**	1.4%
*excluder tested was boat's flapper excluder with lighting system they use								
**test done on full trip combining AFA and EFP fish								

By excluding tows with incomplete video, the potential exists that excluded hauls may have had better escapement. To look at this, NPFRF's project managers also calculated escapement rates for all EFP tows including ones with incomplete video coverage. The results in that case would reflect a lower bound escapement rate given that accounting for what did not escape (counts of salmon in the codend) was likely to be complete and partial accounting for salmon escapement with video on those tows can only be equal to or underestimate escapement. Calculations including the tows with incomplete video coverage, however, did not appreciably change the average escapement rates. It is still possible that relatively large escapements occurred when we were unable to detect them. For this reason we cannot dismiss the possibility that escapement was higher for salmon and pollock than what is reported in the tables for complete video coverage.

The anomalous encounter rates of chums in A season of 2015 (but not 2016) also need to be kept in mind for interpreting results for escapement for that particular season. We do know from the codend accounting on the vessels what the actual catch distribution was for Chinook versus chums for each season. But because escapement is accounted for by video alone and we cannot reliably identify salmon to species in the video, we have to assume escapement by species mirrors the proportion of salmon species in the codend. Making this assumption is probably sound when the EFP testing is encountering the normal pattern of salmon species by season (Chinook in winter, chums in summer and early fall). But for winter 2015, the unanticipated high rate of chum bycatch makes the assumption that escapement rates apply to Chinook questionable. For the 2016 A season it is probably safe to assume that escapement rates apply to Chinook given that rates of encounter for chum in winter/spring 2016 were back to their normal (close to zero) level.

What stands out most from the mean escapement rates for salmon in EFP 15-01 is that they are well below what occurred in the GOA tests for the O/U excluders and particularly far below the design used in the fall of 2014 on the Caravelle, the design that worked best in the GOA testing. Recall also that all the GOA tests with O/U excluders resulted in mean escapement rates in the range of 33-54% (see results for AB Spr 14, CaraSpr 14, CaraFall 14 below) while rates from the Bering Sea tests for this EFP are all below 20%, several under 10%.

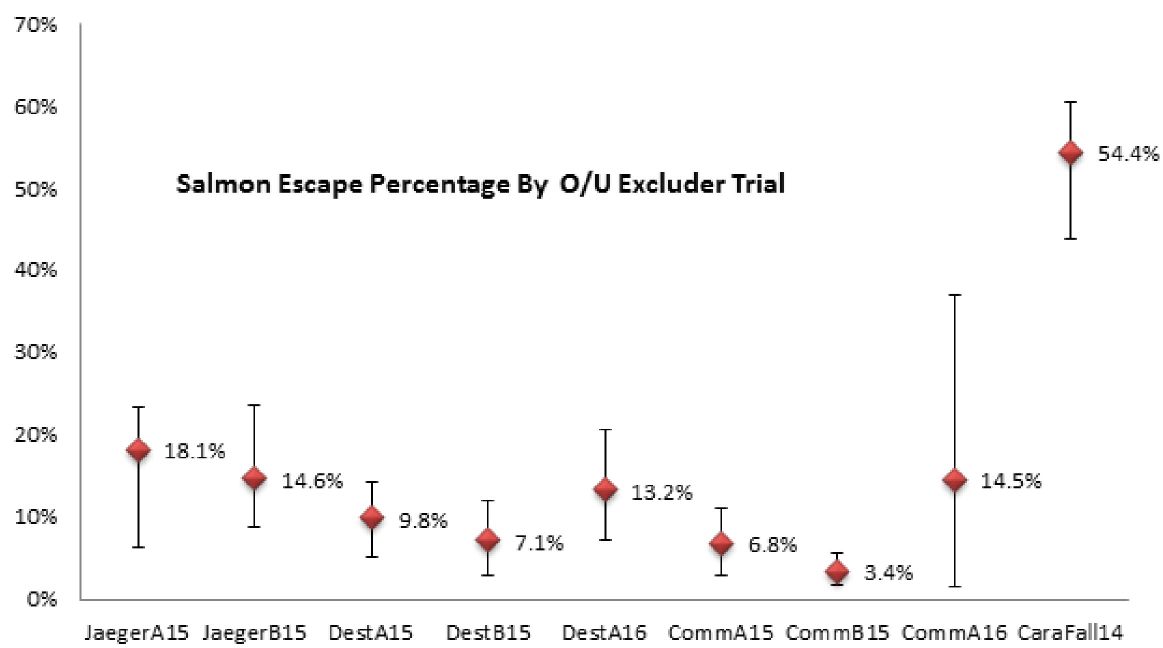
The bottom line is that it was hoped that by “scaling up” the Caravelle’s excluder from the fall 2014 test to the Bering Sea vessels’ horsepower and net size parameters, comparable results would be achieved but this was not the case. We can say this with considerable confidence because the testing covered three seasons and three different vessels.

