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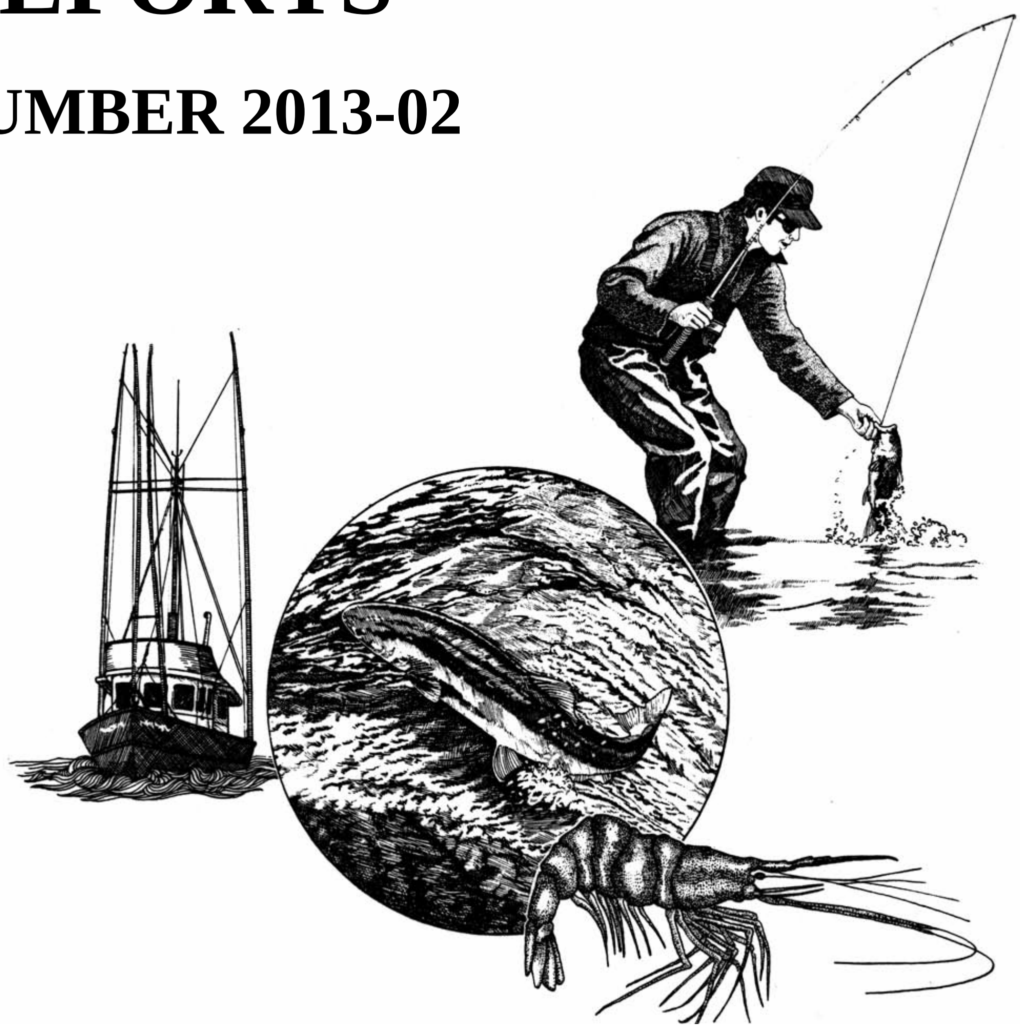

FISH DIVISION
Oregon Department of Fish and Wildlife

Tests of trawl footrope modifications to reduce the bycatch of eulachon (*Thaleichthys pacificus*) and other small demersal fishes in the ocean shrimp (*Pandalus jordani*) trawl fishery

Tests of trawl footrope modifications to reduce the bycatch of eulachon (*Thaleichthys pacificus*) and other small demersal fishes in the ocean shrimp (*Pandalus jordani*) trawl fishery

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Abstract

Three field experiments were conducted to determine if modifying shrimp trawl footropes could be an effective strategy for reducing fish bycatch in the ocean shrimp (*Pandalus jordani*) fishery. Of particular interest was reducing the trawl bycatch of eulachon (*Thaleichthys pacificus*), an anadromous smelt that is considered threatened under the United States Endangered Species Act. The experimental design compared catches between two double-rigged, semi-pelagic shrimp trawl nets equipped with rigid-grate bycatch reduction devices, fished simultaneously, with one net incorporating the modified footrope and the other serving as a control. Recording inclinometers were used to control for differences in fishing line height (FLH) between the nets and a specially divided hopper was used to keep catches from the port and starboard nets separate for sorting and weighing. Experiment 1 tested a footrope from which the entire central section of groundline had been removed to allow fish to pass under the trawl, but that was also rigged with reduced FLH to help minimize shrimp loss. Experiments 2 and 3 tested a footrope from which a small (1.5 m) section of the central groundline had been removed to create an “escape window” for fish to pass under the trawl net. In all 3 experiments, large reductions in the bycatch of small flatfish and juvenile rockfish were obtained, however, the reduction in eulachon bycatch was of similar magnitude to the shrimp loss created by the modifications, suggesting minimal effectiveness for eulachon. Comparison of the results from these experiments and other published research showed that smaller escape windows were more effective at maintaining shrimp catch rates and reducing fish bycatch than removing larger sections of the groundline.

