Alternative Branch Line Weight Designs to Improve Crew Safety and Reduce Bycatch of Sensitive Species Groups in Pelagic Longline Fisheries

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Abstract
Placing weights near hooks in pelagic longline fisheries can reduce seabird, sea turtle, shark and billfish bycatch. However, vessels that do not use a wire leader on branch lines, such as in the Hawaii-based longline swordfish fishery, do not place weights close to the hook, or use any weights on their branchlines, in part, due to safety concerns: If branchlines break during hauling, which frequently occurs when sharks are caught and bite off the terminal tackle, the weight can fly back at the vessel at extremely high velocity, infrequently causing serious injury, and in very rare cases, killing crew. A dockside trial and research fishing trip on a Hawaii longline swordfish vessel was conducted to assess the efficacy and commercial viability of two experimental designs of safer weights. Results from the dockside trial indicate that the two experimental weights present a substantially reduced risk of injury to crew relative to conventionally employed line weights. Results from one experimental fishing trip demonstrated that an experimental weight performed as designed, however, the sample size was too small to demonstrate a significant difference in weight behavior after lines brake during gear retrieval between the control and experimental weight. Additional research and development is needed to overcome identified practicality issues (threading one of the experimental weights onto the line, gear tangling due to absence of a swivel), and durability of the experimental weights, while keeping the per-unit cost low enough to be economical and competitive with conventional lead center swivels. All problems encountered with the two experimental leads are likely possible to overcome. With additional research and development, it will be possible to develop a simple, inexpensive, and durable safer lead weights for use in pelagic longline gear.

1. INTRODUCTION

Maximizing baited hook sink rates in pelagic and demersal longline gear contributes to reducing seabird interactions in longline fisheries (Brothers et al., 1999; Gilman et al., 2005; Robertson et al., 2006). Mortality in longline fisheries is the most critical global threat to most albatross and large petrel species (Gales, 1998; Brothers et al. 1999; Gilman et al., 2005). Furthermore, deeper gear setting contributes to reducing interactions with sea turtles, sharks, and some nontarget species of billfish (Beverly and Robinson, 2004; FAO, 2008; Gilman et al., 2006, 2008). However, captains and crew of longline vessels that do not use a wire leader on branch lines, such as in the Hawaii-based longline swordfish fishery, do not place weights close to the hook, or use any weights on their branchlines, in part, due to safety concerns: If the branch line breaks during hauling, which frequently occurs when sharks are caught and bite off the terminal tackle, the weight has been observed to fly back at the vessel at extremely high velocity (about twice per trip in the Hawaii longline swordfish fishery [personal communication, Hiep Tran, Hawaii longline observer, 8 April 2008]), infrequently causing serious injury, and in very rare cases, killing crew.

A new prototype lead, designed by the United Kingdom-based company, FishTek, and a simpler design employing the same concept, may provide a safe alternative to current commercially available weighted swivels, enabling vessels that do not use a wire trace to place weights close to the hook. The experimental lead weights are designed to slide along the branchline when the line breaks under high tension so that the weight falls safely into the water or otherwise comes back at the vessel at a much reduced velocity so as to not pose a safety risk to crew. The experimental leads are designed to slide along or off the line as a result of the accelerating force when the line breaks under high tension.

We conducted a dockside controlled experiment and an at-sea trial on a Hawaii-based longline swordfish vessel of prototype safer weights. Efficacy and practicality were analyzed to determine if the prototype weights performed as intended and if they are commercially viable (economical and practical for use).