At the same time, Bering Sea pollock escapement rates are also lower than what occurred in the GOA. This would have been a positive result if escapement of salmon had been of similar magnitude in the Bering Sea trials. One way to look at this might be that escapement rates in general were lower in the Bering Sea tests. This might indicate that with faster towing speeds (bigger nets, higher volume of flow of fish through the net) escapement for salmon or pollock is simply going to occur at lower rates. This makes some intuitive sense but as will be seen in the discussion below, it may not be that simple.

Thinking about the differences in rates between GOA and Bering Sea in the context of vessel size, towing speeds, and horsepower, an even more perplexing aspect of the Bering Sea results is that one would have expected to find salmon escapement results on the catcher vessels in the Bering Sea, particularly the lower horsepower vessel (Commodore) to be the closest in terms of salmon escapement to the results from the GOA vessels. But in fact the Commodore’s salmon escapement (and that of the larger CV vessel Destination) is lower than what was seen on the 7,200 HP catcher-processor (see NJ 15-A and NJ 15B). Northern Jaeger actually had results in the range of 15-18% for tests with the O/U excluder and this is at least closest to the GOA results, arguably in the lower range of what occurred in the GOA.

To look at potential for variability around mean results to help explain outcomes, Figure 7 below includes 95% confidence intervals for GOA and Bering Sea excluder salmon escapement rates. Confidence intervals were calculated using a re-sampling routine implemented with Resampling Stats, an add-on for Excel (see: www.resample.com). This was used to fill the sample sizes from each group with salmon and pollock catches and escapes from that group’s results, randomly selected, with replacement, for each haul (R routine). Selections were repeated 5000 times, with percent escapes for pollock and salmon computed for each selection. The results were sorted and the 5% lower (125th) and upper (4875th) values provided as the upper and lower confidence limits at an Alpha of 5%. Results from the GOA and Bering Sea trials are grouped together in Figure 7 below.

Figure 7. Mean salmon escapement rates in excluder trials in the Bering Sea (2015/2016) and Gulf of Alaska (Caravelle fall 2014) by vessel and season with 95% CI's.



The Bering Sea results are the first eight mean values with confidence intervals from left to right. The final seasonal test on Northern Jaeger in A season 2016 did not test an O/U excluder as will be explained below. Based on 95% confidence, the results span from 3%-35% salmon escapement considering the wide confidence intervals around the result for Commodore in A season 2016 but for the rest of the trials, the results are in the 3% to 24% range. By comparison, the result from the Gulf of Alaska trials that were used to select the O/U device (Caravelle fall 2014) ranges from 42% to 60%. Given the wide disparity, it is clear that the Bering Sea results are quite different and a hypothesis test is not needed to determine that the Bering Sea results are categorically different from our expectation in the EFP for performance for the GOA excluder that performed best.

The other result of interest from the 15-01 tests was focused on the vessel's flapper excluder in use on the vessel prior to their being selected for EFP 15-01. The impetus to test Northern Jaeger's flapper arose after seeing the two seasons of somewhat disappointing results on their vessel and other EFP15-01 vessels during the first two seasons. In gearing up for the final testing season, the captain of the Northern Jaeger pointed out that escapement with the O/U excluder tested on his vessel during the first two seasons had occurred predominantly out the top escapement portal. From this he wondered whether escapement out the bottom was actually important and whether the O/U excluder really outperforms a flapper excluder. He felt that the flapper excluder, particularly the one he was using prior to the EFP, was achieving better results than what he had seen so far in the first two seasons of 15-01. The captain had modified their flapper excluder to have two pathways for escapement out the top of the net. He also explained that he had added a strong light to illuminate the escapement area in the hopes that it would attract salmon. On their own, the crew of the Northern Jaeger had monitored escapement periodically with the vessel's recording video system. Based on this they expected their device would outperform NPFRF's O/U.

Given the somewhat disappointing results thus far, NPFRF agreed to test Northern Jaeger's flapper-style excluder for the final season of testing in winter/spring of 2016. Given the similarity in results from the first two trials on the vessel, NPFRF felt pretty comfortable that a third test would result in similar results. The opportunity to look at something the captain thought might work better was interesting, particularly given their use of a large green light at the forward escapement portal which was a quite different approach to lighting than anything that NPFRF had examined. The addition of a second portal to allow salmon to access the escapement pathway was innovative and the lighting utilized a powerful (1,200 lumen) "egg-shaped green light" that the crew charged periodically made it quite unique. The excluder as rigged for the A season 2016 testing on Northern Jaeger is shown below.