Introduction

In the two decades since the development of the Nordmøre grate (Isaksen et al. 1992), rigid-grate codend bycatch reduction devices (BRDs) have become standard equipment in a variety of shrimp, prawn and crustacean trawl fisheries throughout the world, greatly reducing fish bycatch (Broadhurst 2000, Madsen and Hansen 2001, Graham 2003, Fonseca et al. 2005, Hannah and Jones 2007, He and Balzano 2011, Broadhurst et al. 2012). The common limitation of rigid-grate BRD designs, as well as most other codend BRDs, is that small, weak-swimming fishes are inefficiently excluded from the trawl (Parsons and Foster 2007, He and Balzano 2011, Hannah and Jones 2012). These fishes are too small to be physically excluded by the BRD and, after swimming inside the trawl net and tiring, they reach the codend with diminished swimming ability and cannot respond behaviorally to the approaching grate (Hannah and Jones 2012). Some recent research has tested BRD modifications to improve exclusion efficiency for small fishes, including greatly enlarged escape openings (He and Balzano 2011), and decreased spacing of the rigid vertical bars (Hannah and Jones 2012).

In the U.S. west coast trawl fishery for ocean shrimp (*Pandalus jordani*), rigid-grate BRDs, with minimum size restrictions on the escape opening and a maximum allowable bar spacing of just 19 mm have been required since 2012. The bar spacing in these BRDs is approaching the body width of the largest ocean shrimp, suggesting that the limits of bycatch reduction via codend BRDs may have been reached for this fishery (Hannah and Jones 2012).

Regulations requiring efficient codend BRDs in the ocean shrimp fishery have reduced bycatch to very low levels. The initial introduction of BRDs in 2001 reduced fish bycatch from about 32-61% of total catch (weight) to just 7.5% by 2005 (Hannah and Jones 2007). Requiring rigid-grate BRDs with 19 mm bar spacing has reduced bycatch even further. Federal observer data indicate that fish bycatch was down to about 2% of total catch by weight in 2012 (National Marine Fisheries Service Northwest Fisheries Science Center, unpublished data). However, bycatch as a percent of total catch is expected to vary widely between years due to large variation in the abundance and distribution of the primary species comprising the residual bycatch, particularly small Pacific hake (*Merluccius productus*) and eulachon (*Thaleichthys pacificus*), an anadromous smelt. Although bycatch in this fishery has been greatly reduced, the remaining bycatch of eulachon is still a concern because this species is listed as threatened under the U.S. Endangered Species Act (NMFS 2010). Further reduction of the remaining fish bycatch in the ocean shrimp fishery is therefore a high priority for fishery managers.

Studies have shown that modifications to ocean shrimp trawl footropes (Figure 1) can reduce the initial entrainment of small demersal fish, including eulachon (Hannah and Jones 2000, Hannah and Jones 2003, Hannah et al. 2011). Ocean shrimp trawl nets are often referred to as “semi-pelagic”, because the fishing line of the net is elevated about 25-70 cm above the seafloor, and a separate groundline drags along the seafloor to stimulate shrimp to move off of the bottom and into the net (Hannah and Jones 2003). Removing portions of the groundline and increasing the height of the fishing line (FLH) above the groundline have both been shown to reduce small fish bycatch (Hannah and Jones 2003, Hannah et al. 2011). Although these types of footrope modifications have been shown to reduce bycatch, they have also caused substantial shrimp loss (Hannah et al. 2011). For example, in a study by Hannah et al. (2011), removing a large portion of the central groundline reduced catch rates of eulachon, small flatfish and juvenile rockfish (*Sebastes*) by 34%, 96% and 80%, respectively, but also reduced shrimp catch rates by over 20%.

The success of rigid-grate BRDs at excluding fish while retaining shrimp is based on fundamental differences between fish and shrimp behavior in response to the approaching grate (Isaksen et al. 1992, Watson et al. 1992, Hannah et al. 2003, Hannah and Jones 2012). Shrimp tend to drift passively through the grate (Hannah et al. 2003). Fish with sufficient remaining stamina swim ahead of the grate, drifting upwards and out the escape hole, following the inclined angle of the grate (Hannah and Jones 2012). Larger fish that are too exhausted to swim simply slide or bump their way along the grate and out the escape hole (Hannah and Jones 2012). The effective separation of shrimp and fish at the grate is caused, in part, by the difference between the patterned avoidance response of fish and the lack of any patterned response by shrimp. We report here on three field experiments that test footrope modifications designed to exploit this behavioral difference between fish and shrimp to encourage fish escapement under an ocean shrimp trawl net while minimizing shrimp loss.

Methods

All three experiments we conducted utilized similar field methods. Using the chartered, 21 m, double-rigged shrimp trawl fishing vessel *Miss Yvonne*, we modified the footrope of one of the two nets (treatment) and then compared catches between this net and the opposing net that had not been modified (control, Figure 1). The control net was equipped with the footrope configuration most frequently used by the commercial shrimp trawl fleet, known simply as “mud gear” (Figure 1). Each field experiment was conducted over 4 days of trawling in June, with one experiment completed per year, 2011 through 2103. Trawling was conducted at depths ranging from 119-207 m, between Cape Falcon and Cape Arago, Oregon. For all three experiments, both nets incorporated identical rigid-grate BRDs with 19 mm bar spacing. To control for any efficiency differences between the port and starboard nets, the modified footrope being studied was switched between the two nets systematically to equalize the number of hauls with the modification on each net. Because FLH has been shown to influence the catch efficiency of shrimp trawl nets, we measured FLH of each net in-situ, using a recording inclinometer, following Hannah and Jones (2003). Haul duration was limited to about 45-70 minutes to avoid very large shrimp catches that could not be sorted and weighed with the field staff available. Towing speed ranged between about 3.0-3.3 km h^{-1} (1.6-1.8 knots), typical for commercial shrimp trawling. We utilized a specially divided hopper to keep the port and starboard net catch separate for sorting and weighing. Most of the shrimp and fish encountered were sorted to species and weighed at sea. Smelt (Osmeridae) and juvenile rockfish, which can be harder to identify to species, were typically weighed at sea and placed into labeled sample bags and frozen for later laboratory identification. For a few hauls, the smelt catch was too large to bag and freeze at sea, so a subsample (approximately 1 kg) was bagged and frozen and the remaining smelt were weighed and discarded. Aggregate weight by species from laboratory analysis was used to estimate total catch of smelt, by species and net, for these hauls. Lab analysis also included measurement of individual eulachon lengths (TL mm).

