Preliminary report of 2010 weighted branch-line trials in the tuna joint venture fishery in the south African EEZ

(WCPFC-SC7-2011/EB-WP-07)

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PRELIMINARY REPORT OF 2010 WEIGHTED BRANCH-LINE TRIALS IN THE TUNA JOINT VENTURE FISHERY IN THE SOUTH AFRICAN EEZ

WCPFC-SC7-2011/EB-WP-08

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Preliminary Report of 2010 Weighted Branchline Trials in the Tuna Joint Venture Fishery in the South African EEZ

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ABSTRACT

The lack of comprehensive research developing and comparing seabird bycatch mitigation technologies appropriate to pelagic longline fisheries has led to considerable debate regarding best-practice mitigation to prevent seabird mortality among tuna commission and their member countries. Our research in the South African tuna joint venture fishery in 2009 obviated the need to shrink the area astern of the vessel that birds have access to baited hooks via weighted branchlines to force seabird interactions into an area that can be successfully defended with streamer lines – shrink and defend. Taking this philosophy further, in 2010 we compared the performance of a revised “hybrid” streamer lines deployed with weighted (W) and un-weighted (UW) branchlines on two Japanese vessels participating in the 2010 tuna joint venture fishery in the South Africa EEZ. Seventeen birds species attended the vessel during line setting, but only four made primary attacks on baits and were killed. White-chinned petrels were the most abundant bird; they were present during all sets, attacked at the highest rate and were the bird most killed. Albatross attack rates were near two orders of magnitude lower than that of white-chinned petrels, but eight were killed suggesting strongly that secondary attacks – birds stealing baits from birds having made a primary attack – drove albatross mortality. Twenty-four of the 27 bird mortalities occurred after nautical dawn. All three birds caught at night were on UW lines. Weighting branchlines with hybrid streamer lines dramatically reduced seabird attacks, secondary attacks and seabird mortalities with little effect on fish catch. Four of 27 bird mortalities (2 white-chinned petrels, 1 shy albatross, and 1 cape gannet) were on W branchlines – a reduction in seabird bycatch rate of 86 % compared to UW (UW = 0.280 and W = 0.040 birds/1,000 hook). Mean tuna catch was near equal on the two branchline types, but W branchlines tangled on themselves three times more often than UW branchlines. No crew injuries occurred from either branchline type. These preliminary results indicate that the shrink and defend conceptual framework of seabird bycatch mitigation is effective at reducing seabird interactions with pelagic longline fishing gear. Specifically, these results strongly suggest that two hybrid streamer lines together with weighted branchlines and night setting constitute best-practice seabird bycatch mitigation for the joint venture fleet operating in the South Africa EEZ and other white-chinned petrel dominated fishing areas. These results also suggest that the Column A and Column B mitigation approach adopted by WCPFC (CMM 2007-04) and IOTC (Resolution 10/06), as currently written, would not prompt the simultaneous use of two hybrid streamer lines, branchline weighting and night setting, and therefore, falls short of the best-practice mitigation identified in this study.

INTRODUCTION

Internationally managed pelagic longline fisheries targeting primarily tuna and billfishes constitute a major threat to the conservation of albatrosses and petrels due to their vast spatial extent and intensity. The lack of comprehensive research developing and comparing seabird bycatch mitigation technologies appropriate to pelagic longline fisheries (Lokkeborg 2008) has led to considerable debate regarding best-practice mitigation to prevent seabird mortality among tuna commission and their member countries. Although the streamer line (tori line or bird scaring line) is the most widely prescribed seabird bycatch mitigation technology, only recently has research been carried out to determine the optimal streamer line design and deployment specifications (Melvin et al. 2009 and Melvin et al. 2010). Increasing the sink rate of baited pelagic hooks by weighting branchlines has met with limited acceptance due to safety (Gilman 2008 and Marine Safety Solutions 2008) and operational concerns, and the fear that adding weights to lines could negatively affect the catch rates of the visual predators targeted by these fisheries.

