Optimizing Tori Line Designs for Pelagic Tuna Longline Fisheries: South Africa

Report of work under special permit from the Republic of South Africa Department of Environmental Affairs and Tourism, Marine and Coastal Management, Pelagic and High Seas Fishery Management Division (29 September 2008).

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This report made possible with funding from the David and Lucile Packard Foundation and Washington Sea Grant.

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Introduction

Pelagic fisheries managed by international agreements (Regional Fishery Management Organizations or RFMOs) constitute one of the greatest conservation threats to Southern Ocean seabirds. Seabird mortality occurs in longline fisheries when seabirds depredate sinking baits as gear is deployed and become hooked and drown. In some cases, interactions can be secondary where a diving petrel seizes a bait at depth and brings it to the surface, leading to hooking of seabirds more constrained to surface foraging, such as the albatrosses. Due to this secondary interaction, effective seabird bycatch mitigation must exclude diving birds to protect albatrosses. Mitigation involves sinking baits beyond the reach of surface foraging and diving seabirds as quickly as possible and preventing seabirds from accessing baits in the zone in which they are vulnerable. The tori line, an innovation of Japanese pelagic longline fishermen, scares birds from the vulnerable zone astern of the vessel. Although tori lines are the most widely prescribed seabird mitigation tool in longline fisheries, controlled studies demonstrating their effectiveness in the context of production fishing have not been carried out in pelagic fisheries, nor have studies been undertaken to determine the optimal design features of tori lines in longline fisheries in general (Melvin and Robertson 2000; Melvin et al. 2004).

A tori line, also referred to as a streamer line, is a line with streamers that is towed during fishing-gear deployment from a high point on the vessel at or near the stern (Figure 1). As the vessel moves forward, an aerial extent is created by the drag of the on-water extent of the line or by a towed device such as a road cone. Streamers, most typically made of vertical strands of line or plastic tubing, are suspended at regular intervals from the aerial extent. It is the aerial extent with streamers that deters birds. In many fisheries, towing a device or object to create additional drag maximizes this aerial extent. The goal is to maintain the streamer line over the sinking baited hooks in such a way that the streamers prevent seabirds from depredating baits or becoming hooked and subsequently killed. *In this report we refer to the line that suspends the streamers as the backbone of the tori line. Streamers are defined as materials over 1 m long that are attached along the aerial extent of the backbone to scare birds.*

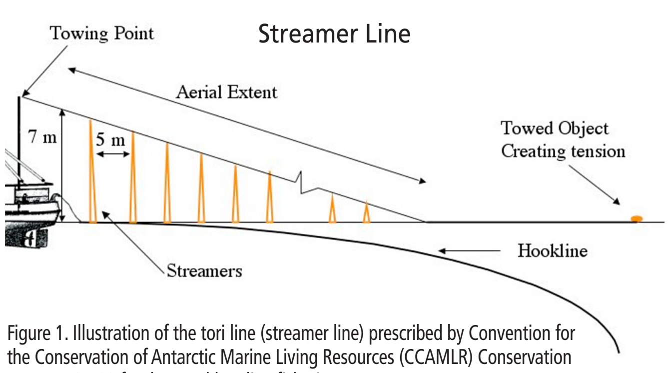

Figure 1. Illustration of the tori line (streamer line) prescribed by Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) Conservation Measure 25-02 for demersal longline fisheries.

Unlike demersal fisheries, where all fishing gear sinks below the surface within 50 m of the stern, pelagic longline fisheries deploy long, typically unweighted branchlines attached to a longline suspended beneath the surface from floats (Figure 2). The potential for fouling surface floats on tori lines makes tori lines more challenging to use in pelagic fisheries. Fishers often deploy tori lines with no towed device, thereby reducing the aerial extent and effectiveness; deploy tori lines to the leeward side of the gear, where they do little to protect sinking baits; or do not deploy tori lines at all for fear of interrupting the fishing operation by fouling surface floats. Development of a towed device that eliminates fouling and maximizes the aerial extent of tori lines is essential to making tori lines practical and effective in pelagic longline fisheries.

The efficacy of different tori line designs used by various longline nations has been debated in the scientific committees of several RFMOs managing shared tuna stocks. The lack of strong and clear underlying science in support of competing tori line designs frustrates progress toward required seabird mitigation in these fisheries. The United States, Australia, New Zealand, South Africa and Chile have expressed great concern over this issue and consequently indicated a strong interest in coordinated trials to test various tori line designs in 2008 and 2009. This project, carried out in South Africa, was conceived to address this issue, but also to assist the Republic of South Africa in developing science-based mitigation for their joint venture tuna fisheries.

Observations of seabird interactions with pelagic longlines were carried out aboard the F/V *Fukuseki Maru No. 5* from October 1-16, 2008. This vessel was one of twelve pelagic longline vessels participating in the joint venture fishery for tuna in the South Africa Exclusive Economic Zone (EEZ) in 2008 (eleven Japanese vessels and one Korean vessel).

Objectives

The objectives of this project were to:

- continue work begun in the New Zealand joint venture fishery (Melvin and Walker 2008) to establish essential tori line design elements that will ultimately be tested in controlled experiments;
- document gear sink rates and test-line weighting modifications designed to increase sink rates;
- and refine protocols to detect seabird behavior shifts in response to varying pelagic tori line treatments.

This project was a collaboration of the Japan Tuna Fisheries Co-operative Association, Combined Fishing Enterprises, the South Africa Marine and Coastal Management (MCM) Pelagic and High Seas Fisheries Management Division, Capricorn Fisheries Monitoring and Washington Sea Grant (WSG). Ed Melvin made the at-sea observations reported here.

Methods

Need For a Permit

Daytime observations of seabird interactions with tori lines were fundamental to the success of this undertaking. Currently, South Africa tuna longline fishery permit conditions (MCM 2008) restrict line setting to nighttime (the time between nautical dusk and nautical dawn). The permit holder is also restricted to a seabird mortality limit of 25 birds per year. If this limit is exceeded, the vessel may continue fishing only if specific additional mitigation conditions are met. The exemption issued by MCM, Pelagic and High-Seas Fisheries Management Division, for this work exempted the F/V *Fukuseki Maru No. 5*, from "any seabird mitigation measures as stipulated in the 2008 tuna longline conditions" for the duration of the trials, provided the vessel fished within the research experimental design. Also during this time, the 25-bird catch cap was suspended allowing the vessel the latitude to try new mitigation measures.