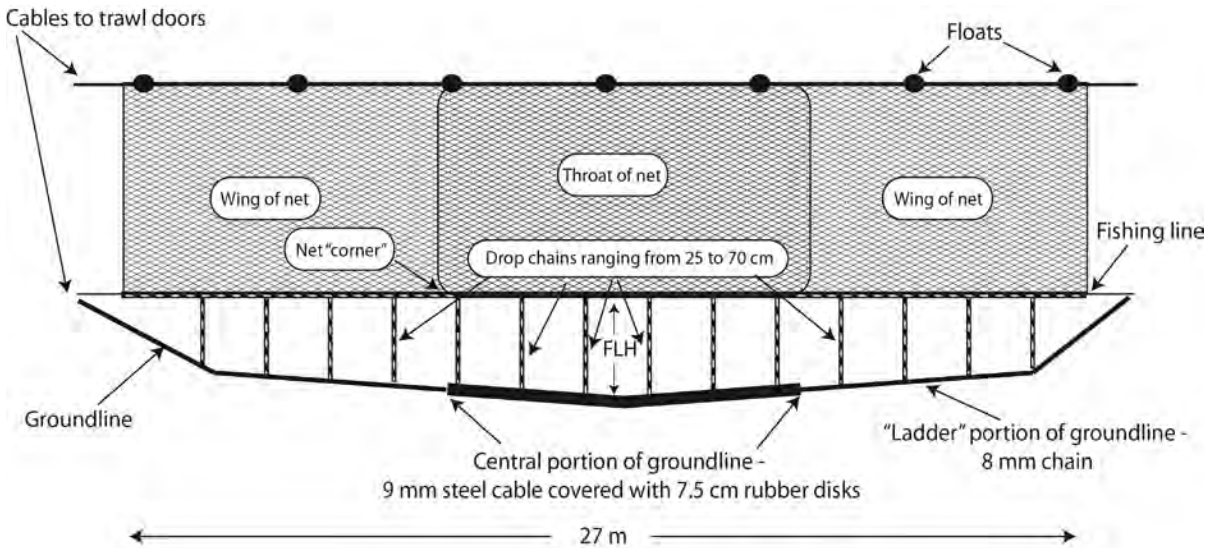

Figure 1. Schematic drawing of an ocean shrimp trawl net with a "ladder style" or "mud gear" footrope configuration (view looking into the net from the front, not to scale). FLH denotes where fishing line height is typically measured.

Catch weight data were analyzed as a multi-factor ANOVA, with haul, side of gear (port or starboard) and the footrope configuration as main effects without interaction, following Hannah et al. (2011). For some species or groups, transformations were used to achieve normality of model residuals. Length data for eulachon were compared between footrope configurations using the nonparametric Wilcoxon two-sample test (Sokal and Rohlf 1981).

Experiment 1

The first experiment was a further investigation of the bycatch reduction potential of removing the entire central groundline section of a shrimp trawl (approximately 1/3 of the total groundline, Figure 1). In prior studies in which the large central section of groundline was removed (Hannah et al. 2011), FLH was equalized between the two double-rigged nets. In this experiment, we again removed the central groundline, but substantially reduced FLH in the modified net to try and reduce shrimp loss. We used recording inclinometers to measure and adjust FLH of both nets prior to starting comparison hauls and also to monitor how FLH changed on a haul-by-haul basis. Reduced FLH in the treatment net was obtained by shortening the drop chains connecting the fishing line to the remaining groundline in the wings and at the "corners" of the net (Figure 1).

Experiment 2

In the second experiment, we tested whether removing just a very short (1.5 m wide) section of groundline to create a fish "escape window" at the center of the footrope (Figure 2) would help maintain high shrimp catch rates while still providing a substantial reduction in bycatch. This was an attempt to exploit the potential herding of fish towards the center of the footrope where they could escape under the trawl. Given the absence of similar herding behavior in shrimp, a relatively larger reduction in fish bycatch than in shrimp catch was expected. The partial groundline was constructed of the same materials as the control groundline, 9 mm steel cable covered with 7.5 cm rubber discs (Figure 3). In this experiment, we utilized recording inclinometers to equalize FLH between the two nets and then removed them for all comparison hauls. This was done to prevent the presence of the inclinometers attached to the center of the fishing line from discouraging fish from using the escape window to pass under the trawl.