2. METHODS

2.1. Dockside simulated bite-off experiment

A controlled experiment was conducted using a control treatment of conventional 60 g lead center swivels, and two experimental treatments: (i) 60 g weight, consisting of two leads sandwiched against a rubber carrier and held together by two O-rings, designed by the UK-based company Fishtek in collaboration with BirdLife International and given the commercial name 'SafeLead', and (ii) an egg lead inserted inside rubber tubing (Fig. 1), to determine any difference in response after cutting the branchline near the hook when the line is at high tension, simulating a shark biting off the terminal tackle during gear retrieval. The egg lead treatment entailed inserting a 57 g (2 oz) egg lead into a 3 g piece of 12 mm diameter outside diameter, 2 mm diameter wall, 6 cm long, rubber tubing; silicone was sprayed into the tubing before inserting the lead into the tube, and threading the fishing line between the lead and tube (Fig. 2). Fig. 3 shows the components of the Safe Lead experimental treatment, which is 38 mm long, 19 mm wide. The fishing line was threaded through a hole in the center of the rubber core carrier of the Safe Lead, facilitated by pinching the sides of the carrier to partially release the O-ring tension.

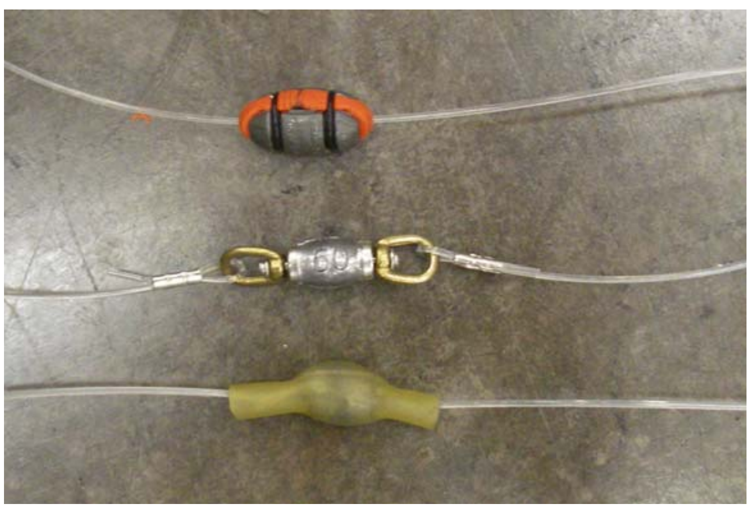

Fig. 1. Experimental FishTek-designed 'SafeLead' consisting of two pieces of lead, a rubber carrier in between the leads, and two O-rings (top), conventional lead center swivel (middle), and experimental egg lead inserter in rubber tubing (bottom).

Fig. 2. One of the two experimental treatment leads, consisting of a 57 g egg lead inserted into thin-walled rubber tubing. Silicone was sprayed into the tubing before inserting the lead.


Fig. 3. The five components of the ‘Safe Lead’ experimental treatment, including two O-rings, two pieces of lead, and a rubber carrier.

Ten of each of the control, half-lead, and tube-lead experimental treatment branchlines were placed under 36.3 kg (80 lb) of tension, the length that the line stretched was measured, and the line was cut a few centimeters above the hook.

The control treatment was placed on a conventionally designed longline swordfish branchline, composed of an 18/0 circle hook, 4.9 m long 2.1 mm diameter monofilament leader, 60 g weighted swivel crimped onto the line, 13.4 m long upper portion of 2.1 mm diameter monofilament between the swivel and a 50.8 cm long length of rope attached to a clip (145 mm 148-1/8” x 8/0).

The two experimental treatments employed the same hook, clip, and monofilament line as the control treatment. The branchline was threaded through the experimental leads to place the lead 4.9 m above the hook, and 13.4 m from the clip at the target.

A target at the clip was made of three sheets of 5.08 cm (2 inch) thick expanded polystyrene (eps), (Fig. 4). Both the clip and target were attached to a forklift.

Fig. 4. Lead weights were projected at an EPS target at the “boat”-end of the branchlines.

After cutting the branchline, the lead was observed to either fall to the floor before reaching the target, or otherwise to hit the target. When a lead hit the target, the depth of penetration was measured using calipers to the nearest 1 mm and recorded.

A forklift was used to create the tension in the branchline. The line tension was measured with a scale (Fig. 5). A new monofilament branchline was employed for each replicate, because used line would remained stretched out (lose some flexibility) after conducting a trial.