Vessels, Fishing Gear and Practices

At 54 m long (length overall), with 8.7 m beam and 22-person crew, the F/V *Fukuseki Maru No. 5* was typical of the high-seas Japanese tuna fishing fleet. The vessel's longline gear configuration, also typical of the high seas pelagic longline fleet, consisted of more than 100 km of monofilament twist longline (mainline) suspended below a series of 0.3 m diameter floats (Figure 2). Float lines were approximately 17 m long and included a weight just above the clip to the mainline. The main line was deployed from the stern via a line shooter — a hydraulic device that delivers the mainline to the water slack at 6.7 m/s, 1.4 times the vessel speed (4.9 m/s). Eleven branchlines, referred to here as a basket of gear, were attached to the mainline along the roughly equal distances (along the catenary) between two floats (Figure 3). With little variation, the third, sixth and ninth hooks in each group of eleven branchlines (a basket), were baited with whole *Illex* squid and the remainder with whole pilchards. Twenty to 30 baskets were deployed between each of thirteen radio beacons. Typically 290 baskets of gear were deployed in 5.5 hours at a vessel speed of 9.5 knots.

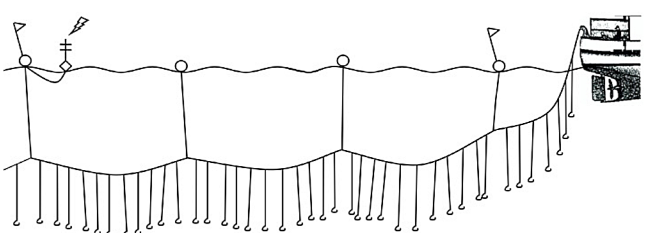

Figure 2. Pelagic longline gear being deployed showing surface floats suspending the longline below the surface. Surface floats can foul on tori lines.

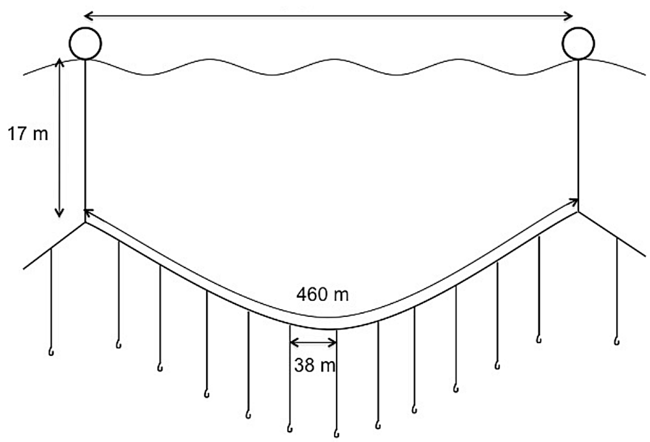

Figure 3. A "basket" of pelagic longline gear on the F/V *Fukuseki Maru No 5*. Eleven branchlines, over 31 m in length, are suspended between two surface floats.

Line Setting

When setting gear, a crewman centered on the stern deck clipped branchlines to the mainline. A second crewman deployed baits via a hydraulic bait-casting machine mounted on the port side of the stern. Baited hooks were delivered outside the vessel's wake every 6.9 seconds. As the bait-casting machine was triggered, it uncoiled the monofilament trace of the branchline (roughly the later third) without tangles, thus making the setting process more efficient and consistent. The remaining coil (two-thirds of the branchline) was hand tossed into or outside the wake of the vessel (see sink rate discussion).

Floats, which bracket each basket of branchline gear, were deployed from the port quarter of the stern. Radio beacons were deployed from the far starboard of the stern. A narrow conveyor belt/table running from a storage area 5 m forward to the stern rail delivered coiled and baited branchlines, and coiled float lines and floats to these two crewmen. A third crewman, standing at the conveyor between the storage area and the stern, baited the hooks on each coiled branchline on the conveyor.

Line Hauling

The gear was allowed to soak for approximately three hours post deployment. Typically the longline was retrieved from the end most recently set. Gear was hauled via a hydraulic line hauler over a small roller at the starboard rail. Incoming line was heaped onto a table and hauled through a network of pipes to the aft-top deck where it was mechanically lofted into bins. Four to five crewmen worked in rotation to unclip and coil individual branchlines. The non-monofilament section was coiled using a vertical high-speed coiler or by hand, then stacked into plastic baskets. The monofilament section was always coiled by hand. One to three crewmen untangled and/or repaired branchlines as necessary. The floats and baskets of coiled branchlines were moved to the stern via a conveyor belt along the port side.

Hooked fish were played by hand and landed through the sea door.

Several crew helped haul the fish in (by hand) or equipped themselves with long handled gaffs or harpoons to assist in the landing process. Retained tuna, with the exception of albacore, were bled, finned, gutted, and gilled on the deck, and the remaining trunks were moved quickly to freezers. Albacore were bled and frozen whole. The hauling process took approximately 11 to 13 hours and occurred during daylight. Retained baits, offal and unwanted fish were discarded at the starboard sea door.

Seabird Observations

Seabird abundance and attack rate protocols were modified for pelagic longline fisheries based on previous tori line experiments conducted in demersal fisheries (Melvin et al. 2001; Dietrich et al 2008). During line hauling, seabird observations were conducted to determine the number of seabirds by species or species group, in the air and on the water. Seabird numbers were estimated in a 100 m hemisphere centered at the stern, one to three times per haul throughout the day.

During line setting in daytime, observations included the following: seabird numbers, seabird attacks on baited hooks, streamer line configurations and performance, and the location of baited hooks relative to tori lines. The number of seabirds by species, in the air and on the water, was estimated in a 250 m hemisphere centered at the stern. The number of seabird attacks on sinking baits was estimated by species within 200 m of the stern for the area inside the two tori lines and 5 m port of the port tori line. We defined "attack" as an attempt to take bait at or near the surface, or a dive where bait was obviously sinking from the surface.

Tori line features and bait delivery procedures were also recorded before each line-setting seabird observation period. These included estimating the minimum and maximum aerial extent, tori line components (number and type of streamers), distance of the first streamer from the stern, and makeup of the tori line backbone. Informal observations of where baits landed relative to the tori lines evolved into estimating the number of baits landing outside the port streamer line per 10 baits tossed, and whether the bait casting machine was being used.

Seabird Mitigation: Branchlines

Several branchline designs were involved in the fishing operation. The two were most common were referred to by the Fishing Master as the "light branchline" and the "heavy branchline," based on their relative weight. The Fishing Master constructed two additional branchline types – "swivel branchline" and "swivel-plus branchline". Both included a stainless steel swivel and different lengths of lead-core line inserted above the terminal thin section of monofilament (the trace). In general, individual branchlines were long (31.2 m to 34.9 m), heavy (400 to 500 g) and complex — involving a minimum of four materials. The upper braided sections varied from 9.6 m to 21.4 m in length and were made up of two materials, which varied in color and diameter and were weighted or non-weighted. The monofilament section varied from 12.3 to 25.2 m in length and was made up of two diameters of monofilament line (2.6 mm to 1.9 mm). We note that the length of the trace is dynamic; as some hooks are cut off and replaced after landing fish, the trace becomes shorter until it is eventually replaced.

