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By-catch Reduction In An Ocean Shrimp (*Pandalus jordani*) Trawl From a Simple Modification to the Trawl Footrope

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Abstract

Two commonly used footrope configurations in the ocean shrimp (*Pandalus jordani*) trawl fishery were fished side by side from a double-rigged vessel to compare catch rates of shrimp and bycatch. The control net footrope incorporated a traditional "tickler chain" groundline, which is shorter than, and runs below and in front of the fishing line of the trawl. The other net utilized a ladder chain groundline with a short roller section in the center, set to run under and slightly behind the fishing line. Both nets were measured using an acoustic trawl monitoring system to allow examination of differences in net spread and rise. The ladder/roller groundline caught 84% fewer slender sole (*Eopsetta exilis*) , 49% fewer greenstriped rockfish (*Sebastes elongatus*) and 47% fewer juvenile rockfish (<8 cm total length) than the tickler chain groundline. After allowing for a wider net spread with the ladder/roller gear, catches of shrimp and other fish species were comparable for both gears. These results suggest that ocean shrimp trawls can be rigged to fish efficiently for shrimp and marketable fish with a groundline that runs behind the fishing line of the trawl, although the exact mechanism behind the increased escapement is unclear. We recommend underwater camera work to determine how small fish are escaping capture and also the testing of a trawl without a groundline, using only dropper chains to maintain a constant height of the fishing line above bottom.

Introduction

Interest in bycatch reduction devices (BRD's) for the ocean shrimp (*Pandalus jordani*) trawl fishery off Oregon, Washington and California (Figure 1) began in the 1960's with the work of High et al. (1969). As a result of this early work, trawls with equal length headropes and footropes came into use in the fishery, reducing the bycatch of smelt and herring (PFMC 1981). The sorting trawl developed by High et al. (1969), however, did not come into common use because it was more difficult to construct and repair and caused reduced catch rates of shrimp (PFMC 1981). Over time, fishermen developed a variety of on-deck sorting devices, including sandpaper "smelt belts", to help deal with the unwanted catch of small fish, reducing their need for BRD's as a fishing tool (Jones et al. 1996).

Ocean shrimp fishermen began experimenting with BRD's again in the early 1990's, in response to a large increase in the abundance of Pacific whiting (*Merluccius productus*) on the shrimp grounds (Hannah et al. 1996). The increased catches of Pacific whiting were so large that entire fishing grounds became unfishable without a BRD. The BRD's fishermen used were homemade or locally made soft-panel excluders (Figure 2) and produced high and variable shrimp loss, along with modest exclusion efficiency, that was generally below the performance of the Nordmore grate (Hannah et al. 1996, Isaksen et al. 1992). Voluntary use of BRD's continued to grow, with 33% of active Oregon shrimp vessels owning some type of BRD by 1994, although most used these devices less than 25% of the time (Jones et al. 1996). However, mandatory use of BRD's has not been implemented by any of the managing states or the Pacific Fishery Management Council and by 1998, BRD use had fallen again to virtually zero (ODFW, unpublished data).

The reasons for the decline in use of BRD's by Oregon shrimp fishermen are numerous. Resistance by fishermen to mandatory use of BRD's is based mostly on the value of the marketable bycatch, which has traditionally been retained and sold. Based on fish ticket data from 1987 to 1995 (see for example Lukas and Carter 1998), the ex-vessel value of marketable bycatch in the Oregon ocean shrimp fishery ranged from 2% to 5.5% of the total ex-vessel value from this fishery. Shrimp loss caused by the various BRD's, as well as net handling problems, contributed to the decline (Hannah et al. 1996). As in the past, fishermen also developed alternative, if not ecologically friendly, ways of handling the unwanted bycatch. Fishermen developed "shaker grates", vibrating grates with widely spaced bars, placed between the hopper conveyor belt and the sorting belt. These devices catch and divert larger fish, separating them mechanically from the shrimp, with marketable fish being removed manually and unwanted fish washing overboard. Some fishermen tied 23 kg weights to their codends and altered haul back procedures to allow the net to hang vertically in the water for several minutes to let fish, primarily Pacific whiting, float out the mouth of the net.

A variety of factors have contributed to the reluctance by managers to make BRD's mandatory in the ocean shrimp fishery. While concerns about enforcement and tri-state coordination probably top the list, concern over the survival of excluded fish has also been raised as an issue. One alternative approach to bycatch reduction that should cause less concern about survival and that could be more compatible with voluntary use is to try and develop footrope designs that keep unwanted species from entering the trawl. The primary objective of this research was to begin examining differences in shrimp trawl footrope performance with respect to effects on ocean shrimp catch and bycatch, with the hope of identifying or developing footrope configurations that reduce bycatch.