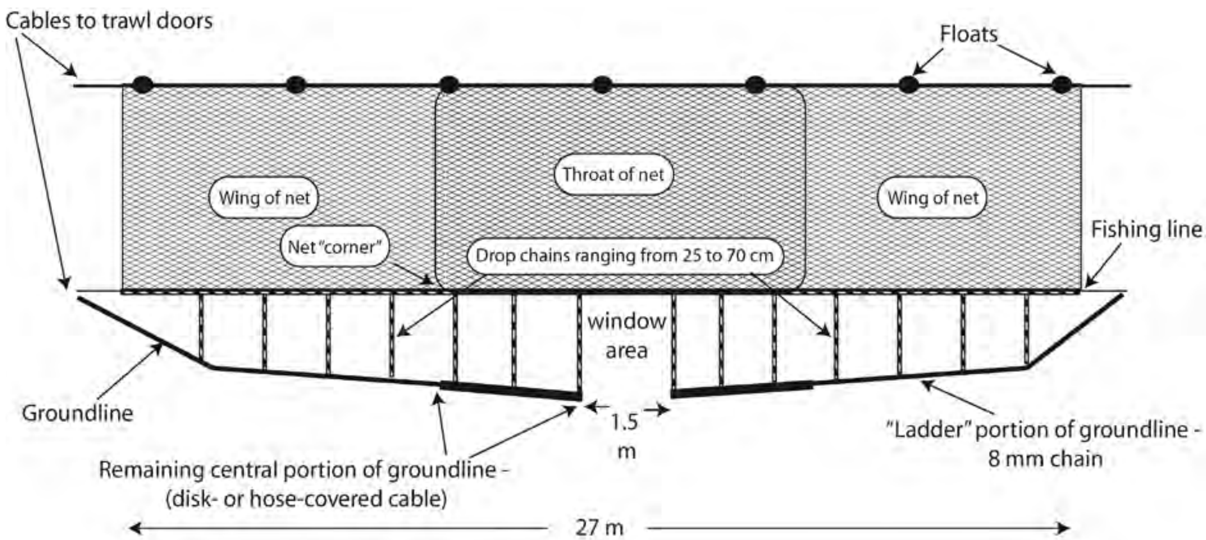

Figure 2. Schematic drawing of an ocean shrimp trawl net with a footrope configuration modified to create a central "escape window" for fish (view looking into the net from the front, not to scale).

Experiment 3

Experiment 3 was essentially a replication of experiment 2 with a few minor differences. The same 1.5 m escape window was evaluated, however the partial groundline sections were constructed of smaller diameter materials, in the hope that, in combination, the smaller groundline and escapement window would provide for more total fish escapement under the trawl net. The experimental groundline sections were made of 9 mm diameter steel cable, covered with 25 mm diameter (OD) rubber hose (Figure 4). For experiment 3, the recording inclinometers were used to measure FLH for all hauls, but were located several feet away from the center of the fishing line, so they would not discourage fish escapement under the trawl in that area.

Figure 3. Picture showing the disk-covered central groundline sections used in experiment 2.

Figure 4. Picture showing the smaller diameter materials used for the remaining groundline in experiment 3.

Results

In experiment 1, we completed 26 useable hauls comparing catches between the control and modified nets (Figure 5). After measurement of FLH and adjustment of the drop chains, the control net FLH averaged (± standard error) 38.4 ± 0.54 cm and the treatment net averaged 27.1 ± 0.38 cm, a difference of over 11 cm (Figure 5). This difference in FLH between footrope configurations also varied between hauls and was larger when the control configuration was on the starboard net (Figure 5, hauls 11 through 23).

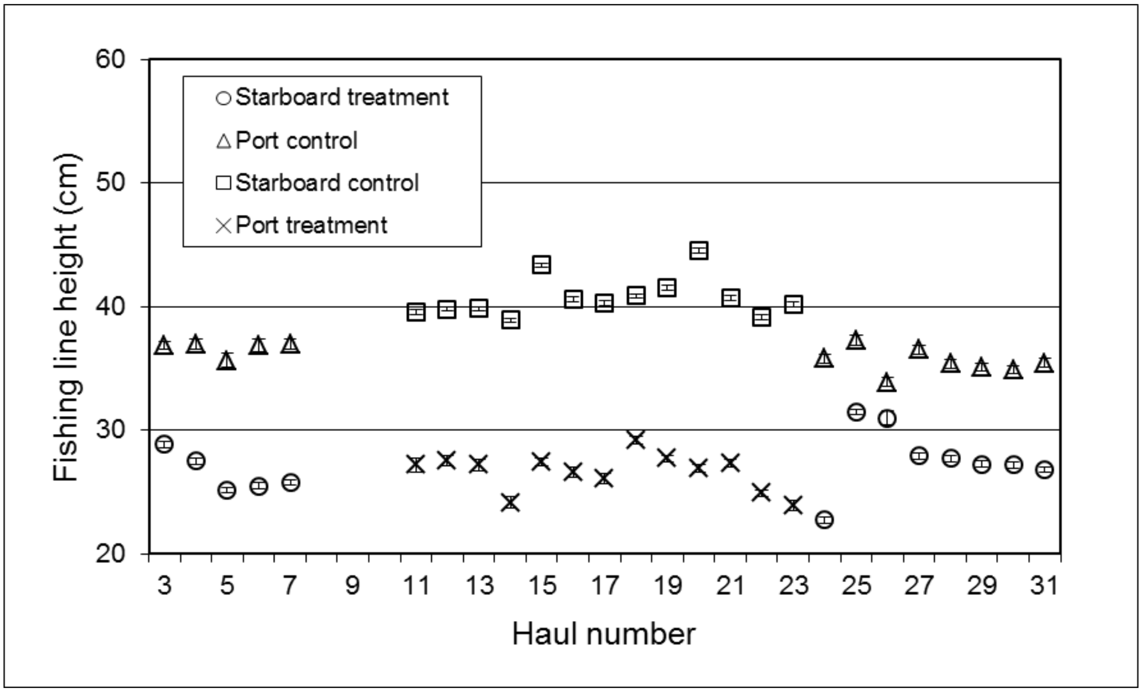

Figure 5. Mean fishing line height (FLH, cm ± standard error, measured at the center of the fishing line) in port and starboard nets, by treatment, in experiment 1.

The footrope configuration with no central groundline and reduced FLH decreased small flatfish bycatch (all reductions are in terms of weight) by 39.8% (Table 1, P=0.017) and juvenile rockfish bycatch by 71.9% (P<0.001) but did not reduce the bycatch of juvenile Pacific hake (Table 1). Eulachon bycatch was reduced 13.3%, a difference that was not statistically significant (P=0.0914). More importantly, the modified footrope reduced shrimp catches by 14.2% (P<0.001), a reduction of similar magnitude to the eulachon bycatch reduction effect (Table 1). The length frequency of eulachon captured was not altered by the modified footrope (Figure 6, P=0.3029). The length frequency of eulachon encountered in this 2011 experiment was strongly dominated by large eulachon (170-240 mm TL, Figure 6).