In 2009, we compared the performance of two streamer line designs – the Japanese “light” line and the hybrid line – and introduced branchline weighting aboard two Japanese longline vessels participating in the South Africa joint venture tuna fishery (Melvin et al. 2010). We found that most seabird attacks occurred beyond the 100 m aerial extent of streamer lines, and that un-weighted gear did not sink beyond the reach of birds (presumed to be 10 m depth) until baited hooks were over 300 m astern. This dynamic limited our ability to produce conclusive results regarding the merits of the two streamer line designs; however, the preponderance of evidence strongly suggested that the hybrid streamer line was more effective at eliminating seabird attacks within the aerial extent. Collectively, these findings obviated the need to shrink the area astern of the vessel that birds have

access to baited hooks via weighted branchlines to force seabird interactions into an area that can be successfully defended with streamer lines – shrink and defend.

Taking our shrink and defend mitigation philosophy further, we compared the performance of a revised “hybrid” streamer lines (designed to reduce streamer line-float line foulings) deployed with weighted (W) and un-weighted (UW) branchlines on two Japanese vessels participating in the 2010 tuna joint venture fishery in the South Africa EEZ. Metrics for comparison included the rates and locations of seabird attacks during the set, seabird and fish catch rates, hook sink rates and the number of seabirds attending the set and the haul. This report summarizes those data into a preliminary report. Statistical analysis and modeling of these data are in progress and will be included in a subsequent report.

METHODS

Research was carried out aboard two tuna longline vessels, the F/V Fukuseki Maru No. 5 and the F/V Koei Maru No. 88. The vessels and fishing operations were typical of the high-seas tuna fleet. The research took place in the austral winter of 2010 – a period when seabirds are believed to be most abundant and aggressive.

The fundamental unit of longline gear consisted of 11 to 12 branchlines clipped along the mainline and suspended below the surface between two surface floats 450 m apart. Fourteen-meter float lines connected individual floats to the mainline and each was weighted with a 220 g lead that could slide from the snap toward the float when the float line was retrieved. A line shooter delivered the mainline into the water slack – 1.4 times faster than vessel speed – allowing the mainline to form a catenary between the two floats establishing the fishing depth of each branchline. Twenty units of gear were set between radio beacons. The Fukuseki deployed 220 branchlines per radio beacon segment and the Koei deployed 240. One set was made each day of 10 to 12 radio beacons of gear or 2,000 to 3,000 hooks. Longlines were typically deployed at 9.5 knots speed over ground; therefore, sets took 5 to 5.5 hours to complete.

Branchlines were 30 to 35 m long and made up of a variety of line types and hardware. Each vessel had several designs and branchlines were unique between the two vessels as Japanese fishing masters consider branchline configurations highly proprietary. Unweighted branchlines typically included 4 to 10 m of 1.8 mm – 1.9 mm monofilament trace leading to a ringed No. 4 (3.6 *sun*), Diataro-style Japanese tuna hook manufactured by Diataro Company Ltd., Japan. Branchlines were clipped to the mainline every 50 m (~ every 7.3 seconds) as baits were cast into still water to port of the vessel's wake using a bait-casting machine. Whole pilchard (*Sardinops sagax)*, mackerel (*Decapterus macerellus*) and squid (*Illex spp.*) were used for bait.

Branchlines were weighted using the double-weight configuration developed by *Fukuseki* Fishing Master, Yamazaki-san, in the course of our 2009 research (Melvin et al 2010). The double-weight configuration consists of two leads placed at either end of a 1 to 1.5 m section of wire trace. The weight nearest the hook is free to slide along the branchline while the second lead is fixed. In the event that a hook comes free from a fish as it is landed, in concept the sliding weight will dampen the force of a lead coming back at the vessel and the fixed weight will be in or near the hands of a crewman thus reducing safety threats to crew. In this research initially an 18 g – 38 g configuration was used on 1 to 1.5 m of 2.7 mm coated wire with the lighter weight closest to the hook (total weight 85 g). The weighted section was inserted into 1.8 mm monofilament at 2 m above the hook. After some trial and error in the first several days at sea to resolve tangling problems with weighted branchlines, the weighting evolved to a 12 g – 38 g configuration on 1 m (65 g total weight; Koei) to 1.5 m (70 g total weight; Fukuseki) of Kodo - a coated, monofilament, lead-core line, which allowed for smaller loops less prone to fouling. Consequently the weights were between 2 and 3.5 m of the hook.