The Northern Jaeger's hope that salmon escapement would be better with their flapper device unfortunately did not pan out from the testing done in the EFP. The result for that test was a mean salmon escapement of 8.9% (95% confidence interval from 6-12%) with slightly higher nominal Pollock escapement rates than the boat had in the first two O/U tests. This flapper test encompassed an entire trip combining AFA and EFP fish and this same approach was done for the Jaeger's fall 2015 EFP test (B 15 results) in Figure 7. While probably not definitive, the results on the Northern Jaeger with O/U excluders suggest that the O/U excluder performed better than their flapper excluder.

Salmon genetics/Sea Share: All encountered Chinook salmon were measured and weighed and scanned for the presence of coded wire tags. Tissue samples were also collected from Chinook salmon when there were more than 50 Chinook salmon in the haul for stock of origin analysis. Tissue samples (PAP's) were collected for DNA/stock of origin analysis and sent to Auke Bay for processing. Per the requirements of the permit, all salmon meeting the quality requirements of the Sea Share program were donated to food banks through the Prohibited Species Donation program.

Discussion:

Several factors merit consideration in exploration of possible reasons for the difference between expectations from the GOA performance and what occurred in the Bering Sea. As was mentioned, towing speed was one that NPFRF expected to be an important factor from the outset. But as will be seen below, the answer may not be as straight-forward as differences in towing speed, particularly since the results for the slower-towing catcher vessels Bering Sea vessel in the EFP showed lower salmon escapement than was seen on the fastest towing catcher processor vessel. In this regard, a set of other possible explanations is offered in the discussion below.

Towing Speed: The towing speed (measured as speed over ground for all EFP vessels either GOA or BS) for the two GOA pollock vessels ranged from 2.5 to 3.0 knots during the 2013-2014 trials. For the Bering Sea vessels in EFP 15-01, speeds per vessel were as follows: Northern Jaeger's ranged from 3.5 to 4.2 knots, Destination towed from 3.8 to 4.0 knots, and Commodore ranged from 3.0-4.0 knots. In reality, this amounts to just a little more than a knot faster than the GOA vessels for the larger CV and CP vessel although these boats tow in the upper part of their ranges more often than in the lower part. For the smaller Bering Sea catcher vessel Commodore, on average their speed was just half a knot faster. Could towing approximately one knot faster or as little as half a knot for the smaller Bering Sea vessel on average account for the performance difference alone? It could but other factors might be equally or even more important.

Consistency in speed might also be a factor. Speed varies during a tow depending on whether the vessel is towing with or against the tide and/or the seas. The angle of the vessel's pathway relative to the tide and seas can vary within a single tow as well. This is especially true if the vessel's fishing practice includes one or more turns during a tow. Some fishermen do not fish in a way that normally involves turns favoring fishing along a depth contour or edge where Pollock sign was seen during searching or from prior tows in an area. Others actually try to fish a dense patch of fish in area where they feel the fish sign in suitable for concentrated fishing with several turns to stay in that area during the tow. The point here is that we know from the video that escapement does not always occur steadily and it probably occurs more when speed and water flow conditions are best for salmon. Perhaps escapement of salmon occurs most when the most advantageous speed to occur, at when these speeds overlap with when salmon happen to be passing through the section of the net where the excluder is installed. Differences in fishing practices may affect the chances that the right speed occurs when salmon are passing through that section of the net or when salmon swim forward to make a second attempt at escapement, such as during slowdowns and turns. From this we can hypothesize that the more variable speed is within a tow the greater the potential that salmon escapement will occur.

In this regard, all else being equal, we would expect that for larger vessels, speed would generally be steadier due to the vessel's inherent horsepower and towing force which can compensate for factors like towing into rough seas and other conditions that would likely slow smaller vessels down or make their progress over ground more variable. Fishing practices like frequency of turns would also have to be taken into account as well. Having more of this detailed information about towing speed within a tow and variability in speeds might be helpful for determining whether instantaneous towing speed explains much about when salmon escapement occurs. The range of towing speeds during the EFP were collected but our data do not provide an archive of speed during tows in time step with when salmon escapements occurred.

<u>Door spread, mesh opening, and towing characteristics</u>: Observations by NPFRF's project managers in reviewing video from this EFP and the one in the GOA was that salmon did not appear to have difficulty moving forward against the water flow in the Gulf of Alaska or Bering Sea Pollock nets. What project managers did mention, however, was that for the Bering Sea vessels, particularly the larger ones, the webbing in the trawl intermediate where the excluder was installed appeared to be "more stretched and tighter" than for the Gulf of Alaska vessels in the EFP there. This is a complex issue that might be important for understanding performance differences as well.