Methods

In this experiment we compared catches from two nets of a double-rigged shrimp trawl vessel, with one side using a tickler chain groundline and the other using a ladder style groundline, with a short-section of 6.4 cm disk gear in the middle (Figure 3). We chose these two groundline configurations for several reasons. First, they represent configurations that are in common use in the ocean shrimp fishery. Secondly, the ladder/roller configuration has come into wide use just recently and has been reported to be fishing "cleaner" by several shrimp fishermen. These two groundline configurations, as we tested them, also incorporate an important functional difference; they have different groundline length. This creates a difference in the relative position of the groundline and the actual fishing line of the trawl (Figure 3). The tickler chain is generally constructed to be shorter and run in front of and below the fishing line. It is designed specifically to cause shrimp to jump off bottom and be captured by the trawl. The ladder/roller groundline we tested was rigged to be of slightly longer length than the fishing line so that it would run directly below or slightly behind the fishing line. The setback of this line is somewhat exaggerated, for clarity, in Figure 3.

This fishing experiment was conducted on the 26m double-rigged shrimper, F/V Lady Kaye, out of Newport, Oregon. The trawl nets were of standard 4-seam design with 27.4m headropes and footropes. The tickler chain footrope was fished on the starboard net. The tickler chain itself was constructed of 25.6m of 8mm galvanized chain. Dropper chains of various gauges were attached at intervals along the fishing line to obtain the proper height above bottom, and did not connect to the tickler chain, but were left to drag freely along the sea floor (Figure 3). The ladder/roller footrope was fished on the port net. In this footrope configuration, the groundline is composed of 3 sections of line, each about 9.2 m long, totalling about 27.6m. The two sections closest to the wings were constructed of 8mm chain, while the center section was made of 6.4 cm rubber disks strung on a 9.2 m section of 13mm steel cable. This groundline was attached at intervals to the fishing line, with chains that increase in length from the wings to the center of the trawl footrope, creating the ladder configuration (Figure 3).

The use of a double-rigged vessel to compare the catch of two nets is an extremely powerful statistical design. It allows the detection of significant differences in catch rate with far fewer tows than an an alternate haul approach. However, it requires that some method be used to control for differences in catch efficiency between the two nets that are not due to the effect being examined. In prior experiments, examining the perfomance of BRD's, differences in net efficiency were controlled for by placing BRD's in both nets and systematically varying which BRD was active every two tows (Hannah et al. 1996). Those data were then analyzed as a three factor ANOVA without interaction, using haul, side of gear and the BRD as main effects. In this experiment, it was not possible to vary the effect of interest, footrope configuration, from side to side. Accordingly, we used an acoustic trawl monitoring system to measure the rise and spread of each net to account for differences in the shape of the fishing circle. A new section of galvanized chain was also attached to the fishing line of each trawl at the beginning of the experiment. This was done so that the approximate height of the fishing line above bottom could be determined from the length of chain that remained unpolished at the end of the experiment.

Catch evaluation included sorting and weighing all the catch by species or species group (Table 1) from each tow. The catch from the port and starboard nets was sorted and weighed separately. This was accomplished by emptying each codend into its respective side of a divided hopper. Catch from one side was completely sorted before sorting of the other side began. Sorting personnel included three biologists and two crew members.

Fish, and invertebrates other than shrimp, were sorted from the catch as it passed from the hopper over the sorting belt. Color coded baskets were used; red for starboard and grey for port, to prevent intermixing the catch from each side. This was a quick preliminary sort enabling us to weigh and ice the shrimp catch from both sides as quickly as possible. After all shrimp were placed in the hold, fish were re-sorted by species, as needed. Eelpouts and other very small and uncommon fish and invertebrates were simply discarded.

In comparative fishing experiments, it is common for some species to be present in some hauls but absent from others. This can make it difficult to make meaningful comparisons at the species level. To deal with this problem, and to facilitate rapid field sorting, we grouped some species together for analysis, including smelt (Osmeridae), juvenile rockfish (*Sebastes* spp.) and larger marketable fish (Table 1). The juvenile rockfish category included all rockfish less than roughly 8 cm.

We analyzed the catch data, by species group (Table 1) as a two factor ANOVA without interaction, with haul and footrope configuration as main effects. For most species groups, the catch by weight was used as the dependent variable. For small fish, such as juvenile rockfish, the catch by number was used instead of, or in addition to, the catch by weight. We log-transformed all catch data prior to ANOVA. The log transformation was used because we expected both fish escapement and shrimp loss to be proportional to the total catch in the control net (tickler chain). Accordingly a multiplicative, rather than an additive model is appropriate. This transformation is also generally helpful with catch data, since it tends to normalize a skewed distribution. To estimate the percentage reduction in catch caused by the ladder/roller footrope, the means of the transformed data were back transformed and the percent difference was calculated relative to the control net.