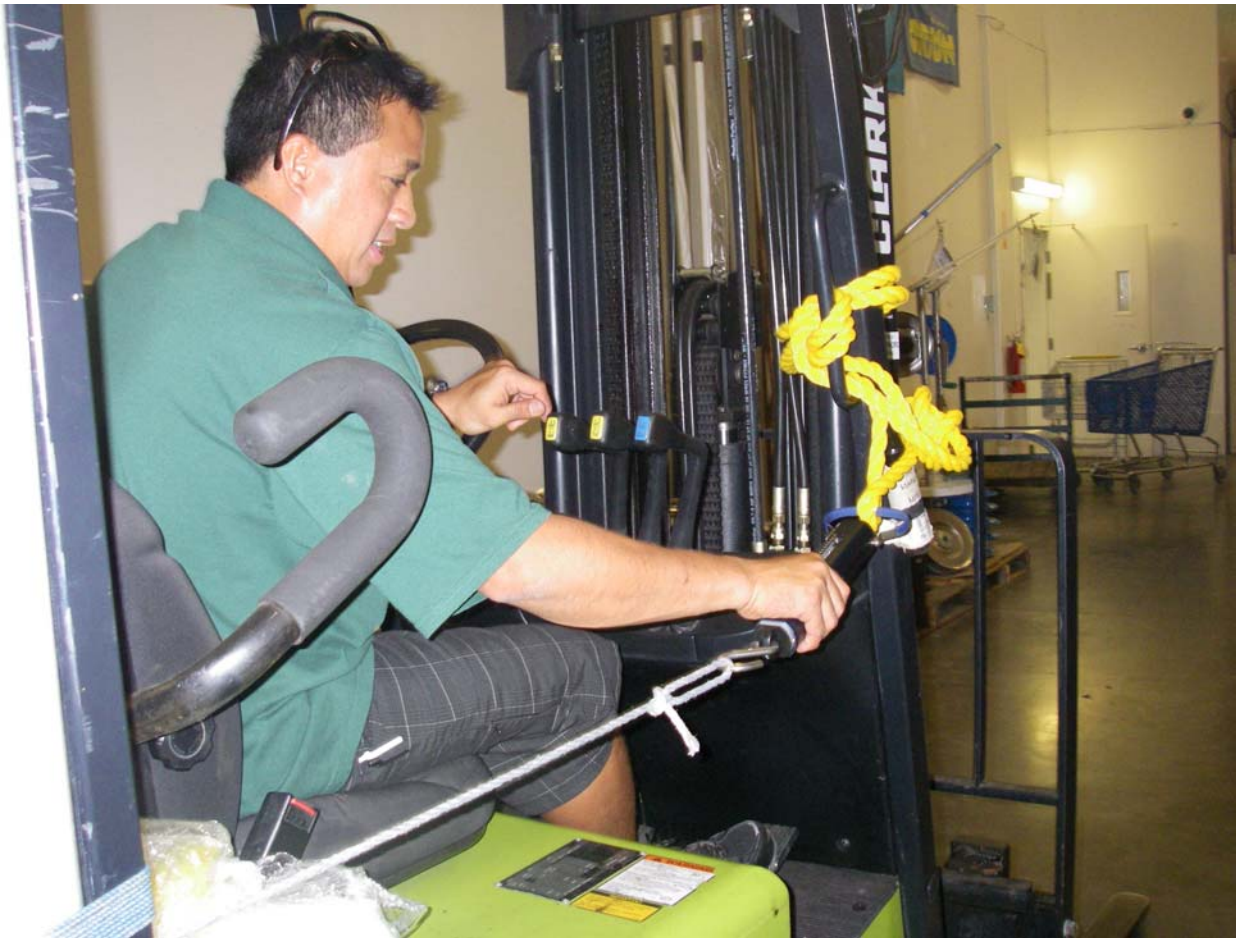

Fig. 5. Scale being used to bring the branchline under 36 kg (80 lb) of mass.