The way a trawl system takes shape and performs is dependent not just on towing speed but the size and design of the doors which spread the trawl. Doors, in combination with the net bridles and towing speed affect the degree to which meshes are spread and how thereby determine "tight" the netting will be. This in turn affects the relative size of the net at different parts of its taper from front to back. For example, two vessels can be using the same net model made by the same manufacturer and of approximately the same degree of use (e.g. brand new, one season, two seasons, repaired once or more). One of those "identical" nets might have large mesh spread and a much larger diameter of the tube of the net at the same location than another vessel. The difference is probably explained most by door size, bridles, and towing speed which all affect this outcome.

All these factors might be important to performance of an excluder in terms of salmon and pollock escapement with the O/U excluder. For example, rigidity of the netting in the trawl intermediate affects the degree to which the O/U's floated and weighted panels come together in the center. Recall that the GOA trials and the specifics of the Caravelle's O/U excluder design were based on the inner excluder panels coming relatively close together in the center of the intermediate. From this we surmise that panels coming together tends to corral fish into the center thus maximizing the amount of room available in the upper and lower escapement pathways (in addition to increasing the room available to salmon to get out of the flow of pollock passing backwards). The degree to which the panels in the Bering Sea trials came together was affected by the amount of weight and floatation on the panels <u>and</u> the rigidity (tension) in the netting. Adding weight and floatation to the panels is intended to compensate for rigidity to some extent in helping the desired shaping of the excluder to occur. But the degree to which the panels come together is limited by the rigidity of the webbing and at a certain point the addition of floats and leadline starts to increase the drag against the flow therefore reducing their marginal contribution to the objective of pulling the panels together in the center.

The photos below were selected as a good representation of how the excluder panels and escapement pathways looked "on average" during towing for each EFP boat. The view in each case is looking forward from aft of the floated and weighted panels. Some differences in size and shape of each specific intermediate section in relation to distance from the camera to the area behind the excluder panels affects our ability to systematically determine differences in the shaping. The photos essentially show how the excluder was set up for escapement of salmon as salmon moved back through the excluder section of the trawl (or when a salmon swam forward after passing this section). By "set up" is meant how much room was available for accessing the escapement pathway and how much room out of the flow of pollock was created. The photos start with the GOA vessel Caravelle's excluder, the shape of which was the objective for this EFP (Figure 8). The remaining pictures (Figure 9, Figure 10, and Figure 11) show the O/U excluder on the Bering Sea test vessels for shape comparison purposes.

Figure 8. Caravelle O/U excluder, Fall 2014. View is from aft of the excluder looking forward towards the mouth of the net. The large over and under escape portals are clearly shown with a salmon swimming forward towards the bottom escape hole.

Figure 9. Commodore O/U excluder, 2016

Figure 10. Destination O/U salmon excluder, 2015.

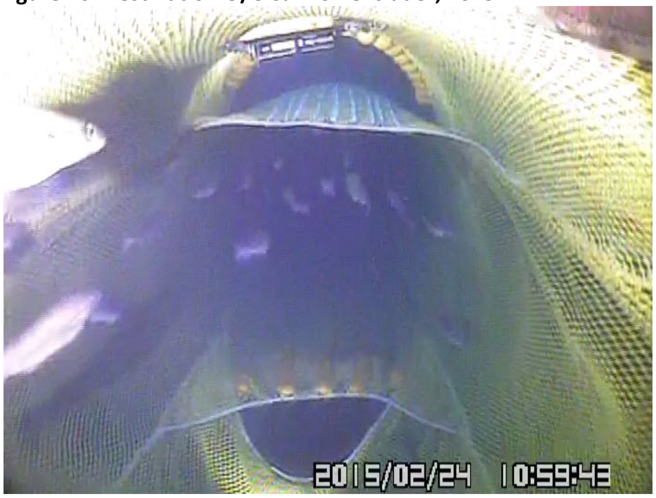


Figure 11. Northern Jaeger O/U excluder, 2015

Looking at the photos, one can see the differences in size of the section in which the excluder is installed and the relative degree to which the upper and lower panels of the excluder come together. The photos also show differences in rigidity of the webbing at towing speed.

Although subjective, the Bering Sea vessel that comes closest to the shape seen on the Caravelle appears to be the smaller Bering Sea vessel (Commodore). But that vessel's salmon escapement rates were the lowest of the Bering Sea test vessels. In this regard, the shaping for Northern Jaeger appears to create the least room for escapement and the narrowest pathway forward to the escapement holes. But that vessel had the closest salmon escapement results to those of the Caravelle.