Results and Discussion

The longer, ladder/roller footrope reduced catches of slender sole (*Eopsetta exilis*) by 79 and 84 percent, by weight and number, respectively, relative to the tickler chain footrope ($p < 0.001$, Table 2 and Figure 4). The catch of greenstriped rockfish (*Sebastes elongatus*), a small species of rockfish, was also reduced 54 and 49 percent, by weight and number respectively ($p < 0.05$, Table 2 and Figure 4). The catch of juvenile rockfish (*Sebastes* spp) was reduced 47 percent, by number ($p < 0.05$, Figure 4).

Shrimp catch was increased in the net with the longer, ladder style footrope by about 6% over the control net ($p < 0.01$, Table 2, Figure 5). However, acoustic net measurements suggest that this may be due more to the greater spread obtained with the ladder style footrope than to any direct footrope effects on shrimp catch efficiency. The spread of the net with the ladder style footrope was measured at 17-18m, compared to a spread of 16-17m for the net with the tickler chain. This is a 6% increase in spread, roughly proportional to the increased shrimp catch observed. In accordance with the wider spread, the height of headrope above bottom was somewhat reduced for the net with ladder/roller footrope. This net had an average headrope height of 4.2m, versus 4.4m for the other net. Based on the degree of polishing on a center drop chain, the fishing lines of both nets were running at a comparable distance above the sea bottom, about 50-70 cm.

The catch of larger fish, including Pacific whiting (*Merluccius productus*) and most marketable fish, was not significantly different between the two footrope styles (p 0.05, Table 2). However, the mean catch for both species groups was higher for the net with a ladder/roller style footrope (Figure 5). The mean catch of smelt

(Osmeridae, not shown) was also slightly higher with the ladder/roller groundline, but the difference was not statistically significant (p 0.05). For all of these species groups, the increased catch is likely due to the wider spread of the net with the ladder style footrope.

One of the most interesting findings of this study was that the catch of the larger marketable fish was not reduced with the ladder style footrope, while the catch of slender sole and small rockfish was greatly reduced. While this could be due to sample variability and a relatively small sample size (N=17), it could also be interpreted as indicative of a size selection process occurring at the footrope. Such a process could arise from the interaction of a number of factors. The maximum swimming speed of fish has been shown to be a function of body length (Wardle 1975, He 1993). If larger fish also tend to “burst” swim ahead of the footrope for longer distances, and rise higher off bottom, the likelihood that they enter the trawl could be greater. Smaller fish on the bottom are also roughly equal in size to, or smaller than, the size of the groundline, and may ignore the fishing line, running roughly 50-70 cm above bottom. With the tickler chain running well ahead of the fishing line, small fish may dart over the tickler chain only to quickly encounter the fishing line, running behind it, and then continue upwards over it and into the trawl. With the shorter ladder/roller groundline, running below or slightly behind the fishing line, small fish darting upwards to avoid the groundline may simply run into the underside of the trawl webbing, escaping capture. Larger fish, in contrast, are more similar in size to the entire footrope configuration, and may perceive the fishing line and groundline more as one unit. If so, the likelihood that they would dart over the fishing line and into the trawl would be greater. While this seems a reasonable hypothesis, underwater camera work is needed to establish why small fish are not being captured by the trawl with a longer, ladder/roller style footrope.

The lack of any evidence for a reduction in shrimp catch with the longer, ladder style footrope, suggests that the tickler chain used traditionally in the ocean shrimp fishery may not be necessary to maintain good catch rates. This sentiment has been expressed by at least a few veteran ocean shrimp fishermen. One such fishermen uses no groundline at all, but rather a series of heavy drop chains to maintain the needed height of the fishing line above bottom. This particular fisherman catches shrimp at rates comparable to other similar size vessels fishing tickler chains. However, other vessel operators maintain that a tickler chain does increase ocean shrimp catch at times. Beardsley (1973) evaluated catches of ocean shrimp with and without a tickler chain, using an experimental vertical distribution sampling device and found that a tickler chain doubled his catches of shrimp, with most of the increase being in the lower sections of his sampling device. An alternative interpretation of the findings in this study is that the ladder style groundline is functioning similarly to a tickler chain with respect to shrimp behavior. Vibration of the seabed, or contact with shrimp on the bottom by the ladder style groundline, may also stimulate shrimp to jump upwards and be taken by the trawl. If that is the case, then something very different must be happening to the slender sole and small rockfish which are escaping capture, arguing further for some underwater camera work to see what is happening.

The growth and development of the ocean shrimp fishery was based, to a large degree, on gear and vessels borrowed from the Gulf of Mexico fishery for penaeid shrimp (Zirges and Robinson 1980), where a tickler chain is definitely needed to maximize shrimp catch. It is possible that the use of tickler chains in the ocean shrimp fishery is based as much on tradition as necessity, and we recommend that further testing be completed to examine this question. If ladder style groundlines, or footropes using only heavy drop chains, can be shown to consistently reduce bycatch of some unwanted species, without decreasing shrimp catch rates, then voluntary use of such gear is likely to grow.