T-tests were used for statistical analysis of observations of branchline stretching, depth of weight penetration into a target, and distance experimental weights slid along the line. A multiple t-test was used when comparing three treatments of the line stretching study component, for which the alpha level was adjusted for a family-wise error rate of ± 0.02 instead of ± 0.05 used for the comparison-wise (two treatment comparison) error rate.

2.2. At-Sea Trial

An at-sea trial using a control treatment of 80 g center lead swivels and an experimental treatment of the FishTek Safe Leads with 50% 45 g and 50% 60 g weights was conducted on the F/V Kimmy 1, a Hawaii-based longline swordfish vessel on one fishing trip of 29 sets between 21 February – 31 March 2008. The branchline design (hook, line lengths and diameter, clip, weight location) was generally the same as described in the control treatment of the dockside experiment, except weights were placed at about 3.7 m from the hook. Gilman et al. (2003) provide details of the fishing gear and methods of the Hawaii longline tuna and swordfish fisheries, and Beverly et al. (2003) provide a general description of pelagic longline fishing methods and gear. Despite the suggestion of Hawaii Longline Association members assisting with the project, the vessel captain declined to incorporate un-weighted barrel swivels above the experimental treatment weights, recommended to reduce the potential risk of gear tangling when no swivel is incorporated within the branchline. Half of the vessel's 1,000 branchlines contained control and experimental weights at the beginning of the trip. For the first set, the first half of branchlines set contained the experimental treatment, and the second half used conventional center lead swivels (a balanced, non-randomized design). Control and treatment weights were randomly mixed during subsequent sets and kept in roughly equal proportions for each subsequent set (randomized and balanced design). During each haul, the following information was collected:

(i) Number of branchlines that broke during gear retrieval, and of these, which contained control vs. experimental weights;
(ii) For each branchline that broke during gear retrieval, did the weight come off the line and fly at the vessel (hit the hull or come over the rail), come off the line and fall into the water (not reach the vessel), or remain on the line and fall into the water.
(iii) Number of branchlines that had terminal tackle (hook, portion of leader) removed during the gear soak, and of these lines that contained experimental weights, how many had the weight remain on the line vs. fall off the line; and
(iv) The number of branchlines containing the experimental weight that had the weight slide close to the hook or clip (approximately 3.7 m from the initial position) during the gear soak (lines that did not have terminal tackle removed).

At the end of the experimental fishing trip, the captain, crew and onboard observer were interviewed to obtain their perspective on the commercial viability (practicality and economic viability) of the FishTek Safe Lead experimental weight.

3. RESULTS – DOCKSIDE TRIAL

Table 1 provides summary statistics of the amount the treatment branchlines stretched during the dockside trial. The error intervals of the three treatments overlap, indicating no significant difference in line stretching between the treatments.

Table 1. Length of branchline stretching when placed under 36.3 kg (80lb) of stress for three treatments of line weighting.

	Length branchline stretched (m)			
	Treatment			
	Control	FishTek Safe Lead	Egg lead	Combined treatments
Mean	1.47	1.42	1.38	1.42
N	10	10	10	30
Range	1.1 – 1.8	1.0 – 1.9	1.0 – 1.7	1.0 – 1.9
SD of the mean	0.084	0.091	0.064	0.048
t-test 95% CI	±0.06	±0.07	±0.05	±0.02

Table 2 provides summary statistics of the amount each treatment penetrated the target. Based on non-overlapping error intervals, the control treatment weight mean depth of penetration into the target was significantly greater than the experimental treatment weights. The FishTek Safe Lead reached the target 2 out of the 10 replicates, and the two contacts penetrated the target a mean of 0.32 cm.

Table 2. Depth of penetration of a control and two experimental branchline weights into a target after the line was placed under 36.3 kg of tension and the line was cut near the hook.

	Depth of weight penetration (cm)			
	Treatment			
	Control	FishTek Safe Lead	Egg lead	Combined treatments
Mean	2.73	0.063	0	0.93
N	10	10	10	30
Range	1 – 5.6	0 – 0.38	0-0	0 – 5.6
SD of the mean	0.47	0.043	0	0.28
t-test 95% CI	±0.29	±0.03	±0	0.10

Table 3 provides summary statistics for the distance that the two experimental treatment weights slid along the branchline after cutting the line under high tension. Based on non-overlapping error intervals, the mean distance that the FishTek Safe Lead weights slid along the branchlines was significantly larger than that of the egg lead weights.