Seabird Mitigation: *Fukuseki Maru No 5* Tori Lines – Status Quo

The *Fukuseki Maru No. 5* used two tori lines. One was attached to a purpose-built tori pole positioned on the upper deck, 5 m from the stern and 1 m from the port side. The other tori line was attached to the crosstree of a stout 7.4 m mast mounted on the upper deck, centered 3.3 m from the stern. The tori pole had three parts. Its base was a stout 1.6 m davit with a ~ 40º elbow section bolted to it. The remainder was a 4 m round stock pole fitted into the elbow and secured with three backstays running to the forward port rail. The tori pole extended the port tori line 2 m outboard of the vessel. Both tori lines were hauled by hand by at least three crewmen. Streamers were unclipped and coiled as they came aboard and stored in plastic baskets.

On October 1, the first set was made in darkness using the *Fukuseki* Maru's standard tori lines. The backbone lines of the port and starboard tori lines differed in materials and total length (Figure 4). The port backbone was 178.5 m long and included a 27 m section with ten three-way swivels spliced into the backbone to which streamers were clipped, and a 61.5 m section with reflective Mylar tape (Mylar bird tape/flash tape used for orchard protection) tied in to the backbone. These streamer/tape sections were bracketed by sections of blank line at either end. Most of the backbone line was a 2.5 mm tarred, three-strand line, although the tail section was made of ~ 1.5 mm red "sekiyama" line – a stiff-coated, solid nylon cordage. A tennis ball was attached to the seaward end of the port line and presumably was used as a towed device to enhance drag and aerial extent.

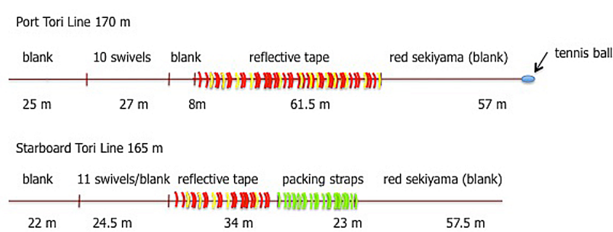

Figure 4. *Fukuseki Maru* standard tori line backbones used on the initial set of the trip on October 1, 2008. The port tori line had 10 branched streamers placed along the 27 m section (see text) and mylar reflective tape tied into the backbone of the 61.5 m section. Reflective tape and packing straps were tied into the 3 ply backbone of the starboard tori line, which was devoid of streamers. Aerial extent could not be determined due to darkness.

Individual streamers were made of 5 mm red plastic tubing, doubled into equal lengths, with red sekiyama line threaded through the center of the tubing and the eye of a small tuna snap and crimped. Three- to five-gram cylindrical weights were crimped into the top and bottom of each branch. Streamers were 1.4 to 6.2 m long and extended to approximately 1 to 3 m of the surface in the absence of wind. The first streamer was positioned approximately 30 m astern.

The starboard tori line was devoid of streamers. The entire length of the backbone was the 2.5 mm tarred, three-strand line and included sections of Mylar tape and packing strap material tied into the backbone line, bracketed between sections of blank line (Figure 4). Aerial extent of both lines was 60 to 70 m when redeployed in daylight at setting speed — 9.5 knots — well short of the 150 m minimum required in the South African Tuna Longline Permit Conditions (MCM 2008).

Seabird Mitigation: Refining Tori Line Elements Through Innovation

While running to a new fishing area on October 2 and prior to daylight trials during fishing operations, the *Fukuseki* tori lines were redeployed and compared to a new tori line, which in turn spurred revisions to the *Fukuseki* tori lines.

A tori line designed by Melvin (the Prototype line), based on experience in Alaska, involvement with the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and observations in the New Zealand Japanese Joint venture fishery (Melvin and Walker 2008), was deployed as the starboard tori line allowing a visual comparison of the two designs. The Prototype line was a 168 m and featured seventeen orange plastic, branched streamers, spaced at 5 m intervals beginning at 5 m from the stern (Figure 5). Individual branched streamers consisted of two strands of 6.4 mm ultraviolet-resistant orange plastic Kraton tubing, attached to the tori line backbone with a tuna clip. Each streamer extended to the water in the absence of wind.

Washington Sea Grant Experimental Tori Line

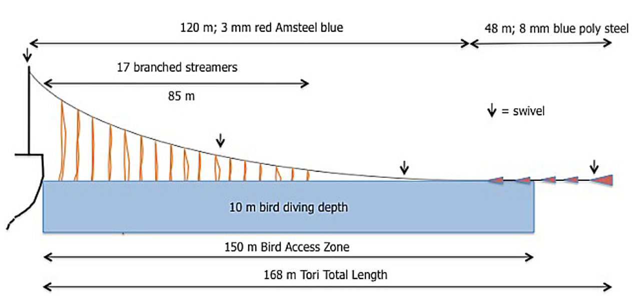

Figure 5. Illustration of experimental Tori Line design used aboard the *Fukuseki Maru No 5.* Streamers are 6.4 mm Kraton orange tubing and extend to the water with streamers spaced at 5 m intervals starting at the stern. Funnels are 17 cm kitchen funnels designed to create drag and create water disturbance to deter birds. A road cone minus its base is attached to the end to create drag and aerial extent. Aerial extent is 150 m. The distance astern that baited hooks sink to 10 m – out of the range of most diving seabirds – was assumed to be 150 m.

The backbone of the Prototype tori line was made up of a light section and a heavy section. The backbone of the light section was 120 m of red-colored, 3 mm "Amsteel blue," a high-tensile strength "Dynema" product designed to float and minimize weight while maximizing tensile strength. The heavy section of backbone was a 48 m length of 8 mm, three-ply "blue poly steel" floating line. The light section included loops of 2 mm line every 5 m as the attachment point of streamer line snaps. The 48 m section included several small kitchen funnels (17 cm long with a 17 cm diameter) integrated along the length of the blue poly line to create more drag and disturb the surface of the water.

In addition, the design included a road cone with its base removed (44 cm length x 20 cm base diameter) attached to the end of the line to increase drag and aerial extent. The combination of the funnels and the road cone was also intended to create disturbance in the water beyond the aerial extent in an effort to make the non-aerial component of the tori line a bird deterrent.

Swivels were placed at the attachment point to the mast crosstree and at the road cone. In addition, a meter length of heavy tubing was placed at the junction of the mast-swivel and the line to absorb shock and minimize stress and the likelihood of snapping the backbone line. This line achieved an aerial extent of 150 m, or two times the aerial extent of the *Fukuseki Maru No. 5* tori lines.

The difference between the Prototype line and the *Fukuseki* line was dramatic (a collective gasp from the crew). It was immediately apparent that the Prototype tori line, with its orange streamers and greater aerial extent, stood out dramatically more than *Fukuseki* tori lines, with dark red streamers and half the aerial extent. It was also apparent that streamers extending to the water and starting closer to the stern created a more effective barrier than a tori line with fewer and shorter streamers starting 25 to 40 m astern. Most importantly, the contrast between the two lines demonstrated to the crew that many possibilities exist for improving tori lines design and spurred additional innovation by the Fishing Master and the crew.