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References

Beardsley A. 1973. Design and evaluation of a sampler for measuring the near-bottom vertical distribution of pink shrimp (*Pandalus jordani*). Fishery Bulletin Vol. 71(1):243-253.

Hannah, R.W., S. A. Jones and V. J. Hoover. 1996. Evaluation of fish excluder technology to reduce finfish bycatch in the pink shrimp trawl fishery. Oregon Dept. Fish Wildl., Information Rept. Ser., Fish. No. 96-4. 46 p.

He, P. 1993. Swimming speeds of marine fish in relation to fishing gears. ICES Mar. Sci. Symp. 196:183-189.

High, W.L., I.E. Ellis and L.D. Lusz. 1969. A progress report on the development of a shrimp trawl to separate shrimp from fish and bottom dwelling animals. Commercial Fisheries Review 31(3):20-33.

Isaksen, B., J.W. Valdemarsen, R.B. Larsen and L. Karlsen. 1992. Reduction of finfish by-catch in shrimp trawl using a rigid separator grid in the aft belly. Fisheries Research 13:335-352.

Jones, S.A., R.W. Hannah and J.T. Golden. 1996. A survey of trawl gear employed in the fishery for ocean shrimp *Pandalus jordani*. Oregon Dept. Fish Wildl., Information Rept. Ser., Fish. No. 96-6. 23 p.

Lukas, J. and C. Carter. 1998. 1996 pounds and value of commercially caught fish and shellfish landed in Oregon. Oregon Dept. of Fish and Wildlife. 120 p.

Pacific Fishery Management Council. 1981. Discussion draft fishery management plan for the pink shrimp fishery off Washington, Oregon, and California. PFMC. 169 p.

Wardle, C.S. 1975. Limit of fish swimming speed. Nature 225: 725-27.

Zirges, M.H. and J.G. Robinson. 1980. The Oregon pink shrimp fishery, management history and research activities, Oregon Dept. Fish Wildl., Information Rept. Ser. Fish. No. 80-1. 15 p.

Table 1. Species composition of species groups used for analysis of catch data.

Species Group	Species Included	Scientific Name
Marketable Fish	Dover sole	*Microstomus pacificus*
	Canary rockfish	*Sebastes pinniger*
	Yellowtail rockfish	*Sebastes flavidus*
	Sablefish	*Anoplopoma fimbria*
	Lingcod	*Ophiodon elongatus*
Smelt	Various	Osmeridae
Juvenile Rockfish	Various	*Sebastes* spp.

Table 2. Average percent reduction (increase) by number and weight, by species group, for the ladder/roller groundline relative to the traditional tickler chain groundline.

Species /Group	Percent Reduction By Weight	Percent Reduction By Number
Ocean Shrimp	(6.2)**	--
Pacific whiting	ns	--
Marketable Fish	ns	--
Slender sole	79.2***	83.9***
Smelt	ns	--
Juvenile Rockfish (<8cm)	--	47.4*
Greenstriped Rockfish	53.6*	49.0*