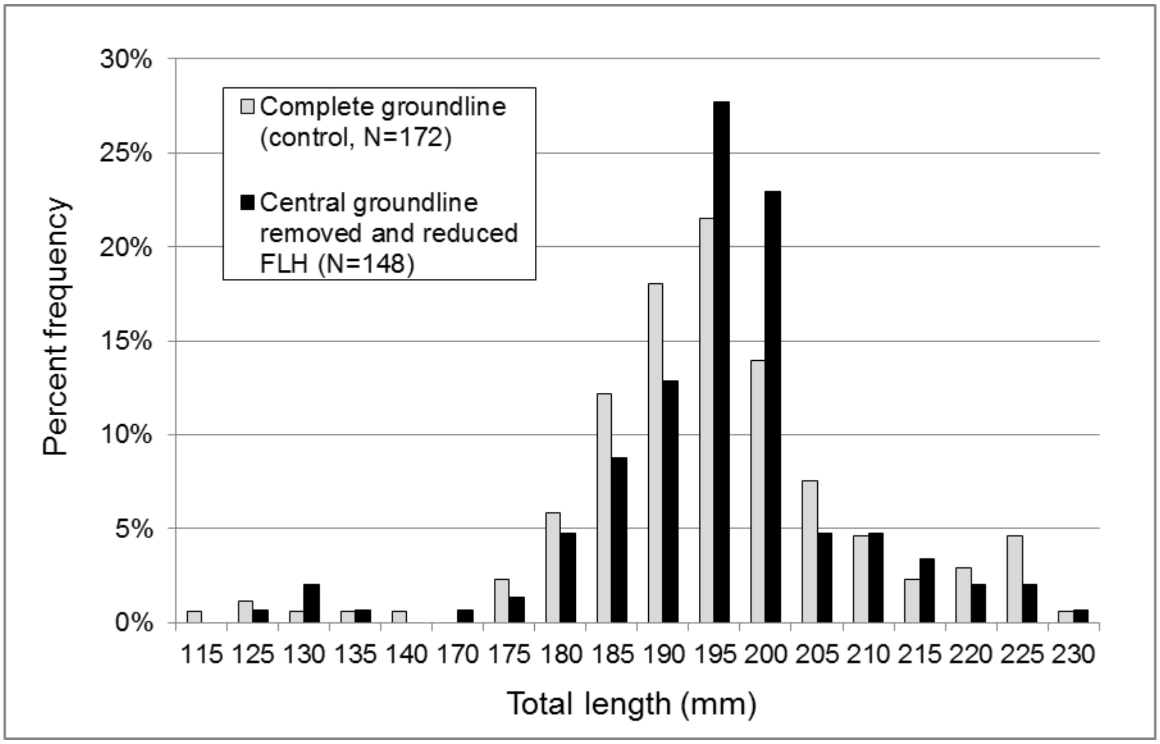

Figure 6. Length frequency of eulachon (total length, mm) captured in ocean shrimp trawl nets, by treatment, in experiment 1.

Table 1. Comparison of mean catch (kg·haul^{-1} for all categories except eulachon, small flatfish and juvenile rockfish which are reported as g·haul^{-1}) by species or group between ocean shrimp trawl nets with (control) and without (treatment) the entire central section of groundline (experiment 1). Species were captured off the Oregon coast in 26 hauls employing double-rigged nets, during June 2011. SE = standard error.

Species name	Complete central groundline Mean catch (SE)	Central groundline removed Mean catch (SE)	Percent reduction with treatment groundline	P-value[1]
Ocean shrimp *Pandalus jordani*	207.40 (19.58)	177.99 (17.51)	14.2	< 0.001
Eulachon *Thaleichthys pacificus*	305.63 (46.07)	265.05 (53.11)	13.3	0.0914
Juvenile Pacific hake *Merluccius productus*	6.33 (1.53)	7.63 (1.99)	-20.5	0.119
Small flatfish	424.81 (72.65)	255.76 (66.69)	39.8	0.017
Juvenile rockfish	137.29 (21.49)	39.25 (10.48)	71.9	< 0.001

[1] 3 factor ANOVA, 1-tailed P-value for treatment effect (see text)

In the second experiment, conducted in June 2012, we completed 26 useable comparative hauls, 13 each with the footrope escape window on the port and starboard trawl nets. However, we found it difficult to completely equalize FLH between the two nets. The recording inclinometers showed that FLH was initially quite different. Mean FLH for the first haul was 40.63 ± 0.59 cm for the control (port) net and 26.33 ± 0.59 cm for the treatment (starboard) net. Adjustments to the drop chains of both nets decreased FLH in the control net to 35.68 ± 0.71 cm and increased FLH in the treatment net to 28.11 ± 0.68 cm. This difference was considered acceptable and the inclinometers were removed and comparative hauls were initiated. After 6 useable comparative hauls were completed, the central groundline sections were switched between nets. After the switch, FLH was measured again on both nets and adjusted to match the relative difference between the treatment and control nets from the first 6 hauls. After some adjustments, FLH averaged 36.9±0.5 cm and 25.54 ± 0.52 cm for the control (starboard) and treatment (port) nets, respectively, and comparative hauls were resumed. After an additional 13 comparative hauls were completed, the nets were switched back to the configuration used for the first 6 hauls and 7 additional comparative hauls were completed.

Table 2. Comparison of mean catch ($kg \cdot haul^{-1}$ for all categories except small flatfish and juvenile rockfish which are reported as $g \cdot haul^{-1}$) by species or group between ocean shrimp trawl nets with a complete groundline (control) and with a small central section of groundline removed (treatment, experiment 2, remaining central groundline is disk-covered). Species were captured off the Oregon coast in 26 hauls employing double-rigged nets, during June 2012. SE = standard error.