The bottom line here is that there are too many factors controlling shape alone when one considers speed, net and mesh spread, room available to get out of the flow and for movement forward. The results suggest that speed and shape alone are not necessarily going to guarantee better results.

One final aspect of a net that could affect escapement is how "fast" or "slow" it tapers (transitions to smaller, more retentive meshes) from front to back. This affects the length of the net from the opening to where the excluder is installed. A "slow" tapered net (more gradual) would be longer and this could possibly affect how fatigued a salmon would be when it arrives at the section where the excluder is installed. Nets used in the Goa trials tended to be shorter (faster, more abrupt taper) relative to the Bering Sea nets used in EFP 15-01. This could have influenced escapement assuming that the ability of a salmon to make use of the escapement opportunity is dependent on degree of fatigue. Water flow and other factors are affected by the degree of taper in the net and these would also need to be taken into account in assessing how tired a salmon might be when it encounters the excluder. Size of salmon might also need to be taken into consideration as well, as is discussed next.

<u>Size of salmon as a factor affecting escapement</u>

One idea we considered to potentially explain the differences between GOA and Bering Sea results was that for the same species (Chinook is really the only GOA species encountered), size distribution of the salmon encountered in the EFP might be related to escapement performance differences. The expectation might be that if GOA Chinooks are larger and better swimmers so they could escape at a higher rate. Data collected in the EFP allowed for examination of this but because data on escapement was collected via video alone, firm conclusions on this issue cannot be made. The use of video to track escapement leaves only length data pertaining to salmon that did not escape. Ignoring that issue for the moment, the size frequency graphs shown below (Figure 12, Figure 13, Figure 14, Figure 15) do not show any remarkable differences in size of salmon between GOA and BS by species. Most of the Bering Sea and GOA Chinook salmon are in the range of 45 to 75 cm. Somewhat anecdotally we can say that the salmon in the video seen escaping look similar in size to those that do not (those seen in the codend). Without a systematic way to measure salmon in video footage, however we can only report that salmon escapements appear to resemble salmon that did not escape as a qualified guess. Another piece of potentially relevant information here comes from our past use of recapture nets to track escapement. Back when salmon escapement was tracked that way, we did not see any significant differences in salmon size between the codend salmon and those in the recapture net.

Figure 12. Salmon size frequencies, Commodore (2015 A season).

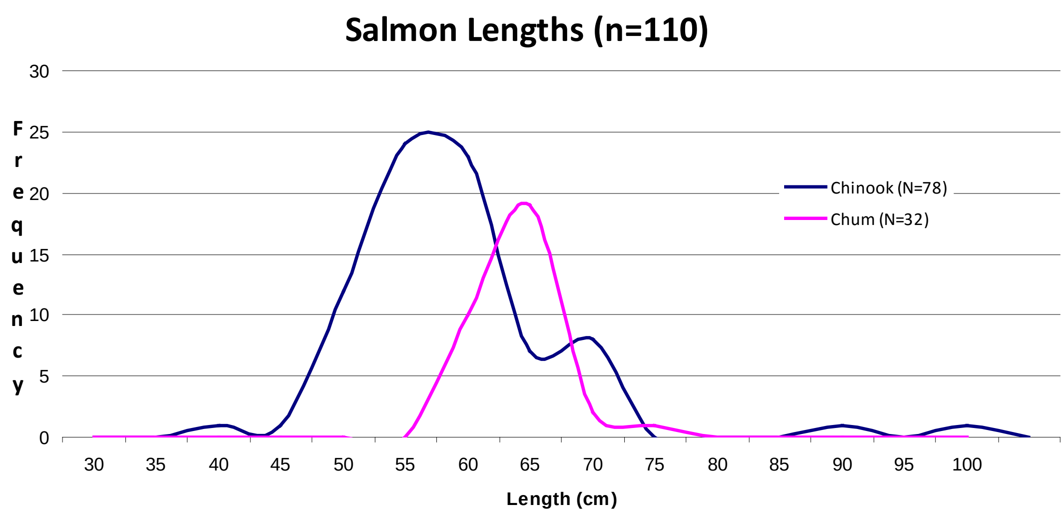


Figure 13. Salmon size frequencies, Destination, 2015 A season.