ns = non-significant
* $p<0.05$, **$p<0.01$, *** $p<0.001$

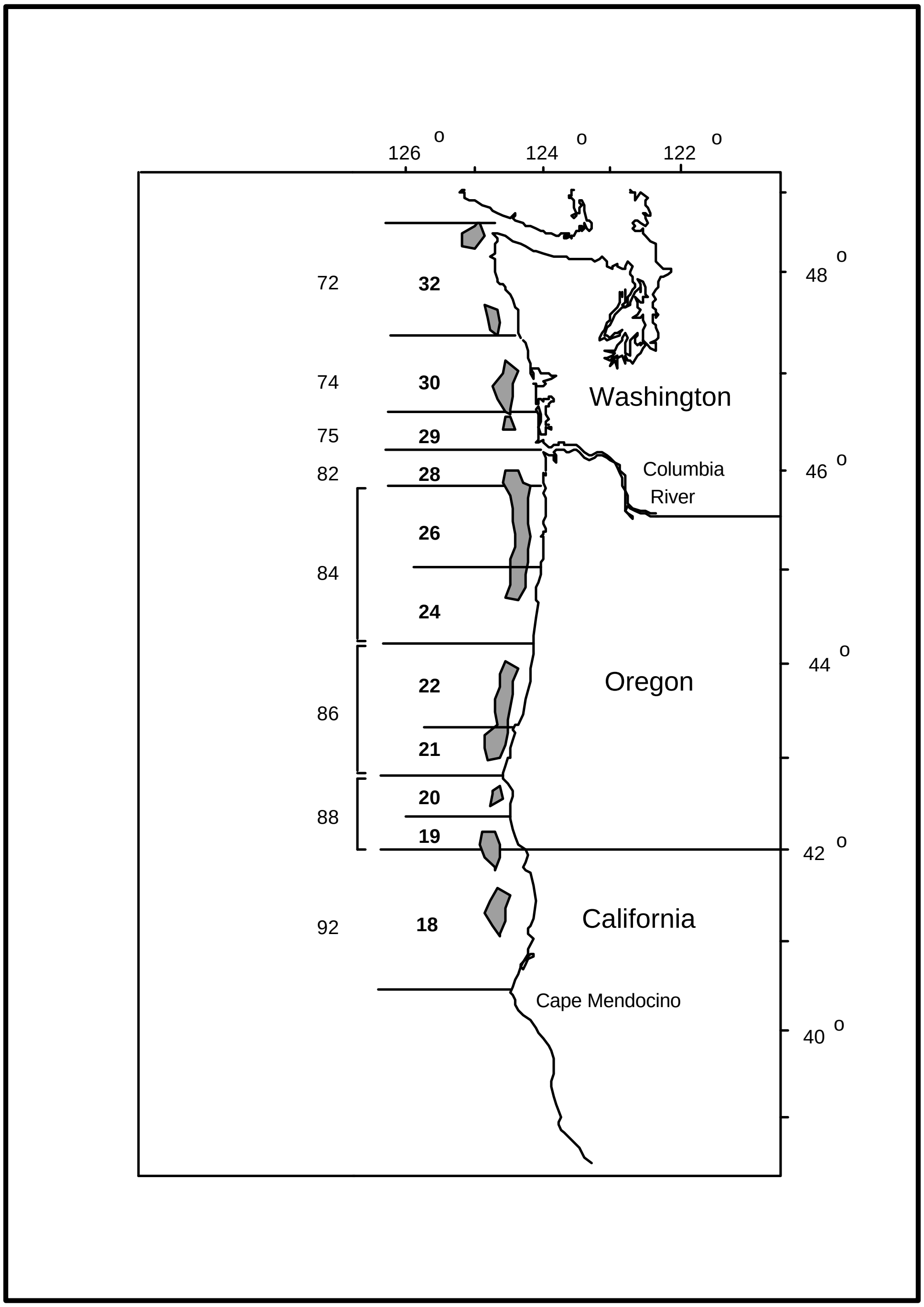
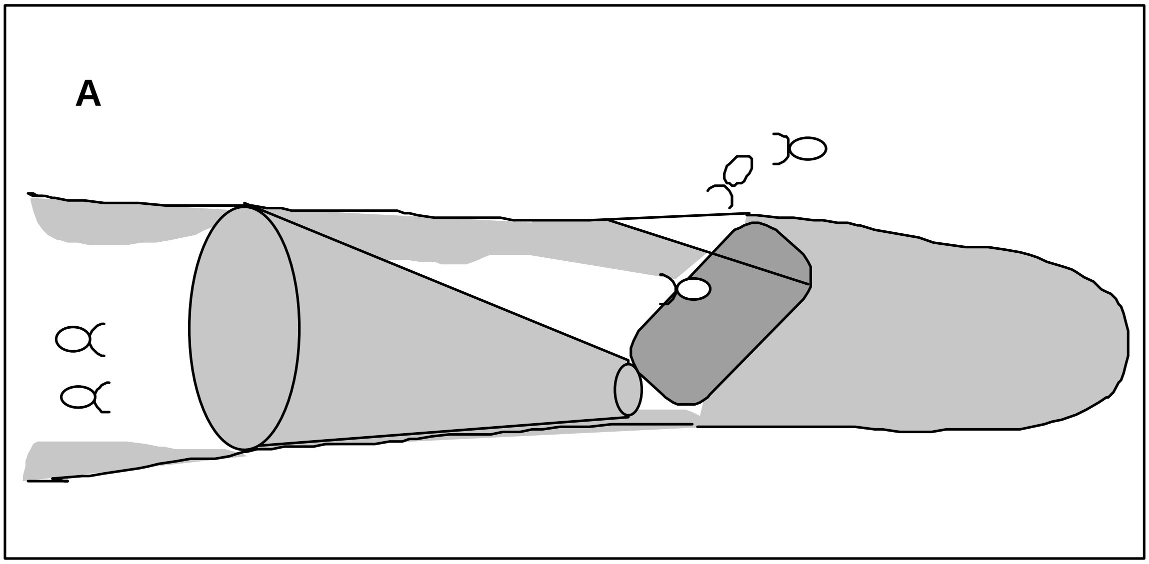


Fig. 1. Location of commercial concentrations of pink shrimp *Pandalus jordani* along the U.S. Pacific coast (shaded areas), PSMFC statistical areas 72-92 and Oregon State statistical areas 18-31 (bold).