When the *Fukuseki* port tori line was redeployed beside the Prototype tori line on October 2, it included branched streamers made with Mylar tape as well as streamer made from dark red tubing. Mylar streamers were made up of 12 cm lengths of 1 cm-wide, red-silver and gold-silver Mylar tape, tied through the mono twist at spacings of 5 to 10 cm. The monofilament twist was doubled through the eye of a small tuna snap and crimped. Like the red-tubing streamers, 3 to 5 g cylindrical weights were crimped into the top and bottom of each streamer branch. Like the orange tubing of the Prototype tori line the Mylar tape streamer stood out dramatically above the sea and was more obvious than the red tubing. Based on these observations, more orange streamers were made to replace red, and some included the addition of reflective material at the bottom section of individual orange streamers.

After considerable discussion and concern that a road cone added to the port streamer line could damage the port tori pole, a cone slightly smaller than the one on the Prototype line was added to the port tori line. Additional swivels were spliced into the backbone to allow attachment of streamers closer to the stern.

The 57 m section of red sekiyama in the port tori line was replaced with 44 m of line with red packing tape tied into it, based on the idea that other colors of packing strap, other than pale green, might be more effective at deterring birds (Figure 6). The starboard tori line backbone was adjusted to include a 20.5 m section of red packing tape in addition to sections of Mylar tape and a light green packing strap material.

The revised *Fukuseki* line was set up as the port tori line, and the Prototype tori line was set up as the starboard tori line for deployments two days later in the new fishing location.

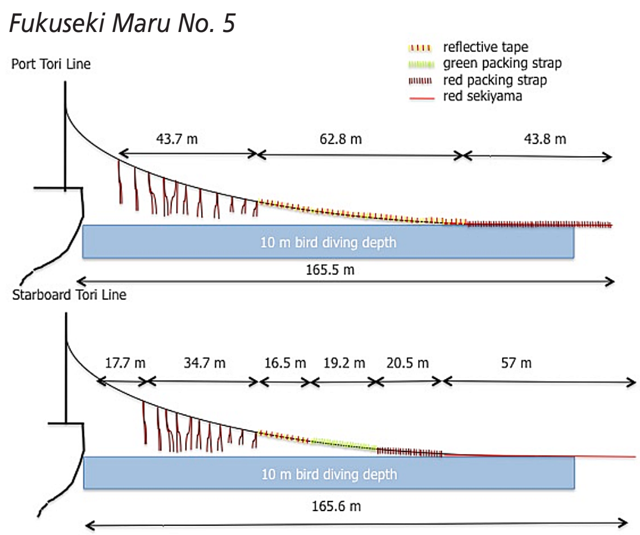

Figure 6. Illustration of early refinements to *Fukuseki Maru No 5* Tori Lines. The distance astern that baited hooks sink to 10 m – out of the range of most diving seabirds – was assumed to be 150 m.

Sink Rates and Time Depth Recorders

Star–Oddi time depth recorders (TDRs), model DST Centi-ex, and *SeaStar* software were used to measure the sink rate of baited hooks under a variety of scenarios. These bullet-shaped devices measured 15 mm x 46 mm and weighed 12 g in water and 19 g in air. They were configured by the manufacturer to measure depth at 0.07 m intervals with an accuracy of ±0.12 m every second, from 1 m to 280 m. Before deployment in the field, each instrument was calibrated by establishing the transducer reading at a known depth of 2 m. The depth offset was adjusted for individual instruments using the "Reconvert Pressure Definition" function in the *SeaStar* software to increase the accuracy of each pressure/depth reading for each deployment.

In all scenarios, TDRs were fixed to the branchline with Tesa tape, 20 to 30 cm above the eye of the hook. The water entry time for each device was recorded to the nearest second using a digital Timex Ironman Triathlon wristwatch. The number of seconds in drift between the wristwatch and the PC clock just prior to activating the SeaStar software was used to adjust the time of water entry in the computer record. Seconds to 2 m, 5 m, and 10 m depths were extracted from each data record and used to calculate the sink rates (m/s) to each of these benchmark depths.

These methods were used to contrast the sink rate of four types of branchlines with either whole squid or whole pilchard bait. Branchline comparisons included the "light" and "heavy" lines described above, as well as two variations constructed by the Fishing Master in an effort to achieve a target sink rate of 0.3 m/s to 10 m depth. The heavy branchline was modified into two variants in an attempt to increase the sink rate of baited hooks away from the surface. The first — "swivel" — added a 10 g swivel, plus 0.7 m of weighted line (25.1 g total) above the trace; and "swivel plus" added the same swivel and 1.4 m of weighted line (40 g total) above the trace. The Fishing Master was averse to adding weight at the hook for fear a thrown hook could injure crew. In addition to quantifying sink rates, fishing depth and temperature, one-hour post-settings were tabulated for the purpose of informing the fishing operation on attributes of the habitat fished.

Results

Fishing

The *Fukuseki Maru No. 5* made 14 sets of 2,750 to 3,245 hooks from October 1-17, targeting bigeye tuna (*Thunnus obesus*). One set was made in the South Africa EEZ near 32ºS and 16ºE in darkness. The remaining sets were made in the Atlantic near 29ºS and 7ºE. All but the first set straddled night and day, with sets starting near 0300 and ending 0830 to 0900, allowing approximately two hours of daytime observations during line setting. Primary species caught were bigeye tuna, albacore (*T. alalunga*) and blue shark (*Prionace glauca*), with small catches of swordfish (*Xiphias gladius*), oilfish (*Ruvettus pretiosus*), moonfish (*Lampris guttatus*), pelagic rays (*Pteroplatytrygon violacea*), shortnose lancet fish (*Alepisaurus brevirostris*), Ray's bream (*Brama australis*) and longfinned bream (*Taractichthys longipinnis*). One seabird was caught: a juvenile black-browed albatross (*Thalassarche melanophrys)* on November 7.

Seabird Observation During Line Hauling

Thirty-two observations were made over 14 fishing days. The total number of birds per observation averaged 41, and ranged from 11 to 62. Of the birds most vulnerable to longline mortality, white-chinned petrels (*Procellaria aequinoctialis*) were most common, averaging 19.4 birds per period (range 3 to 45 birds per observation).

On average, 34% of the birds observed were albatrosses. Atlantic yellow-nosed (*Thalassarche chlororhyncos*) and black-browed albatrosses were most common, both averaging ~5.0 birds per observation. Most black-browed albatrosses were juveniles. Shy (*T. steadi*) and wandering albatross (*Diomedea exulans*) were seen inconsistently, but in small numbers — typically zero to two individuals per observation. Spectacled petrels (*Procellaria conspicillata*) were similarly uncommon.