Each vessel deployed two "hybrid" streamer lines during each set (Figure 1). Hybrid lines combine long streamers, typical of Alaska streamer lines (Melvin et al, 2001), in the first half of a 100 m aerial extent and short streamers, typical of the Japanese "light" streamer lines (Yokawa et al. 2008) in the later half. Long streamers in our hybrid lines consisted of singe strands of orange UV protected tubing ranging from 8.5 m to 1.5 m long attached every 5 m within the first 10 to 50 m of the aerial extent. All short streamers consisted of lengths of plastic packing strap material folded in half and tied into the line yielding branched short streamers. Branched 2-m streamers were tied into the line between each long streamer and branched 1-m streamers were tied into the line every meter from 51 to 100 m – the second half of the aerial extent. The first 50 m of the in-water section of the line (101 to 150 m) had clusters of three branched 1-m streamers every 5 m to create drag. The remaining 151 to 200 m section had clusters of branched 1-m streamers every 10 m. The clustering throughout the in-water section was designed to create drag, yet be less prone to tangling on surface floats. This hybrid streamer line design is similar to, but exceeds, the minimum requirements of the hybrid line now required in the South Africa tuna joint venture fishery, in that ours was longer (200 m vs. 150 m), branched short streamers were slightly longer beyond 75 m (1 m vs. 0.5 m), and we flew two lines simultaneously. Streamer lines were attached to dedicated davits (tori poles) port and starboard. On the *Fukuseki* the port streamer line was positioned 5 m outboard and on the *Koei*, 4 m outboard. The *Koei* pulled its starboard streamer line to port using a lazy line typically positioning it midway between the starboard side and the center stern mast.

Experimental Design

In a departure from South Africa requirements, longline sets extended at least one hour into daylight to allow researchers to monitor seabird behavior in response to our experimental treatments. Consequently, a typical set began at 03:00 hours and straddled night, dawn and early day with two to three radio beacon segments set in the dawn to day period. Three to five radio beacons of weighted (W) or un-weighted (UW) branchlines were deployed at the end of each set and W and UW branchlines were alternated in the first four radio beacons deployed at the beginning of the set (Figure 2). To reduce bias due to environmental factors, vessels deployed opposing line weighting sets in any given day and alternated designs day to day. Vessels coordinated fishing operations and set gear in the same direction, typically within sight of each other.

Data Collection

Fishery researchers collected data on seabird attacks on baited hooks and seabird numbers during the daylight portion of each set. Primary (by species) and secondary attacks were monitored during the setting of one radio beacon (220 hooks for Fukuseki; 240 hooks for Koei) of longline gear. A primary attack is an unambiguous attempt by an individual bird to take bait from a hook – typically a dive or plunge directly over a sinking hook. A secondary attack is another bird or a group of birds attempting to steal a bait or baited hook from a bird that made a primary attack. Both were recorded as occurring in one of 21 location bins delineated by distance astern (0-25 m, 26-50 m, 51-75 m, 76-100m, 101-125m, 126-150 m, and 151 to 200 m) and lateral position (between streamer lines, or outside streamer lines to port or starboard). Markers inserted into the streamer lines served as reference points to judge distance.

Data were recorded on the physical environment and vessel operations before the attack rate observation period. The landing location of baited hooks and coils relative to the wake and port streamer line was recorded for 10 sequential bait throws prior to attack rate observations. Immediately following the attack rate observation, researchers recorded the number of seabirds (on the water and in the air) by species in a 250 m hemisphere centered at the midpoint of the stern and recorded observations on the performance of the streamer lines.

The two researchers on the Fukuseki observed the retrieval of all hooks during each haul. The single researcher on the Koei observed five to six of the 11 to 12 radio beacon segments set with priority given to observing the retrieval of all hooks deployed during the dawn-daylight period. Catch of all taxa was recorded at the species level by radio beacon segment. A count was made of seabirds attending the vessel during each haul at the midway point in the haul using the same protocol as for the set. The bridge crew independently recorded the number of fishes and birds caught by radio beacon throughout the entire haul in the ships logbook. Researchers routinely crosschecked their data with those in the logbook to confirm the accuracy of data collected by crew.