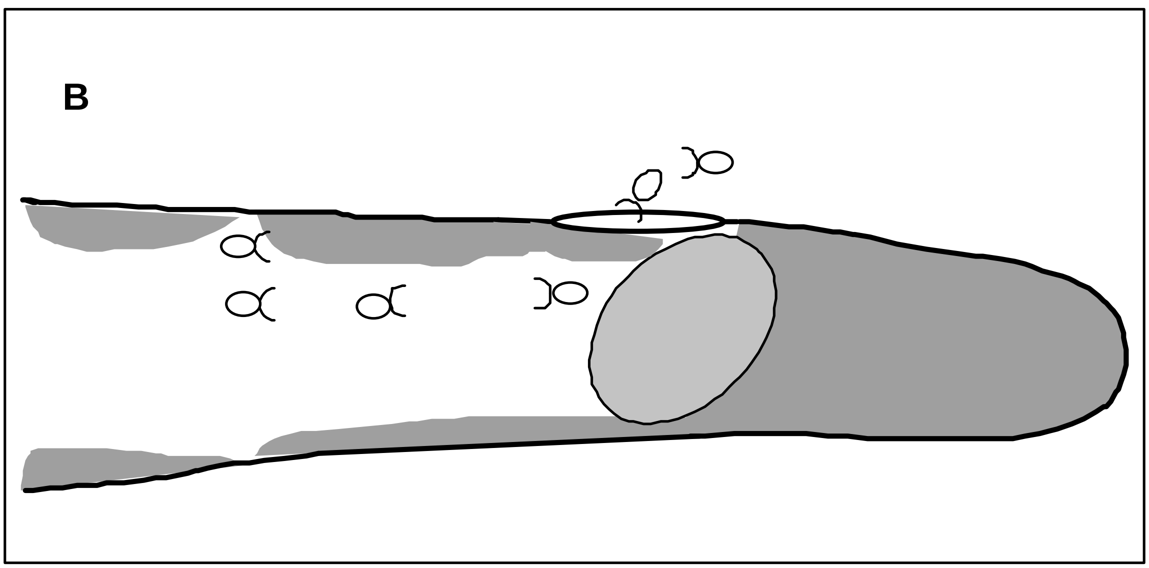


Fig. 2. Nordmore gate (A) and large mesh panel (B) by-catch reduction devices.