Table 3. Distance of sliding along branchlines of two experimental weights after the line was placed under 36.3 kg of tension and the line was cut near the hook.

	Distance of sliding (m)		
	Treatment		
	FishTek Safe Lead	Egg lead	Combined treatments
Mean	1.53	1.09	1.31
N	10	10	20
Range	0.8 – 2.2	0.7 – 1.4	0.7 – 2.2
SD of the mean	0.13	0.08	0.09
t-test 95% CI	±0.08	±0.05	±0.04

During the dockside trial, the majority of the 45 g Safe Lead weights proved to be extremely difficult to thread onto the monofilament line without having the line exit out the side of the intended pathway (Fig. 6). This problem was encountered with 1.8 mm, 20.0 mm and 2.1 mm diameter monofilament line. This problem was also encountered with the 60 g safeleads but only in a small minority of attempts. It was also difficult to thread the egg lead weight onto the line, but to a lesser degree than with the Safe Lead weights.

Fig. 6. Difficulty threading fishing line through the Safe Lead weight: line exits through the wall of the carrier rubber core.

The simpler egg lead design was found to be substantially less durable than the Safe Lead design: the tubing used for the simpler design tore after 1-2 uses. This was likely caused by the friction of the lead sliding along the line with each replicate.

4. RESULTS – AT-SEA TRIAL

There were a total of 29 sets with a total of 24,592 hooks set during the experimental fishing trip. Table 4 provides summary statistics comparing the performance of the control and experimental weights. For both the control and experimental weights, for all branch lines that broke during gear retrieval, all of the weights remained on the line and fell safely into the water; none of the weights reached the vessel. Of the branchlines where terminal tackle was removed during the gear soak, all of the control and experimental weights remained on the line. During the trip, 34 of the experimental leads were observed to substantially move position of a total of about 12,296 branchlines containing the experimental weights (0.3%).

Table 4. Summary statistics of the performance of conventional center lead swivels and experimental FishTek Safe Leads weights, from an at-sea trial on a Hawaii longline swordfish vessel.

		Branchline broke during gear retrieval - Conventional weights				Branchline broke during gear retrieval - Experimental weights				Terminal tackle removed during soak		
	Experim -ental weights slide to hook[a]	Total broke	Weight came back to vessel	Weight fell off line into water	Weight stay on line fall into water	Total broke	Weight came back to vessel	Weight fell off line into water	Weight stay on line fall into water	Lines with conventional weight[b]	Lines with experimental weight	Experiment- al weight fell off line
Number	34	58	0	0	58	59	0	0	59	7	10	0
Rate (no./1000 hooks)	2.77	4.72	0	0	4.72	4.80	0.00	0.00	4.80	0.57	0.81	0.00
Percent	0.28	0.47	0	0	0.47	0.48	0.00	0.00	0.50	0.06	0.08	0.00
Mean per set (95% CI)	1.17 ± 0.09	2.00 ± 0.11	0	0	2.00 ±0.11	2.03 ± 0.11	0.00	0.00	2.03 ± 0.11	0.24 ± 0.03	0.34 ± 0.05	0.00

[a] All safeleads observed to substantially move position during the soak slid to the hook, none were observed to slide towards the clip.

[b] All branchlines containing conventional swivels retained the swivels when terminal tackle was lost during the soak

The onboard observer noted that only when a large fish (swordfish or shark) was caught did the experimental weight substantially move position, otherwise, the weight was not observed to move position. Only on rare occasion was the experimental weight observed to be damaged: when very large fish were caught, they tend to tangle the gear, which in rare occasions (fewer than 10 times during the trip) did an O-ring of an experimental weight fall off.

There were no observed interactions with protected species (seabirds, sea turtles or marine mammals) during the trip.