Sink rates were measured with Wildlife Computer MK9’s, as well as Star Oddi DST Centi-ex time-depth recorders (TDRs). Individual sink rate records were corrected for the weight of the instrument, and in the case of Star-Oddis, for the effect of the protective housing. Consequently, data presented in this report are our best estimate of actual sink rates. The water entry time was recorded for each TDR to the nearest second using a digital wristwatch. Seconds to 10 m depths were extracted from each data record and corrected to compensate for the weight of the TDR using the results of static sink rate tests.

Data summaries were restricted to those sets for which both streamer lines did not foul, and streamer line aerial extents were > 80 m, and for which branchlines within gear segment were consistently weighted or unweighted (not mixed).

RESULTS

The first research sets were made 28 July and the last 30 August. Daylight surveys were successfully carried out during 62 research sets; 31sets (16 UW/15 W) on the *Fukuseki 5* and 31 sets (16 UW/15 W) on the *Koei 88*. Bad weather prevented daylight surveys on 8 and 9 August and streamer lines were damaged on the *Fukuseki 5* when they fouled on floats on 23 August and on the *Koei 88* on 17 August negating those days' surveys. Weather was relatively mild. Wind speed averaged 13.4 knots (range = 0 to 33 knots) and swell height averaged 2.2 m (range = 1 to 5 m). Mean aerial extent of streamer lines was 100 m for streamer lines on both vessels.

Seventeen birds species attended the vessel during line setting, but only four made primary attacks on baits and were killed (white-chinned petrels, yellow-nosed and black-browed albatrosses and cape gannets; Table 1). A total of 27 bird mortalities were recorded. Only 2 of 27 were caught in the days bracketing the full moon[1] suggesting no linkage between lunar phase and seabird mortality. Although three shy albatross mortalities occurred, no primary attacks were observed. White-chinned petrels were the most abundant bird; they were present during all sets, attacked at the highest rate and were the bird most killed. Albatross attack rates were near two orders of magnitude lower than that of white-chinned petrels, but eight were killed. These results strongly suggest that secondary attacks – birds stealing baits from birds having made a primary attack – drove albatross mortality.

Twenty-four of the 27 bird mortalities occurred after nautical dawn. All three birds caught at night were on UW lines.

The two final and most used weighted branchlines (65 g and 70 g) sank at 0.306 and 0.240 m/sec to 10 m and reached 10m depth at an average distance of 178 and 218 m astern, again well beyond the aerial extent of the tori lines.

Weighted vs. Un-weighted Branchlines

Weighting branchlines with hybrid streamer lines dramatically reduced seabird attacks, secondary

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[1] Days around the full moon defined as "3 days around the full moon"; Section 11.11, pg. 12 of 2009 South Africa permit conditions.

attacks and seabird mortalities with little effect on fish catch. Four of 27 bird mortalities (2 white-chinned petrels, 1 shy albatross, and 1 cape gannet) were on W branchlines – a reduction in seabird bycatch rate of 86 % compared to UW (UW = 0.280 and W = 0.040 birds/1,000 hooks; Table 2).

Mean tuna catch was near equal on the two branchline types, but W branchlines tangled on themselves three times more often than UW branchlines. No crew injuries occurred from either branchline type.

Overall primary attack rates were over 4 times lower on W lines and consistently less than half that of UW branchlines throughout the 200 m area monitored (Table 2 and Figure 3). Importantly, the percent of secondary attacks on W lines was half that of UW. If secondary attacks are a proxy for primary attacks that successfully yielded a bait, then this result suggests that not only were there fewer primary attacks on W branchlines, but also fewer were successful.

Few seabird attacks occurred within 100 m of the stern (the mean aerial extent of the hybrid streamer lines) regardless of branchline type (Figure 3). Those that did occur were outboard (to port or to starboard) of the streamer lines (Figures 4). That no attack occurred between the two streamer lines throughout their aerial extent is strong testimony that the hybrid streamer lines flown in pairs are highly effective at preventing seabird attacks. Only six albatross primary attacks were recorded; all were on UW branchlines, beyond 75 m, and to port of the port tori line.

Seabird numbers were down in 2010 compared to our 2009 research for both surface foragers and divers, but divers attack rates were higher (Table 3). Note that the researchers collecting these data were the same in both years.