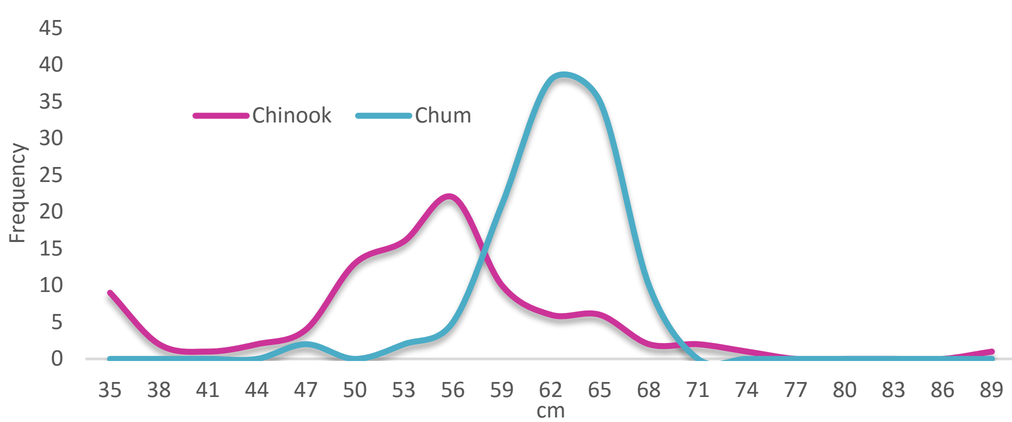


Figure 14. Salmon length frequencies, Northern Jaeger, 2015 A season.

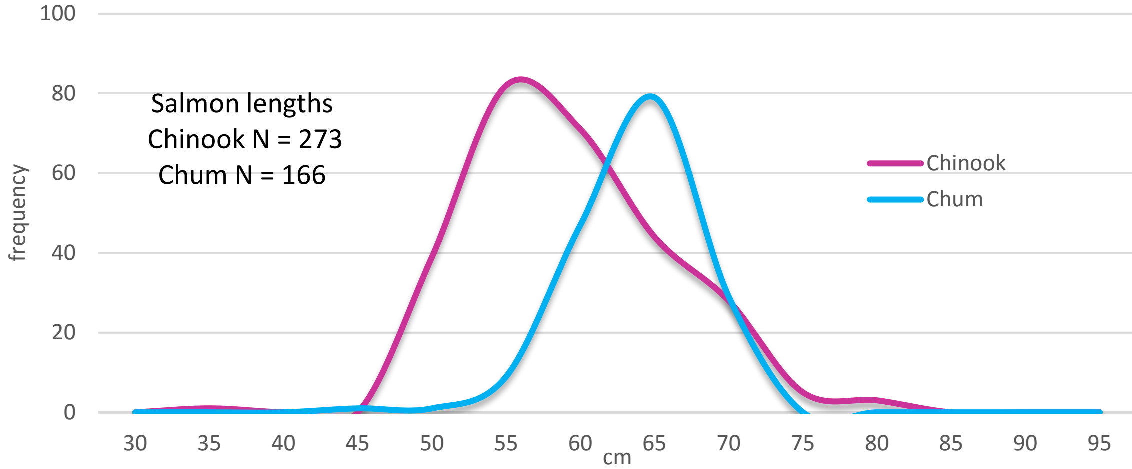
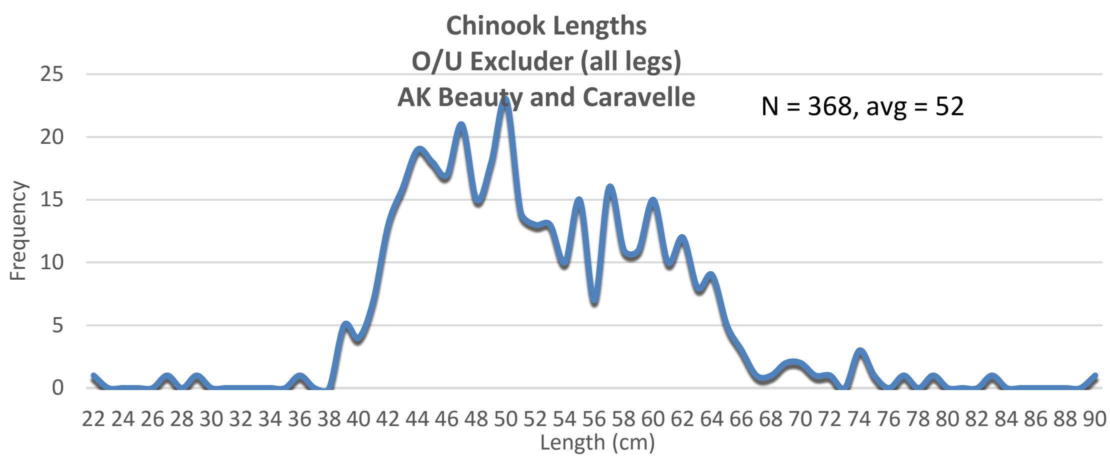


Figure 15. Chinook size frequencies, GOA EFP 13-01.