Other common seabirds included Wilson's storm-petrels (*Oceanites oceanicus*) and cape petrels (*Daption capense*), 6.3 and 5.0 birds per observation, respectively. Great shearwaters (*Puffinus gravis*), great skua (*Stercorarius skua*) and cape gannets (*Morus capensis*) were also observed but inconsistently and in small numbers.

Daytime Observation While Line Setting: Seabirds

Twenty-one counts were made over 12 days of partial daylight setting. During line setting, all birds were in flight and wheeled at 180 to 250 m astern. Few came within 100 m of the stern. As during line hauling, white-chinned petrels were most abundant, averaging 17.5 birds per observation (range: 4 to 50). Albatrosses, Atlantic yellow-nosed and black-browed, were present for all observations, averaging 5.3 birds per observation (range: 1 to 8 birds). These two species were often difficult to distinguish and count to species in the dim light of dawn at distances > 100 m astern. Almost all black-browed albatrosses were juvenile birds. Wandering albatrosses were seen in five of twelve days of daylight observations. Other birds included Wilson's storm-petrels, cape petrels and great shearwaters, averaging 6.1, 2.2 and 1.0 birds per observation, respectively.

Despite the presence of typically aggressive seabird species, issues with placement of baits outside the protection of tori line, tori line fouling events, and compromises in tori line design, seabird attacks within 170 m — the length of tori lines — were virtually absent. Seabirds landing on the water between the two streamer lines were exceedingly rare. Only 2 attacks were recorded in 12 observation days and none occurred where baits landed outside the protection of the port tori line. In general, birds circled beyond the tori lines and occasionally formed aggregations on the water beyond 200 m, presumably competing for a lost bait or a bait brought to the surface by a diving seabird. We do note that the single seabird mortality occurred on October 7, during a partial daylight set, when streamer lines were at their least aerial extent — 40 to 80 m — and the pre-revision *Fukuseki* tori lines were in place (those without packing tape at the end to create drag). In general, seabirds were not aggressive and did not attempt to attack baits near tori lines.

Daytime Observation: Tori Lines

Longline floats fouled on tori lines regardless of design in five of fourteen sets; four were with the starboard tori line and three with tori lines with cones. In the initial deployment of revised and Prototype tori lines (see methods) during a nighttime set, the port tori line fouled on floats of the longline, bending and twisting the tori pole as well as the elbow bolted to the supporting davit. We assumed floats caught on the cone. *These fouling events demonstrate the challenge of placing objects on tori lines to create drag and aerial extent while avoiding fouling with surface longline gear.* Damage to the tori pole quickly showed that that the fears of the Fishing Master on potential weakness of the tori pole were well justified. Due to damage to the tori pole, road cones were not added to the port tori line for the balance of the trip. Fouling events also led to multiple changes to tori lines throughout the trip.

The starboard Prototype tori line had a maximum aerial extent of 150 m with a road cone and 45 m without a road cone. The revised *Fukuseki* tori had an aerial extent of 60 m to 110 m with red packing tape and 40 m to 80 m without red packing tape. When the density of packing tape was increased, the aerial extent ranged to 130 m. Clearly, packing tape creates considerable drag, and the density of tape is an important factor. The placement of the first streamer varied from 5 m from the stern with the Prototype tori line to 12 m with the revised *Fukuseki* tori line. As the attachment loops of the Prototype line wore and broke, the crew attached streamers to the first unbroken loop at 15 m astern, suggesting the need for an alternative streamer attachment strategy.

After the tori pole mishap, the port tori line was fairly consistent in composition and ranged in aerial extent from 55 to 85 m, depending on the height of swells. Adding a small kitchen funnel at the end resulted in an aerial extent of 90 m. A short (40 cm) section of high-density packing tape at the end of the port tori line had little effect on aerial extent. The placement of the first streamer varied from 18 to 40 m, presumably due to decisions by the crew deploying it.

Daytime Observation While Line Setting: Bait Casting Machine

The bait-casting machine delivered baits 2 to 4 m port of the vessel — up to 1 to 2 m port of the port tori line beyond the protection zone. Later in the trip, the Fishing Master directed the crew to cast baits by hand during daylight hours to minimize the threat to seabirds. In continued discussion on this point, the Fishing Master demonstrated that the bait-casting machine could be adjusted in at least three ways: the vertical angle of the throw (how high), the speed of the throwing arm, and the arc of the throwing arm. Despite these options, the Fishing Master opted for hand-setting during daylight hours.

Gear Sink Rates

The sink rates of the "light" and "heavy" branchlines — the branchlines used routinely by the F/V *Fukuseki Maru No. 5* — were contrasted with that of "swivel" branchlines in our first trials on October 5 (Figure 7). Mean seconds to 10 m varied from 51 to 71 seconds across the three branchline types, with the "swivel" branchline sinking fastest and the "heavy" and "light" branchlines sinking slowest (63 and 71 seconds, respectively). Variability among TDR records within each branchline grouping was high. For example, seconds to 10 m for individual "light" branchlines varied from fastest to slowest by 44 second (55 to 99 seconds). This variability has huge implications for risk to seabirds, by extending exposure of baited hooks within 10 m of the surface to more than 400 m astern of the vessel.

When this same trial using the same branchlines was repeated on October 7, all branchlines reached 10 m considerably faster and with less variability. "Light" branchlines sank to 10 m 26 seconds faster, while "heavy" and "swivel" branchlines, on average, sank 11 and 14 seconds faster (Figure 7). In terms of variability, the time to 10 m for the "light" line on October 7 was 13 seconds, compared to 44 seconds on October 5. Swell (2 m and 1.5 m) and wind conditions (17 and 17.5 knots) were similar between days, suggesting the anomalies could not be explained by physical conditions.

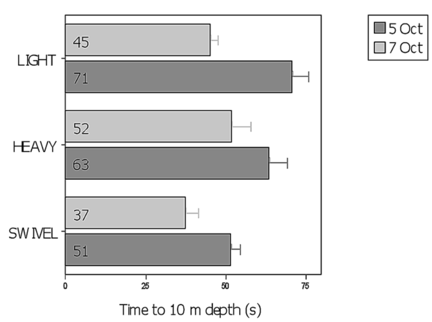

Figure 7. Mean TDR sinking times (seconds) of branchline designs to 10 meters depth observed for each branchline design between 5 and 7 October 2008 aboard the F/V *Fukuseki Maru No. 5*. Error bars indicate one standard error.

The within branchlines variability and slow sink rates between trials led to closer scrutiny of the sink profiles of individual branchlines. The expected sink profile is typified by Figure 8A, which is essentially a straight line. Upon closer examination, we found that all but one of the branchlines deployed on October 5 showed some degree of stalling at 2 to 4 m (Figure 8B), while those deployed on October 7 showed little or no stalling. After extended observations of hook deployments over subsequent days, the anomalies documented in the first trial were most likely due to tossing the branchline coil into the wake, as opposed to outside (port) of the wake. Essentially, the sink rate of the hook was suspended until the coil was free of the wake, some tens of meters astern.