Species name	Complete groundline Mean catch (SE)	Escape window Mean catch (SE)	Percent reduction with treatment groundline	P-value[1]
Ocean shrimp *Pandalus jordani*	188.18 (26.43)	179.16 (24.74)	4.8	0.0036
Eulachon *Thaleichthys pacificus*	12.55 (2.20)	11.38 (2.29)	9.3	0.0598
Small flatfish	212.32 (39.73)	73.80 (16.25)	65.2	0.0002
Juvenile rockfish	77.58 (25.59)	41.29 (19.75)	46.8	0.003

[1] 3 factor ANOVA, 1-tailed P-value for treatment effect (see text)

In experiment 2, the footrope escape window reduced the bycatch of small flatfish by 65.2% (Table 2, P=0.0002) and juvenile rockfish by 46.8% (P=0.003), while reducing shrimp catch by only 4.8% (P=0.0036). Unfortunately, eulachon bycatch was reduced by only 9.3%, a difference that was marginally non-significant (P=0.0598) and again, of approximately similar magnitude to the shrimp loss observed (Table 2). Similar to experiment 1, the length frequency of eulachon captured was not influenced by the modified footrope configuration (Figure 7, P=0.1566). In contrast with experiment 1, conducted in 2011, the length frequency of eulachon encountered in 2012 was strongly dominated by small eulachon (< 170 mm).

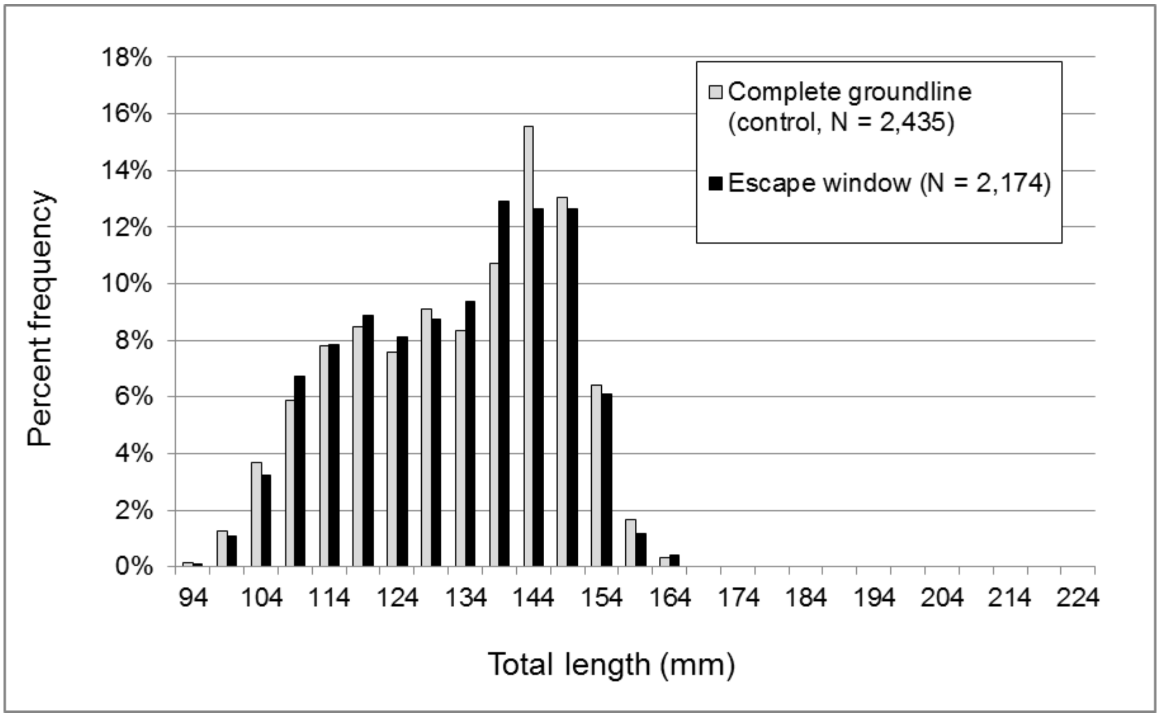

Figure 7. Length frequency of eulachon (total length, mm) captured in ocean shrimp trawl nets, by treatment, in experiment 2. Experimental treatment is an escape window with the remaining central groundline covered with rubber disks.

In the third experiment, difficulties in consistently equalizing FLH between the two nets were again encountered. Initial measurement and adjustment of FLH resulted in well-equalized FLH for the first 6 hauls (hauls 3-8) with the modified groundline on the starboard net (Figure 8). The central groundline sections were then switched between the two nets and FLH was found to be well-equalized between the two nets in haul 9 (Figure 8). However, when FLH was checked again at the end of the second day of comparative hauls, the port (treatment) net was found to be averaging much lower FLH than the control net (hauls 10 through 15, Figure 8). No changes were made to the nets and comparative hauls were continued through haul 22 and then the footropes were switched back to the configuration used for hauls 3 through 8 (Figure 8). Four more comparative hauls were completed before the vessel was forced to return to port for repairs to the steering linkage.

Although 24 comparative hauls were completed before the chartered vessel became inoperable, this resulted in an unbalanced data set with respect to the number of hauls with each net incorporating the modified groundline. To balance the data set, four hauls conducted with the modified groundline on the port net had to be chosen for exclusion. Two hauls were chosen for exclusion based on net performance issues that were noted at sea. Haul number 12 was excluded because a twist in the intermediate section of the starboard net did not allow proper functioning of the BRD. Haul 11 was excluded because the port net groundline was found to be fouled with a large section of clay pipe. Hauls 16 and 17 were excluded during data analysis because they resulted in very low shrimp and eulachon catches, respectively, leaving a balanced data set with 20 comparative hauls.