At the end of the experimental fishing trip, the crew identified one concern of practicality with the FishTek experimental weight: There was a relatively high incidence of branchline tangling with the mainline on branchlines containing the experimental weight, believed to be a result of there being no swivel incorporated into these branchlines. The captain's only concern with the experimental weights was that they were of smaller weight than his conventionally employed weight, where the lighter branchlines likely set at shallower depths than the conventional design, potentially adversely affecting the target species catch rate. Neither the crew nor captain expressed having had any difficulty threading the experimental weights onto the branchlines.

5. DISCUSSION

5.1. Efficacy

In the dockside trial, both experimental lead weights proved to be substantially safer than the conventional weighted swivel. The egg lead did not reach the target during 10 replicates. The Safe Lead weight reached the target only 2 of 10 replicates, and penetrated the target a mean of 0.32 cm for the two times that it did reach the target, compared to a mean of 2.73 cm for the conventional lead. The majority of the time, the experimental weights would fall safely into the water when the branchline breaks during gear retrieval, and when the weight does reach the vessel, it would be moving at a substantially smaller velocity than conventional weights (Table 2), posing a substantially lower risk of injury. Results from the at-sea trial demonstrated that the FishTek experimental weight performed as designed, however, none of the conventional weights reached the vessel when lines broke during gear retrieval. Based on anecdotal information (about 2 conventional leads will reach the vessel during a typical Hawaii longline swordfish trip, [personal communication, Hiep Tran, Hawaii longline observer, 8 April 2008]), a much larger sample size would be needed to observe a significant difference between the control and experimental weights in their behavior after lines brake during gear retrieval.

The observation of no significant difference in branchline stretching between the three treatments (Table 1) enables dismissing this potential confounding factor. If there had been a significant difference in mean line stretching between the treatments, differences in line elasticity could have affected observed differences in weight behavior after lines were cut under tension.

Results from the dosckside trial suggest there is likely a very small and non-significant difference between the two experimental weights in terms of their frequency in reaching the fishing vessel and risk to crew when they do reach the vessel. However, as a result of the rarity of weights reaching the target for the two experimental treatments, the confidence interval estimates of uncertainty for these treatments are likely to be inaccurate, especially in cases of no observed contacts with the target for the egg lead, with a confidence interval of 0.00 – 0.00 (Table 2). In other words, with a sufficiently larger sample size, the egg lead would likely eventually reach the target. However, results from the dockside trial indicate that the two experimental weights clearly are less likely to reach the vessel than the conventional weight, and are moving at a substantially smaller velocity, posing a substantially smaller risk of injury to crew.

The observation that both experimental weights slid 1-1.5 m along the branchline after the line was cut is further evidence that the weights are performing as designed, in that their velocity after cutting the line is diminished due to movement along the line relative to the conventional weight, which is fixed in its position on the line. The result that the Safe Lead slid significantly further than the egg lead, while only a small < 0.5 m difference between the means (Table 3), would suggest that the FishTek lead would be projected from the line after cutting at a smaller velocity than the egg leads. However, observations presented in Table 2 indicate that the difference in velocity of the weights after cutting the line is small, where the observation of the mean impact on the target being greater for the FishTek lead relative to the egg lead was inconsistent with the observation of differences in sliding.

5.2. Cost

The estimated cost of the FishTek Safe Lead weight is estimated to be USD 1.00 each for both the 45 and 60 g weights (personal communication, 26 April 2008, Pete Kibel, FishTek). The retail cost for one conventional 45 g and 60 g leaded swivel is USD 1.50 and 1.75, respectively (personal communication, Jim Cook, Pacific Ocean Producers, 10 April 2008). The egg lead device costs about USD 0.15 per unit (personal communication, 29 February 2008, Jim Cook, Pacific Ocean Producers). The durability of the experimental weights as currently designed means that they would need to be replaced substantially more frequently than conventionally employed weighted swivels.