DISCUSSION

These preliminary results indicate that the shrink and defend conceptual framework of seabird bycatch mitigation is effective at reducing seabird interactions with pelagic longline fishing gear. Specifically, these results strongly suggest that two hybrid streamer lines together with weighted branchlines and night setting constitute best-practice seabird bycatch mitigation for the joint venture fleet operating in the South Africa EEZ and other white-chinned petrel dominated fishing areas. The ICAAT Inter-sessional meeting of the Sub-Committee on Ecosystems concluded at their May 2011 meeting that our finding reinforce previous recommendations adopted by the ICCAT SC-ECO (Rec 07-07): the combined use of tori lines with a minimum aerial extent of 100 m, night setting, and weighted branchlines (minimum 60 g weight within 3 m of baited hook) "… would be the most effective way to minimise seabird by-catch in pelagic longline fisheries." Further, these results also suggest that the Column A and Column B mitigation approach adopted by WCPFC (CMM 2007-04) and IOTC (Resolution 10/06), as currently written, would not prompt the simultaneous use of two hybrid streamer lines, branchline weighting and night setting, and therefore, fall short of the best-practice mitigation identified in this study.

This study provides compelling evidence that two hybrid streamer lines (vs. a single streamer line) are highly effective at preventing seabird attacks within the 100 m aerial extent of streamer lines with or without branchline weighting. Excluding most seabird attacks within the 100 m aerial extent and allowing none between the two hybrid streamer lines in a white-chinned petrel dominated system during 62 longline sets was a dramatic achievement. In contrast to 2009, when float lines fouled on streamer lines frequently, in this study float line-streamer line foulings were reduced. When fouling did occur researchers and crew were prepared with replacement streamer lines allowing consistency in our experimental comparisons.

The higher rate of tangling of double-weighted branchlines (relative to un-weighted branchlines) remains the primary obstacle to acceptance of branchline weighting as a practical seabird bycatch mitigation strategy. Tangling problems early in our study were due partly to the flat edge of the 18 g weights, which resulted from cutting 38 g spindle-shaped weights in half. Also, the coated wire trace

at 2.7 mm was too thick. When either end of the coated wire was crimped into a loop for attachment into the branchline, the loops were large and prone to tangling. This precipitated the change to 2.7 mm Kodo, which forms smaller and less rigid loops, and replacement of the 18 g half-spindle weights with spindle shaped 12 g weights. Lessons learned from this experience will guide fishing masters toward selecting materials less prone to tangling.

In that no injuries occurred while retrieving over 95,000 double weight branchlines strongly suggests that this weighting system is reasonably safe. In considering branchline-weighting prescriptions, it is important to understand the rationale for placing the weighted section 2 m above the hook. With regard to safety this accomplishes two things should a hook come free while a branchline under tension as a fish is landed: 1) with a fish at or near the sea door the heavier of the two weights is in or near the hands of a crewman and not free to recoil, and 2) inserting stretch resistant material (Kodo or wire of the weighted section) into the terminal 3 to 3.5 meters of the branchline reduces the force of recoil.

The mass and position of weights ultimately used to weight branchlines in this study (65 g to 70 g within 3 to 3.5 m of the hook) deviated considerably from that called for in our original research proposal to the South African government – 60 g within 2 m of the hook. Our branchline-weighting proposal stemmed from two things. The first was our conceptual framework that branchlines must sink to a depth of 10 m within the achievable aerial extent of streamer lines (~ 100 m). This 10 m depth benchmark is based on the maximum diving depth of white-chinned petrels (Huin 1994), which dominate seabird-longline interactions in this system. The second was our finding in 2009 that 60 g weights positioned within 2 m of the hook achieved the target of sinking to a depth of 10 m within 100 m of the vessel (within the streamer line aerial extent) in the South African joint venture fishery (Melvin et al. 2010). However, although the branchline-weighting configuration used in this study was lighter and positioned further from the hook than planned, it proved highly effective (reducing bycatch rates by 9 times) and was safe. This finding directly supports the ICCAT SC-ECO (Rec 07-07) calling for minimum 60 g weight within 3 m of baited hook and the WCPFC (CMM 2007-04) line weighting option of greater than 60 g and less than 98 g weight attached to within 3.5 m of the hook. However, this result also suggests that our underlying conceptual framework (sink hooks to 10 m depth within 100 m of the vessel) requires adjustment. New information on the typical foraging depth of white-chinned petrels is about to be available (Richard Phillips, BAS, pers. comm.). The typical foraging depths of these birds (as opposed to maximum diving depths) will better inform seabird bycatch mitigation depth targets, and with it, branchline weighting prescriptions, and may help explain our most recent results.