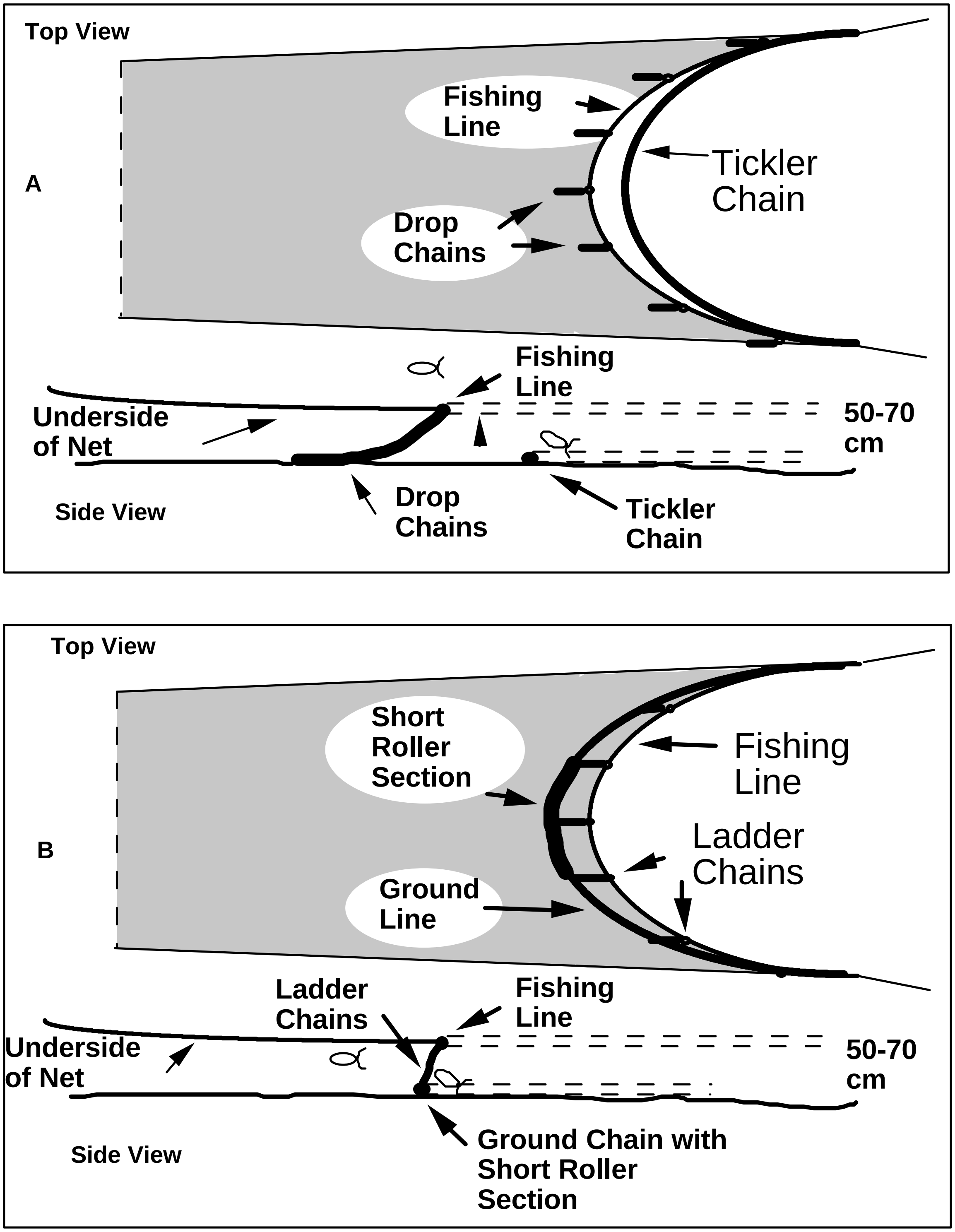


Fig. 3. Schematic of trawl footrope with tickler and dropper chains (A) and with ladder/roller footrope (B).