5.3. Practicality

Movement of the FishTek weight on branchlines and loss of the weights when terminal tackle was lost during the gear soak was not observed to be problematic during the at-sea trial. Of the branchlines where terminal tackle was removed during the gear soak, all of the experimental weights remained on the line (Table 4). During the trip, only about 0.3% of the experimental leads were observed to substantially move position, believed to occur only when large fish are caught. Modifications to the design of both experimental lead weights could be made to change the degree to which the weight slides along the line when a fish bite off occurs. For example, the egg lead weight treatment could employ a cylinder-shaped lead to increase surface area contact with the rubber tube, increasing friction and reducing the weights ability to slide on the line. Using a thicker or smaller diameter rubber tubing could also modify the weights ability to slide.

The problem encountered during the dockside trial of threading the Fishtek Safe Leads onto the line, and to a lesser degree, threading the egg leads into the rubber tubing, likely could be resolved with use of different materials and modified designs. The crew did not experience problems threading the FishTek weights onto the line during the at-sea trial

5.4. Durability

The design employed for the egg lead experimental weight would likely be unsuitable for commercial application due to poor durability. Use of a thicker rubber tube, or crimping the lead directly onto the line without needing a rubber tube, could overcome the durability problem.

5.5. Incorporating an un-weighted swivel with the experimental sliding leads, line tangling

If fishermen want to use a swivel with either experimental lead, the experimental lead should be fitted below the swivel (between the swivel and hook), so that in the event of the line breaking, the lead can slide off the end without getting stuck on the swivel. However, if the leads are fitted above a swivel (between the swivel and clip on the mainline), the FishTek Safe Leads are designed so that the lead halves separate from the carrier. Using a swivel with the experimental leads could resolve problems encountered with line tangling experienced during the at-sea trial.

6. CONCLUSIONS

Placing weights near hooks in pelagic longline fisheries can reduce seabird, sea turtle, shark and billfish bycatch (Brothers et al., 1999; Beverly and Robinson, 2004; Gilman et al., 2005, 2006, 2008; Robertson et al., 2006; FAO, 2008). However, vessels that do not use a wire leader on branch lines, such as in the Hawaii-based longline swordfish fishery, do not place weights close to the hook, or use any weights on their branchlines, in part, due to safety concerns: If the branch line breaks during hauling, which frequently occurs when sharks are caught and bite off the terminal tackle, the weight has been observed to fly back at the vessel at extremely high velocity, infrequently causing serious injury, and in very rare cases, killing crew. A dockside trial and research fishing trip on a Hawaii longline swordfish vessel was conducted to assess the efficacy and commercial viability of two experimental designs of safer weights.

Results from the dockside trial indicate that the two experimental weights present a substantially reduced risk of injury to crew relative to conventionally employed line weights: the control treatment weight mean depth of penetration into the target was significantly greater than the experimental treatment weights. The egg lead did not reach the target during 10 replicates, the FishTek Safe Lead weight reached the target only 2 of 10 replicates, and penetrated the target a mean of 0.32 cm when it did reach the target, compared to a mean of 2.73 cm for the conventional lead. Results from the single at-sea experimental fishing trip demonstrated that the experimental FishTek Safe Lead weight performed as designed, however, because none of the conventional weights reached the vessel when lines broke during gear retrieval, results do not demonstrate a difference in safety between the control and experimental weights. Based on anecdotal information, a much larger sample size would be needed to observe a significant difference between the control and experimental weights in their behavior after lines brake during gear retrieval.

Additional research and development is needed to overcome practicality issues (threading the Safe Lead weights onto the line, gear tangling due to absence of a swivel with the experimental weights), durability (rubber tubing of the egg lead, O-rings of the Safe Lead), while keeping the per-unit cost low enough to be economical and competitive with conventional lead center swivels. All practicality and durability problems encountered with the two experimental leads are likely possible to overcome, so that with additional research and development, it will be possible to develop a simple, inexpensive, and durable safer lead weights for use in pelagic longline gear. If a ‘safe lead’ design is produced that overcomes currently experienced issues with practicality, durability and cost, pelagic longline fisheries that currently do not place weights near hooks due to safety concerns may use the new safer weights.

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