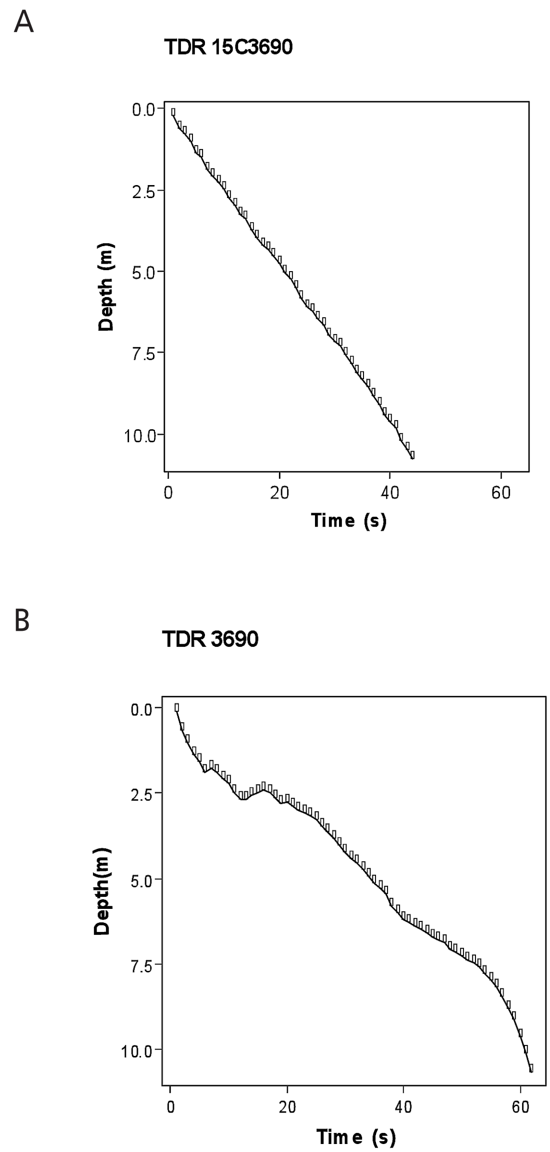

Figure 8. Expected or typical sink profile (A) and a stalled sink profile (B) of a baited tuna hook to 10 meters depth on a "light" branchline on 7 October 2008 aboard the F/V *Fukuseki Maru No. 5*.

With keen attention to how branchline coils were tossed relative to the wake, four subsequent TDR deployments were conducted. The sink rates of the three branchlines described above and a fourth variant — the "swivel plus" branchline with more weighted line inserted above the swivel — were compared. If data are parsed out by branchline type and bait type (Figure 9), the modified branchlines — "swivel plus" and "swivel" — baited with squid, sank fastest (30 and 32 seconds, respectively). These rates exceeded the 0.3 m/s sink rate to 10 m (or 33.4 seconds) — the minimum target sink rate specified in the Tuna Longline Permit Conditions (MCM 2008). With the exception of the "light" branchline, branchlines baited with squid sank faster than those baited with pilchards. Smaller sample sizes for the "light" branchlines may explain this inconsistency. Weight data for individual baits are unavailable; however, we assume that the larger and denser squid were heavier than sardines, explaining the bait effect. If we pool data and ignore the bait effect (Table 1), which may be the most appropriate perspective, given that both squid and sardine are used for bait, none of the branchlines met the 33.4 second sink rate to 10 m. And none met the target of reaching a depth of 10 m, 150 m astern — the other sink rate target specified in the Tuna Longline Permit Conditions (MCM 2008). With the exception of the "swivel" branchline, in general, branchlines sank at a faster rate to 2 m and to 5 m than to 10 m (Table 1). Sinking faster near the surface is a very desirable outcome, because this is where most birds are vulnerable to hooking.

Branchlines achieved an average depth of 137.5 m, one hour post-setting (range 76.0 m to 182.4 m; SD=22.02 m). Most variation was due to placement of the branchline within a basket, which affected its location across the catenary of the mainline. Temperature averaged 15.9° C and varied within a narrow range (range 14°C to 16.7°C; SD =0.60).

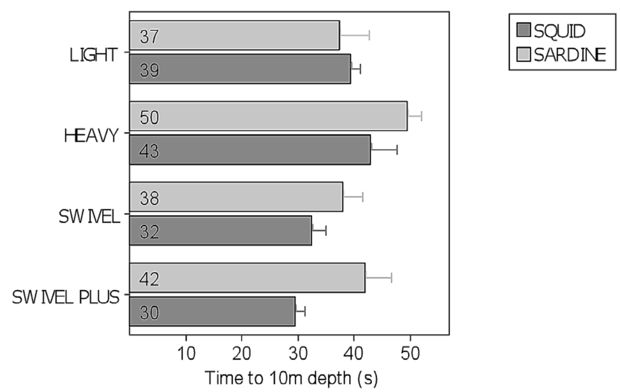

Figure 9. Mean TDR sinking times (seconds) of branchline designs to 10 meters depth observed among branchline designs by bait type on 12-17 October 2008 aboard the F/V *Fukuseki Maru No. 5*. Error bars indicate one standard error.

Table 1. Mean TDR sink time (s), one standard error of the mean sink time (seconds & SE), mean sinking rate (m/s), and distance astern of the ship (m) for 2 meter, 5 meter, and 10 meter depths for each treatment observed on 12-17 October 2008 aboard the F/V *Fukuseki Maru No. 5*.

		2m				5m				10m			
Treatment	n	s	SE	m/s	m	s	SE	m/s	m	s	SE	m/s	m
Light	8	5.9	0.64	0.340	34	17.6	1.84	0.284	91	38.6	2.07	0.259	194
Heavy	8	7.5	0.82	0.267	42	18.3	1.83	0.274	94	46.3	2.75	0.216	231
Swivel	9	6.7	0.58	0.300	38	17.7	1.60	0.283	91	34.9	2.22	0.287	175
Swivel Plus	9	6.3	0.37	0.316	36	15.7	1.04	0.319	82	36.4	3.37	0.274	183

Discussion

Collectively a great deal was accomplished aboard the *Fukuseki Maru No. 5* owing to the excellent cooperation of the Fishing Master and the crew. With regard to tori lines, an optimal design emerged that incorporates most lessons learned (Figure 10). This design proposes that tori lines be broken into two components – a "protection" section and a "drag" section. The "protection" section includes a light, high-tensile strength floating backbone with clip-on streamers and woven in packing-strap material. Streamers are used in the span where the backbone is more than 1 m above the surface, and packing-strap material is used for the span where the backbone is less than 1 m above the surface. Streamers would be of several designs — branched orange tubing, reflective tape woven into branched monofilament twist. Combinations of the two should be alternated at a minimum spacing of 5 m. Packing-strap material would alternate bright, high-contrast colors like orange and luminescent green in a single section or alternate different-colored sections.