<u>Effect of pollock catch rates on salmon escapement.</u> One last possible explanation that was considered was the possibility that pollock catch rates could affect salmon escapement rates. Catch per hour of towing was examined to see if, for example, Bering Sea catch rates differed significantly from GOA rates. What was found when these data were analyzed both by simple regression analysis and visually through scatter plots is that there is a very large variability in catch per hour over the Bering Sea and Gulf of Alaska trials. Rates ranged from as low as a few tons an hour to highs of over 40 metric tons per hour in each area. The repressions and scatter plots of salmon escapement and groundfish catch per hour for Bering Sea and Gulf of Alaska showed nothing useful in terms of correlation here.

In discussing the lack of a finding of some (probably negative) correlation between Pollock catch rates and salmon escapement with fishermen, they were not at all surprised. Their reasoning was that catch per hour on average was probably not a very relevant way to think about how pollock catch rates might affect salmon escapement. Alternatively, they thought it is probably really about the relative amount of congestion that occurs when a salmon is trying to find its way out and this would occur intermittently over the course of a tow. In their experience, schools of pollock tend to be patchy and the fish do not always feed into the net steadily. All the fish caught in a three hour of towing might come from just a few minutes of fishing when a dense patch of pollock enters the net or this could occur over the entire duration of the tow. This suggests that data on catch per hour could really miss the key factors affecting congestion as fish move through the excluder section of the net.

To really understand how pollock moving back and flowing through a net might affect salmon escapement, fishermen suggested that a recording echo-sounder would need to be installed in the intermediate where the excluder is located. The density of fish moving through could then be tracked over time and examined to see if the timing of salmon escapements coincides with dense patches of fish moving through the excluder section or not. To do this correctly, the video would need time stamps that track with the eco-sounder data so an actual measure of congestion could be tracked in time step with salmon escapements. This is a very interesting area for exploration but unfortunately NPFRF did not collect this kind of data in our EFP.

Recommendations for future research

Based on NPFRF's research, the performance of the O/U in the Gulf of Alaska trials still represents the upside expectation for an effective excluder in the pollock fishery. The findings from EFP 15-01 suggest that scaling the excluder that worked best in the GOA trials to the Bering Sea fishery is not a straight-forward endeavor and getting the excluder to take the correct shape consistently is a first order step for future work on the O/U excluder in the Bering Sea. To attempt to do this systematically based on what was learned in this EFP, a set of measurement devices and parameters, some probably unique, would be very useful to gauge achievement of standardization and effects on performance of fishing variables. For example, measurement devices, many of which are available today could be used to track and record tension on net meshes. This could be tracked with speed over ground during a tow to gauge differences with towing speed, door spread, and other factors.

To evaluate shaping standardization, instead of relative visual distance between the excluder panels, the degree to which they come together could be measured with lasers designed to do standardized length/distance measurements. This could be used to give more systematic and precise estimates of escapement pathways and vertical room available for salmon to get out of the flow of Pollock and variability of these with tow speeds, door size and net spread.

Likewise, a recording echo-sounder device could to be developed that provides a calibrated estimate of the amount of pollock moving through the intermediate over time. With this the escapement events in the video data could be evaluated in time sequence to see if salmon escapements are affected negatively or positively by congestion from groundfish moving through the excluder.

Other types of meters and metrics along these lines could probably be fashioned with input from fishermen, gear manufacturers, fish behavior experts. These would be intended to elucidate potentially important variables systematically and in a manner that can be compared in real time to escapement throughout the duration of tows (dynamic rates).

Another approach for moving forward in the Bering Sea would be to set up a testing opportunity where fishermen would be selected for the EFP based on the degree to which they are able to make their O/U excluder take the desired shape based on the GOA device that worked best. This could be done by adjustments to the construction/rigging of their excluder, adjustments to trawl gear including doors, and/or changes in fishing practices such as towing speed. Fishermen could tap into the ideas of gear manufacturers, other experts, or rely on their own ideas on how to best get their excluder to take the desired shape based on what was the most efficient way to make that happen for their net/vessel horsepower, doors, fishing practices.

As a starting point for this approach, as set of systematic measurements as discussed above would need to be made for the GOA excluder during normal Pollock towing conditions. This baseline shape and mesh rigidity would serve as the objective to achieve in the Bering Sea and its achievement would be established through the same systematic measurement process that would be done for the GOA excluder.