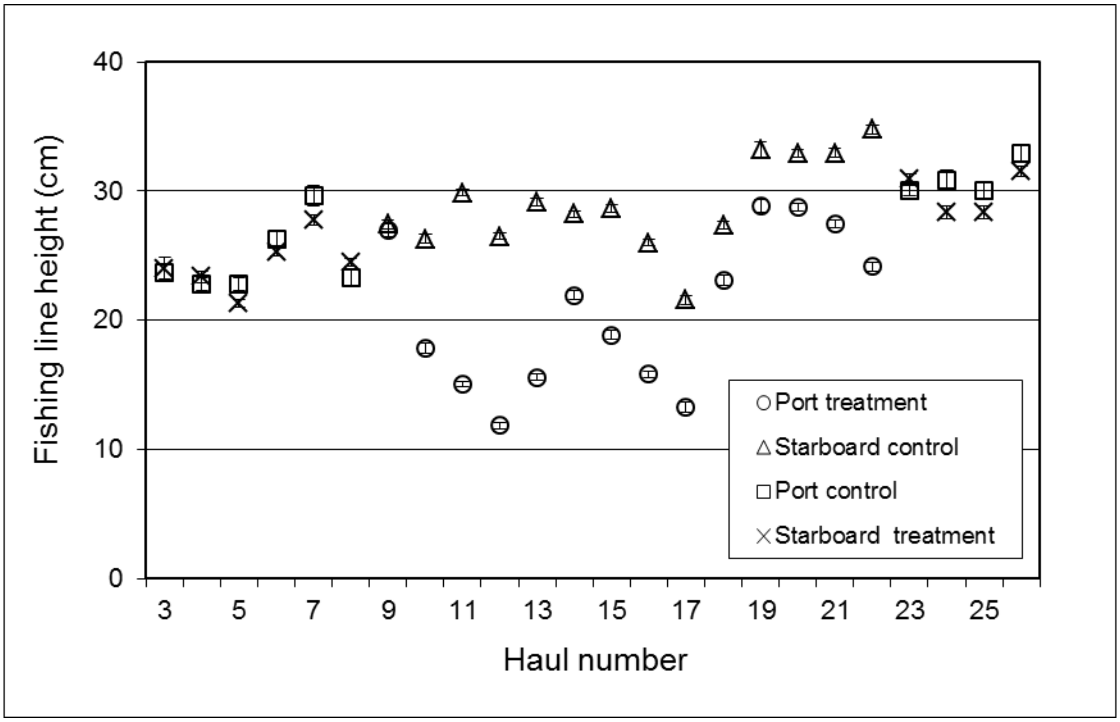

Figure 8. Mean fishing line height (FLH, cm, measured several feet outside of the escape window) in port and starboard nets, by treatment, in experiment 3.

The footrope incorporating the escape window in experiment 3 reduced small flatfish bycatch by 82.1% (Table 3, P=0.0001), while reducing shrimp catches by only 10.1% (P=0.002). Juvenile rockfish bycatch was reduced by 68.9%, a difference that was not statistically significant (P=0.1447). Eulachon bycatch was reduced 15.8%, a difference that was marginally non-significant (P=0.0535). As in the prior two experiments, eulachon bycatch reduction was of a similar magnitude to the reduction in shrimp catches (Tables 1-3). The length frequency of eulachon captured in experiment 3 was not significantly altered by the modified footrope (Figure 9, P=0.0814), however the length data suggest that the control net may have captured small eulachon more efficiently than the net with the modified groundline (Figure 9), suggesting more utilization of the footrope window by small eulachon. The length frequency of eulachon captured in this 2013 experiment shows that a broad range of eulachon sizes were encountered, including both large and small eulachon (Figure 9).

Table 3. Comparison of mean catch (kg·haul^{-1} for all categories except eulachon and juvenile rockfish which are reported as g·haul^{-1}) by species or group between ocean shrimp trawl nets with a complete groundline (control) and with a small central section removed (treatment, experiment 3, remaining central groundline is hose-covered). Species were captured off the Oregon coast in 20 hauls employing double-rigged nets, during June 2013. SE = standard error.

Species name	Complete groundline Mean catch (SE)	Escape window and hose-covered groundline Mean catch (SE)	Percent reduction with treatment groundline	P-value[1]
Ocean shrimp *Pandalus jordani*	247.14 (39.83)	222.12 (40.09)	10.1	0.002
Eulachon *Thaleichthys pacificus*	457.89 (138.13)	385.49 (144.15)	15.8	0.0535
Small flatfish	1.84 (0.28)	0.33 (0.06)	82.1	0.0001
Juvenile rockfish	492.09 (211.67)	153.22 (29.37)	68.9	0.1447

[1] 3 factor ANOVA, 1-tailed P-value for treatment effect (see text)