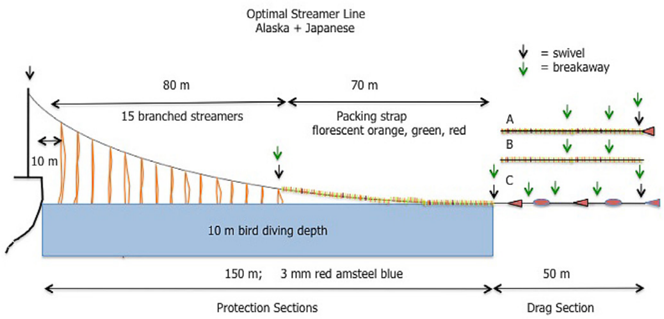

Figure 10. Proposed Optimal Tori Line for Pelagic Longline Fisheries. A fusion of Alaska and Japanese concepts. Streamers of varying designs are alternated along the aerial extent where the backbone is 1 m or more from the water. A variety of bold colored packing straps are attached to the backbone at < 1 m. The drag section creates drag to achieve an aerial extent equal to the distance astern that baited hooks sink to 10 m and disturbs the water to deter birds. The drag section can be composed of many elements and includes breakaways to protect the more expensive and important "protection" section from loss.

The drag section is designed primarily to create the drag necessary to achieve an appropriate aerial extent and secondarily to disturb the water in such a way as to deter birds from the in-water section of the tori line. The drag section can be composed of a variety of elements: packing-strap material and a small cone; high density packing-strap material, and/or a series of floats and cones or various combinations. Given that fouling a tori line with the floats of the longline is difficult to prevent or predict — even without a cone or towed device — the drag section incorporates breakaways or weak links that ensure that the "protection section" (the most expensive in terms of materials and time invested in construction) is never lost due to fouling on floats. Ideally the drag section would be composed of low-cost components and would be sacrificial. *This design acknowledges that tori lines must be maintained on a daily basis and that elements of the sacrificial drag section be restored as they are lost.* If this approach proves successful, frequently lost material would need to be biodegradable. Mylar reflective material in the backbone of the line degraded quickly and is recommended only for use in streamers.

We intend to continue our work (not reported here) developing a towed device that will displace the end of the tori line outside the wake to eliminate or greatly minimize fouling surface floats on tori lines. At the same time, we are working to develop towed devices that are fusiform or devoid of rough surfaces to minimize fouling. We note however, that any work on tori line towed devices is predicated on the existence of a solid tori line attachment point at the vessel.

Crucial to effective use of tori lines is a strong attachment point to the vessel. The center mast of the *Fukuseki Maru No. 5* certainly met this criterion, but the tori pole did not. We believe that there is a need to redesign the traditional Japanese tori pole to a structure that can support the drag necessary to create an aerial extent that protects birds out to the point that gear sinks to 10 m and that can sustain the force of fouling on a longline float at 10 to 12 knots. The outboard extent of the port tori pole must also be aligned with the location that baits land when thrown by the bait-casting machine.

The tori pole on the *Fukuseki Maru No. 5* extended the tori line 2 m outboard to port. Ideally, to create latitude for bait casting, a redesigned tori pole should extend a tori line a minimum of 4 m outboard. Alternatively, a lesser outboard extent would serve to protect birds only if the bait-casting machine were adjusted to deliver baits just inside the port tori line, or if baits were cast by hand.

Another critical element of tori line design is the placement of the first streamer relative to the stern. In order to protect birds, especially when a bait-casting machine is used, the first streamer should be within 10 m of the stern to protect baits as they land and are most exposed to depredation. At a setting speed of 9.5 knots, baits hit the water at 4 to 7 m from the stern. A first streamer at 5 m is not recommended, because it could lead to tangling branchlines with the first streamer under some sea conditions.

Innovation in branchline design increased the sink rate of baited hooks, but further innovation is required to meet the Tuna Longline Permit Conditions of a minimum sink rate of 0.3 m/sec to 10 m and sinking the hook to 10 m within 150 m of the stern (MCM 2008). Based on results during this cruise, the sink rate could be further increased by increasing the mass of the swivel and/or the amount of weighted line above the monofilament trace. The Fishing Master avoided this approach because of concerns that adding weight to the hook could lead to serious injury to crew if a fish threw a hook as it was being landed. It is possible that some "fisherman-safe" weighting at the hook, coupled with adding a swivel and/or weighted line above the hook, as done here, could provide an optimal result and meet permit conditions. Extensive at-sea and land-based trials in Australia comparing traditional weighted swivels to "safe leads" (a weight designed to drop from the branchline when under tension from a fish capture) are providing convincing proof that "safe leads" work and are safer than traditional weighted swivels (Graham Robertson, Australian Antarctic Division, pers. comm.). Collectively, these developments suggest that a range of innovations to increase the weighting and sink rate of branchlines are achievable and should be advanced in future research.

We are compelled to note that TDRs placed close to the hook are likely to affect the absolute sink rate of a given hook to some degree, but this effect is difficult — perhaps impossible — to determine *in situ*. Therefore, we suggest that TDR comparisons are useful to determine the relative sink rates of different branchline designs or weighting scenarios; however, the sink rates recorded are unlikely to be absolute.

Clearly sink rates and tori lines are closely linked, with regard to the risk of seabirds to bycatch. The faster the sink rate of the baited hook, the smaller the area that needs protection with tori lines. In this study, the branchline type and the manner in which the coil was delivered to the water had a substantial effect on sink rate altering the area that needed protection with a tori line. The area needing protection using the unmodified branchlines on the *Fukuseki* ranged from 187 m to 247 m (Figure 11), while the greatest aerial extent achieved was 150 m using the Prototype tori line with a road cone. *We suggest that increasing the sink rate of the branchline is more achievable than extending the aerial extent of the tori line to 250 m and that efforts directed at optimizing both are essential to achieving seabird conservation in tuna fisheries.* We further note that sinking the gear to a depth of 2 m as quickly as possible is the critical priority for protecting seabirds, because all species are vulnerable in this zone. Our focus in this report on sink times to 10 m is based on the language of the permit conditions.