One benefit to this approach would be that the test tows at the outset would simply be to confirm the shaping and this would obviate the need to use any of the EFP groundfish allowance to make adjustments to the excluder. Another benefit would be that fishermen could use whatever approaches are most efficient for them to use in order to achieve the desired shape. Given the heterogeneity of vessels and nets, this avoids the need to come up with a “one size fits all” approach to excluder construction/shaping/usage recommendations, something that is clearly not realistic.

In thinking about setting up such a challenge, it would be important to note that are surely limits on the degree to which Bering Sea pollock gear and the way it is fished can be modified and still catch pollock efficiently. For instance, trawl doors and other gear in the Bering Sea are tailored to the boats in the fishery. Simply slowing down the vessel by, for example, one knot might make the gear perform poorly for catching pollock. Reducing catch per unit effort might be more problematic than expected because even if it improved the effectiveness of the salmon excluder to some extent, the savings may be negative in terms of salmon bycatch reduction if the vessel has to tow longer to catch its allotment of pollock.

The attractiveness of setting up a testing opportunity based on meeting a set of systematic shape and size parameters for the excluder is that it avoids the “top down” engineering approach. In the end what might be discovered is that some small, relatively simple modifications to gear and fishing practices, something that was not expected to have too great an effect, might actually be all it takes to get the excluder to work in the Bering Sea. Trying to figure these out in an engineering setting might not be as effective as letting people who make a living with trawl gear figure out how to do it simply and cost effectively.

Whatever process is used to figure out how to get the excluder to have the desired shape/room for escapement attributes in the Bering Sea, an actual field test of the modified device and its fishing practices would need to be conducted to ensure it actually works. That test would once again only be truly relevant if it included a realistic range of vessel/horsepower differences in the Bering Sea Pollock fishery. Systematic proof that the O/U excluder performs like it did in the GOA (or better) is very important because simply assuming that getting the desired shape would generate the same escapement results ignores the possibility that the O/U may not work was well for the Bering Sea pollock fishery due to reasons other than shape and how the net is fished. If after that test it still turns out that the O/U excluder does not work as well in the Bering Sea, at least at that point the research can focus on differences that are independent of the excluder.

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Appendix

Table of total groundfish and halibut catches from EFP 15-01 (based on ELandings/fish tickets, note: salmon catches reported in Table 1 above)

Species FT lbs	**Dest A 15**	**NJ A 15**	**Comm A 15**	**Dest B 15**	**NJ B 15**	**Comm B 1**	**Dest A 16**	**NJ A 16**	**Comm A 1**	**Total lbs**	**Total MT**
Pollock	1,968,690	1,610,360	1,378,242	1,935,292	2,325,874	1,420,859	2,043,463	1,836,647	1,409,622	15,929,049	7,225.3
P. cod	9,123	13,732	21,891	11,946	12,101	4,366	19,695	5,207	10,877	108,938	49.4
Rex sole	0	532	130			22		4,988	5	5,677	2.6
Rock sole	3,818	1,809	193		62		484	69	10	6,445	2.9
Flathead	1,020	10,479	1,990	211	507		408	4,944	343	19,902	9.0
Arrowtooth	186	530	100	91	2,809	6	30	1,794	20	5,566	2.5
Kamchatka Fl		87			789			641		1,517	0.7
Turbot		261			60					321	0.1
Thornyheads		170								170	0.1
Dusky RF				7			6	4		17	0.0
POP		39	8			17		360		424	0.2
Shortraker RF								41		41	0.0
Atka Mack.				11	11		6			28	0.0
Sculpin		69	63		631					763	0.3
Skate	577	586	698		5,454		49	33	1	7,398	3.4
Squid	0	925	1	35		167		2,698	2	3,828	1.7
Octopus		103			9			1,472		1,584	0.7
Shark								12		12	0.0
non-Groundfish											
Eulachon	0	126						267		393	0.2
Jellyfish	906	5,396	87	116	227			285	193	7,210	3.3
Eels		47								47	0.0
Prowfish	1			13					4	18	0.0
Lamprey		17								17	0.0
Misc.					104			118		222	0.1
Poacher	1									1	0.0
Lumpsucker	247	418	150		11		477	171	2	1,476	0.7
Herring			1	457	97				2	557	0.3
Tanner Crab					7					7	0.0
Halibut	37	332	10	0	71	0	19	2,185		2,654	1.2
Total lbs GF	**1,983,414**	**1,639,682**	**1,403,316**	**1,947,593**	**2,348,306**	**1,425,437**	**2,064,141**	**1,858,898**	**1,420,880**	**16,091,667**	**7,299.1**
Total MT GF	**899.7**	**743.7**	**636.5**	**883.4**	**1,065.2**	**646.6**	**936.3**	**843.2**	**644.5**	**7,299.1**	