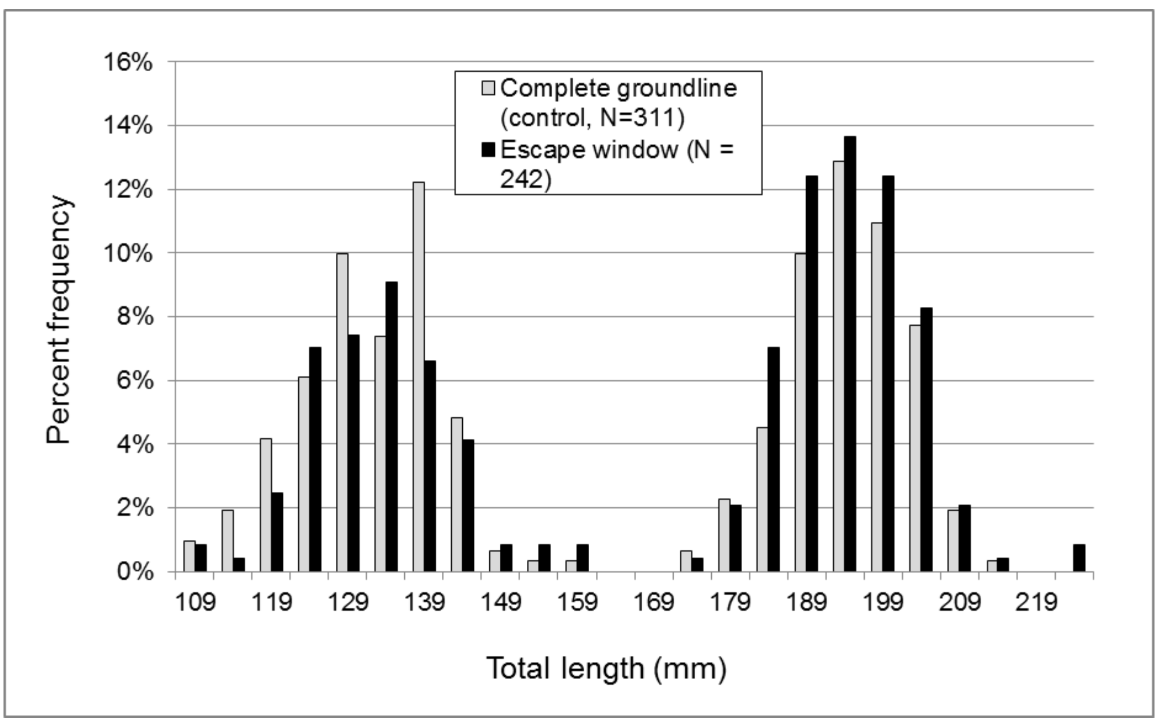

Figure 9. Length frequency of eulachon (total length, mm) captured in ocean shrimp trawl nets, by treatment, in experiment 3. Experimental treatment is an escape window, with the remaining central groundline covered with rubber hose.

Discussion

These experiments demonstrate that behavioral separation of ocean shrimp and some species of small demersal fishes can be effectively achieved at the footrope of a shrimp trawl by removing sections of groundline. In all three experiments, the reductions obtained in small flatfish and juvenile rockfish bycatch were several times greater than the shrimp loss created by the modifications (Tables 1-3). Unfortunately, none of the groundline modifications were effective at reducing the bycatch of eulachon substantially more than the reduction in shrimp catch rates (Tables 1-3). These findings are consistent with prior research testing complete removal of a large section of the central groundline in which small flatfish and juvenile rockfish catches were greatly reduced while eulachon catch reductions were similar to the reduction in shrimp catches (Hannah et al. 2011). The most likely explanation for this general result is that these footrope modifications work best for fish species that are consistently near the seafloor and those that tend to herd towards the center of the footrope. They are probably less effective for species like eulachon and Pacific hake, that may be more variable in either their vertical position or their behavioral response to the approaching trawl.

The footrope escape windows evaluated in experiments 2 and 3 were more effective at maintaining shrimp catch rates, while reducing bycatch, than the experiments in which much larger sections of the central groundline were removed. In Hannah et al. (2011) and experiment 1 here, where large sections of groundline were removed, the reduction in flatfish bycatch was approximately 4.1 and 3.4 times as large, respectively, as the shrimp loss created (Table 4). In our experiments 2 and 3 testing footrope escape windows, flatfish bycatch reduction was 13.6 and 8.1 times larger, respectively, than the shrimp loss (Table 4). Although the results are not as strong for juvenile rockfish, the trend is similar (Table 4). However, the footrope escape windows increased the ratio of bycatch reduction to shrimp loss only very modestly for eulachon (Table 4). These results suggest that footrope escape

Table 4. Comparison of the ratio of bycatch reduction (weight) to shrimp loss, by species or group, for four experiments testing modified groundlines in ocean shrimp trawls.

Groundline experiment	Treatment	Small flatfish reduction to shrimp loss	Juvenile rockfish reduction to shimp loss	Eulachon reduction to shrimp loss
Hannah et al. (2011)	Remove central groundline	4.1	3.4	1.5
Experiment 1	Remove central groundline, reduce FLH	2.8	5.1	0.9
Experiment 2	1.5 m escape window, disk-covered groundline	13.6	9.8	1.9
Experiment 3	1.5 m escape window, hose-covered groundline	8.1	6.8	1.6

windows do function effectively as bycatch reduction devices for some species, but that they are weakly and inconsistently effective for eulachon.

A comparison of the results from experiments 2 and 3 does not suggest that the smaller diameter groundline materials used for the remaining central groundline in experiment 3 were a meaningful improvement over the larger, disk-covered groundline materials used in experiment 2. Bycatch reduction percentages were higher in experiment 3 with the smaller diameter groundline, but overall shrimp loss more than doubled (Table 3).

A generally consistent result from these experiments was that the footrope modifications tested did not significantly alter the length composition of eulachon captured in the modified trawl net. This finding should be interpreted cautiously because, in most of these experiments, a wide size range of eulachon was not encountered. In experiment 3, in which a wide size range was encountered, there was some evidence of size selectivity in escapement favoring small eulachon, although this difference was marginally non-significant statistically ($P=0.0814$).

The difficulties we encountered in equalizing FLH between the two nets in these field experiments highlight the general challenges of developing lower bycatch footropes for shrimp trawls. Although it is known that FLH influences trawl catch rates for shrimp and some bycatch species (Hannah and Jones 2003) the factors that influence variation in FLH between two paired nets or between individual hauls are not well understood. Altering the length of dropper chains and other footrope components generally creates the anticipated changes in FLH if averaged over several hauls, however it is also clear that FLH can change unexpectedly, most likely because of changes in current direction and speed, substrate type, vessel speed, catch weight and sea state (Figure 4). Fouling of the groundline with debris can also alter FLH and sometimes increase bycatch unexpectedly in one of the two nets (Hannah and Jones 2003). Our difficulties in equalizing FLH between the nets also suggest substantial uncertainty in how footropes that have been modified to reduce bycatch might perform at a fishery scale. Vessel operators commonly adjust their footrope rigging in response to observed catch rates for shrimp and bycatch species and they do not have access to recording inclinometers to measure FLH. In altering the rigging of any “low bycatch” footrope configuration to try and improve catch efficiency for shrimp, much of the bycatch reduction effects could be lost, a problem that is generally not an issue for rigid-grate BRDs.

Acknowledgements

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