We also note that the branchline-weighting configurations found successful in this study differ from the ACAP Seabird Bycatch Working Group recommended weighting configuration for future research (120 g within 2 m of the hook; SBWG 2010;). The ACAP research weighting recommendation, based solely on sink rates trials (Robertson et al. 2010), draws on the same underlying conceptual framework (sink hooks to 10 m depth within 100 m of the vessel based on the maximum diving depth of white-chinned petrels), however, it differs in that it focuses on maximizing the initial sink rate from 0 to 2 m depth. The focus on the initial sink rates ignores the mitigating effect of streamer lines and night setting as the hooks sinks from the surface, and consequently draws into question the need for research using weights heavier and closer to the hook. This study shows that the simultaneous use of mitigation measures is an important consideration in prescribing branchline-weighting configurations. In the bigger picture, these findings also strongly suggest that all seabird bycatch mitigation requirements, including branchline-weighting prescriptions, should be based on comprehensive studies that consider seabird behavior and seabird and fish catch rates, as well as sink rates.

We also note, however, that diving birds were in fact killed on the weighted branchlines (albeit at low rates) in this study, and that seabirds attacked baits on weighted branchlines beyond the aerial extent of streamer lines. It follows, therefore, that a weighting greater than that used in this study and greater than the ICCAT SC-ECO recommendation (Rec 07-07; a minimum 60 g weight within 3 m of baited hook) is likely to further reduce seabird catch rates and conserve baits. If the goal of the a seabird conservation measure were to reduce bycatch to the lowest possible level, then a line weighting requirement with a total mass greater than that used in this study could be justified.

Finally, we note that fishing masters in the South African joint venture fishery began weighting branchlines voluntarily in the 2010 season, and are continuing to innovate to find weighting configurations that are safe and least prone to tangles. This innovation on branchline weighting was quite unexpected in that the fishing masters we worked with in 2009 reluctantly accepted our introduction of weighted branchlines in our 2009 research program (Melvin et al, 2010). Innovation in 2009 yielded the double weight system used in this study. Ongoing innovation post 2009, suggests to us that fishing masters are convincing themselves that weighted branchlines do not reduce their target catch and can be configured to be safe. We also note that, in our experience, branchline designs are a key component of the fishing strategies of individual Japanese fishing masters as they operate in the highly competitive environment of tuna fishing. Consequently, branchline designs are complex and highly proprietary. Multiple branchline designs are typically used in any one set on a given vessel. Given these dynamics, to be fully accepted and adopted by fishing masters, branchline-weighting requirements should strive to encourage innovation and allow some degree of flexibility in the materials used, and the number, mass and placement of weights. Our future research will nurture this trend toward innovation.

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Table 1. Abundance (set and haul), attack rates and mortalities of seabirds by species and foraging guild (S=surface forager; D=diver) in 2010. Data are summarized across all research sets (62). Blank = 0.

Common Name	Guild	Haul	Set	Set Occurance	Attack/1,000 hooks	Mortalities
white-chined petrel	D	38.6	40.6	1.0	24.2	18
yellow-nosed albatross	S	9.8	32.6	1.0	0.3	4
cape petrel	S	7.6	23.2	0.8		
black-browed albatross	S	3.8	13.6	0.5	0.1	1
shy albatross	S	2.8	5.5	0.7		3
Wilson's storm petrel	S	3.1	5.5	0.2		
cape gannet	D	1.4	9.5	0.2	1.1	1
giant petrel	S	1.1	2.1	0.2		
Antarctic skua	S	1.1	3.3	0.1		
soft-plumaged petrel	S	1.4	1.4	0.1		
Arctic tern	S	1.8	1.0	0.1		
great-winged petrel	S	1.2	1.3	0.1		
northern royal albatross	S	1.2	1.0	0.1		
sooty shearwater	D	1.0	1.2	0.1		
southern royal albatross	S	1.0	1.2	0.0		
southern giant petrel	S	1.0	1.9	0.0		
wandering albatross	S	1.0	1.3	0.0		
Antarctic prion	S		1.7			
grey petrel	D		1.0			
northern giant petrel	D		1.3			

Table 2. Performance comparison for weighted and un-weighted branchlines.