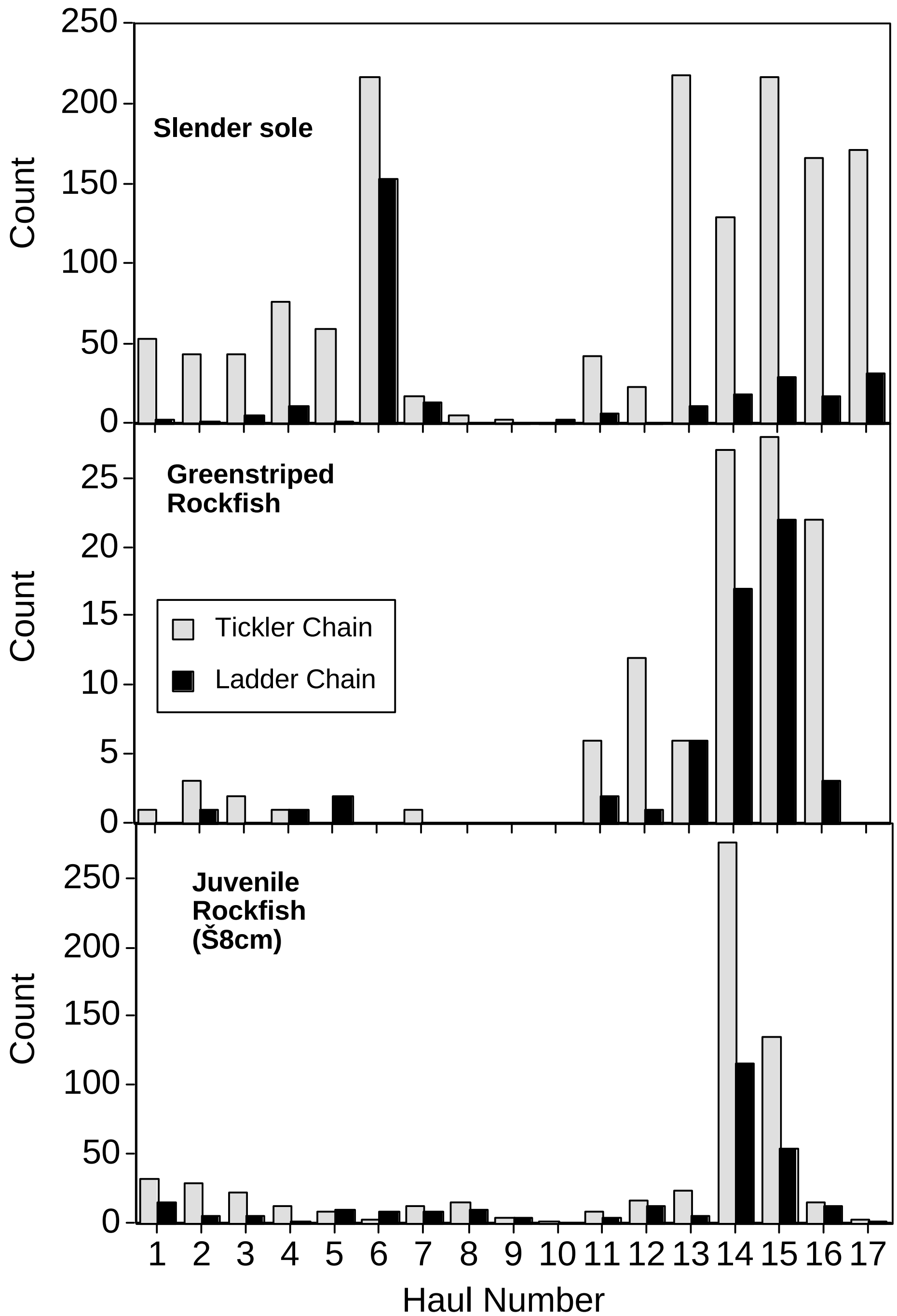


Fig. 4. Catch of slender sole, greenstriped rockfish and juvenile rockfish, by haul, for the tickler chain and ladder/roller style footropes.

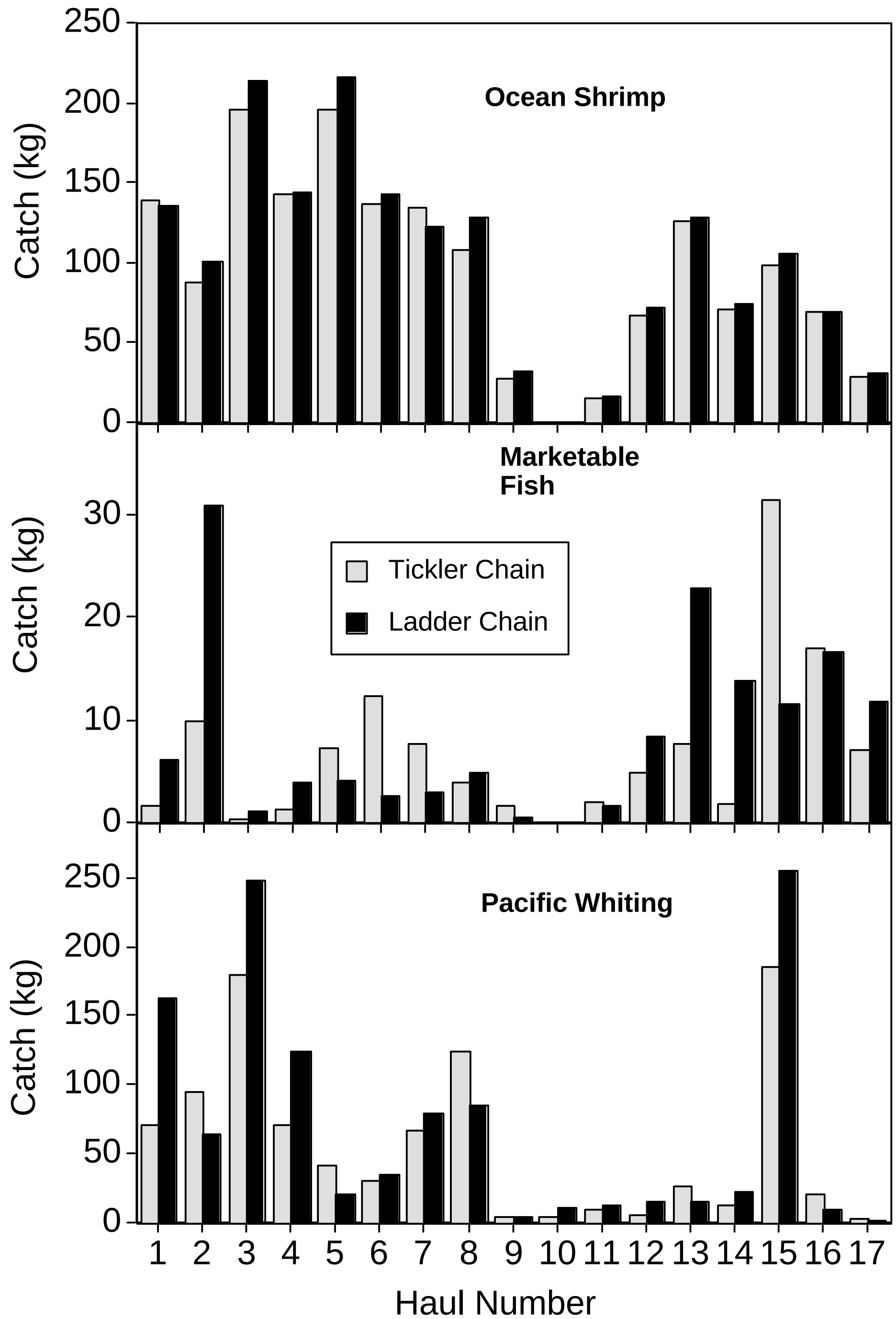


Fig. 5. Catch of ocean shrimp, marketable fish and Pacific whiting, by haul, for the tickler chain and ladder/roller style footropes.