Metric	Un-weighted	Weighted
Bird Catch	23	4
Number of hooks	80,888	93,849
Birds/ 1000 hooks	0.28	0.04
Primary Attacks	290	66
Number of hooks observed for attacks	7,218	6,768
Primary Attack Rate (per 1000 hook)	40.18	9.75
% Secondary Attacks	57.59	33.33
Tuna / 1000 hooks	13.64	12.94
Distance to 10 m depth (m)	268	205
Mean Sink Rate (10 m)	0.203	0.27
Tangles / 1000 hooks	60	190

Table 3. Comparison of seabird numbers during the set and attack rates (attacks/min) for un-weighted branchlines in 2009 vs. 2010.

Guild	2009		2010	
	Abundance	Attack Rate per minute	Abundance	Attack Rate per minute
Divers	59	0.29	43	0.38
Surface	41	0.04	15	0.01

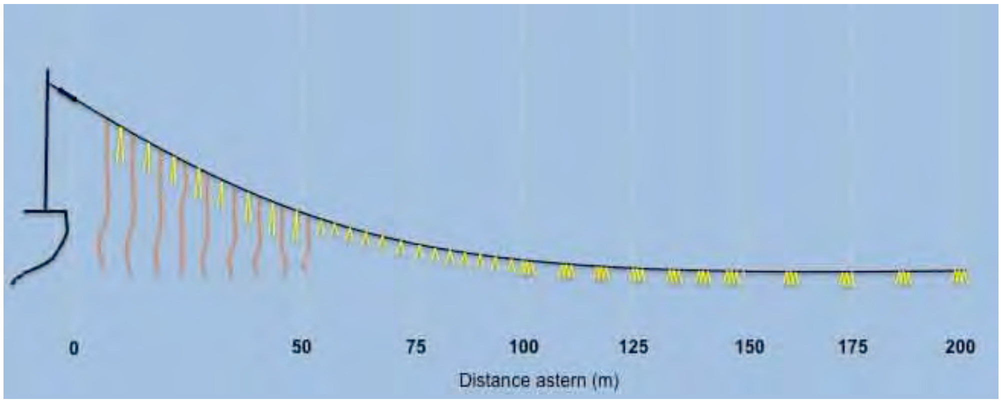

Figure 1. Hybrid streamer line.

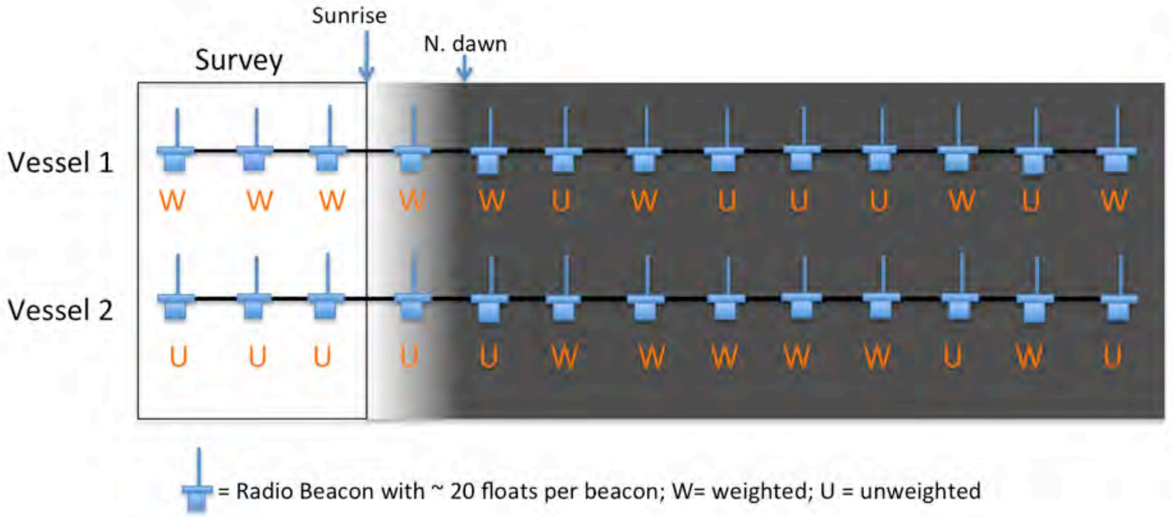

Figure 2. Setting protocol for weighted and un-weighted BLs. A minimum of three radio beacons of gear will be set with enough light to allow for seabird behavior observations.

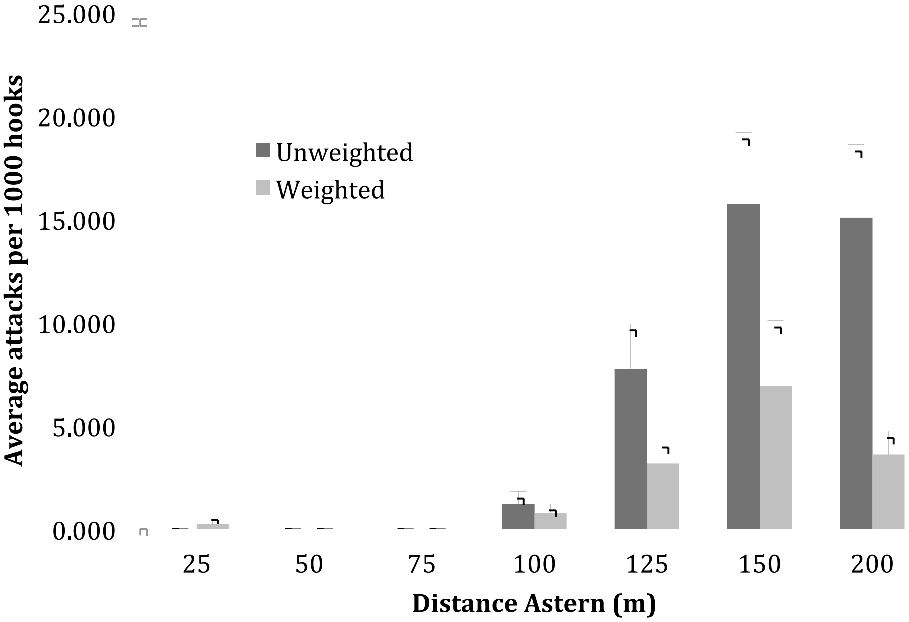

Figure 3. Attack rate of diving seabirds by distance astern for weighted and unweighted branchlines. Error bars are 95% CI.

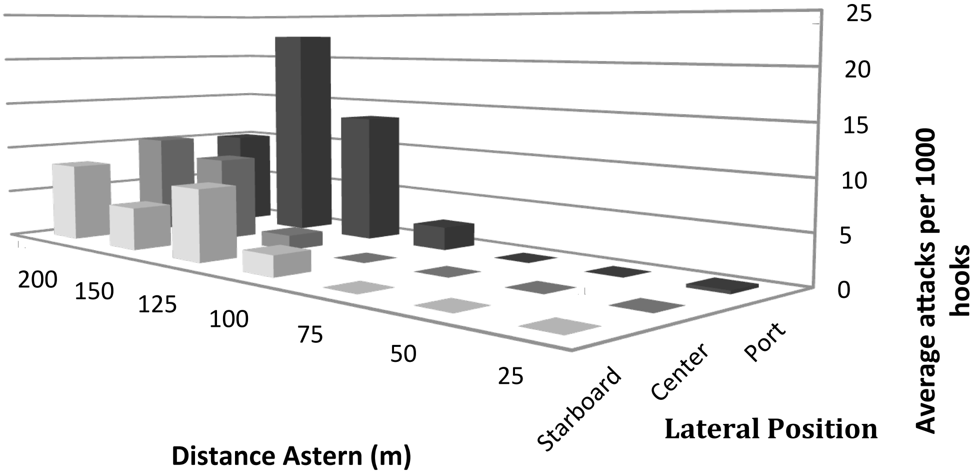

Figure 4. Attack rate of diving seabirds by distance astern and lateral position (center = between streamer lines; starboard is outboard of the starboard streamer line (green); port is outboard of the port streamer line (blue). Only 6 attacks occurred by surface foraging birds and all were to port beyond 75 m (see text).