Based on previous experience in other fisheries, seabirds encountered during this cruise were not aggressive, and interactions were weak. In the New Zealand joint venture fishery in May 2008, twenty birds were killed in just over two hours of daylight setting when baits were delivered outside the protection of streamer lines and the first streamer was far from the stern. If conditions were similar to those in New Zealand, hundreds of birds would have been killed during 12 days of partial daylight setting on this cruise. That few birds were killed during this work should not be attributed to the quality of seabird mitigation techniques, but to other factors that are difficult to identify. Weak interactions could be due to the season (early spring) and more northern latitude (29 to 32º South). Given the challenges with tori lines and modest success with increasing sink rates, these weak seabird interactions allowed us to make progress in improving mitigation dynamics with only one seabird mortality. This experience reinforces the need to conduct definitive mitigation research, such as comparing tori line designs, when seabird interactions are at their highest level. In South Africa, this is likely to be June and July, when tuna catches peak.

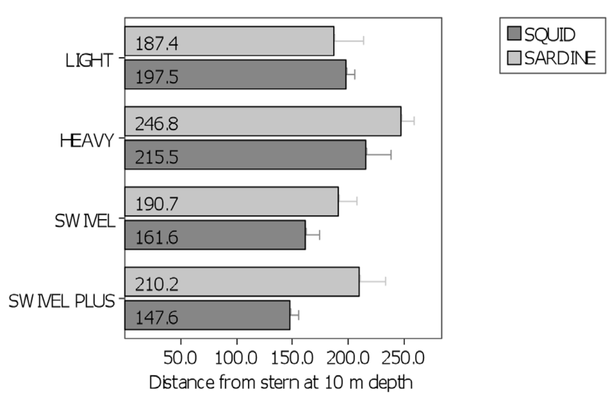

Figure 11. Mean distances of baited hooks from the stern to 10 meters depth observed among branchline designs by bait type on 12-17 October 2008 aboard the F/V *Fukuseki Maru No. 5*. Distance = (seconds to 10 m x sink rate in m/s) + 5 m. Error bars indicate one standard error.

The seabird abundance aspect of the protocol for both the set and the haul proved very doable and produced high quality data. Weak seabird interactions in this study limited insights into the fine points of our attack rate protocol — specifically what increments of distance could be used as attacks occur further from the vessel. However, we are confident that seabird attacks can be observed out to 200 m or more, depending on sea conditions. Based on our collective experience, a draft seabird behavior and abundance protocol for tuna fisheries is presented in Appendix 1. We encourage other scientists to use this protocol and work with us to refine it.

Next Steps

Based on progress on this cruise, the establishment of a good working relationship with cooperators, and the continued need to improve seabird mitigation in pelagic tuna fisheries in South Africa and elsewhere, we proposed that this effort be expanded to a controlled study on at least two vessels operating in the South African EEZ in June and July 2009. The objective would be to compare the efficacy of select tori line and branchline designs at reducing seabird attacks on baits and reducing seabird bycatch. In the case of tori lines, the optimal tori line design developed in this study would be the basis for comparisons with other designs. Comparing the performance of one vs. two tori lines would be seriously considered. Ideally, other tori line designs and branchline weighting strategies would be proposed by Fishing Masters and scientists involved with seabird bycatch mitigation. To make this work comprehensive, serious effort would be needed to redesign the traditional Japanese tori pole to one that can support the drag of a tori line and the shock of fouling a tori line on surface floats. Ideally, it should also extend the tori line 4 m outboard to port. The toss distance of the bait-casting machine would need to be aligned to deliver baits consistently within the outboard extent of the port tori line day and night. We are exploring the possibility of broadening the collaboration to include Japanese tuna fishery scientists to bring their expertise in tuna fisheries to bear and gain agreement on data collection protocols and data analyses, and perhaps to enhance communication at the vessel level and at the management level. Continued work in the South African fishery, as well as New Zealand and perhaps other fisheries, has great potential to identify best practices for tuna longline fisheries that are safe and practical as well as effective.

Summary

Tori Lines

An optimal tori line design was developed based on the collective experience of this cruise on the F/V *Fukuseki Maru No. 5* and earlier work in New Zealand (Melvin and Walker 2008). This design proposes that tori lines be broken into two components: a "protection" section and a "drag" section. The "protection" section includes a light, high-tensile strength, floating backbone, with suspended streamers and packing-strap material that protect the distance at which gear is within 1 m of the surface (Figure 10). The drag section, designed to create the drag necessary to achieve an appropriate aerial extent and ideally disturb the water in such a way as to deter birds from the in-water section of the tori line, incorporates breakaways or weak links that ensure that the "protection section" (the most expensive in terms of materials and time invested in construction) is never lost due to fouling on floats. *This design acknowledges that tori lines must be maintained on a daily basis, and that elements of the sacrificial drag section be restored as they are lost.*

Mylar reflective material in the backbone of the line quickly revealed signs of wear and is recommended only for use in streamers. Dark red streamers were demonstrably less visible than either orange or Mylar streamers and therefore are not recommended.

A strong attachment point to the vessel is crucial to effective use of tori lines. We propose that the traditional Japanese tori pole be redesigned to a structure that can support the drag necessary to create an aerial extent that protects birds out to the point that gear sinks to 10 m and that can sustain the force of fouling on a longline float at 10 to 12 knots. The outboard extent of the port tori pole must also be aligned with the location that baits land when thrown by the bait-casting machine.

A towed device that displaces the end of the tori line outside the wake would eliminate or greatly minimize fouling surface floats on tori lines. Washington Sea Grant, with the support of the David and Lucile Packard Foundation, is working to develop such a device; however, the success of *any* towed device is predicated on the existence of a solid tori line attachment point at the vessel.

In order to protect birds, especially when a bait casting machine is used, the first streamer should be within 10 m of the stern to protect baits as they land and are most exposed to depredation. At 9.5 knots setting speed, baits hit the water at 4 to 7 m from the stern. A first streamer at 5 m is not recommended because it could lead to tangling branchlines with the first streamer under some sea conditions.

Sink Rates

Innovation in branchline design increased the sink rate of baited hooks, but further innovation is required to meet the Tuna Longline Permit Conditions of a minimum sink rate of 0.3 m/sec to 10 m and sinking the hook to 10 m within 150 m of the stern (MCM 2008). This goal could be achieved by continued innovation, specifically, by adding some "fisherman-safe" weighting at or near the hook, coupled with adding a swivel and/or weighted line above the hook, as done by the Fishing Master in this cruise. Advances in the developments of "safe leads", and progress in branchline weighting in this study, provide the opportunity for further innovation to develop fast sinking branchlines.

The manner in which the branchline coil is deployed can delay the sink rate of the baited hook. Baited hooks as well as branchline coils should be cast beyond the wake to facilitate sinking the baited hooks from the surface as quickly as possible.

Clearly, sink rates and tori lines are closely linked with regard to the risk of seabirds to bycatch. The area needing protection using the unmodified branchlines on the *Fukuseki* ranged from 187 m to 247 m (Figure 11), while the greatest aerial extent achieved was 150 m, using the Prototype tori line with a road cone. We suggest that increasing the sink rate of the branchline is more achievable than extending the aerial extent of the tori line to 250 m, and that efforts directed at optimizing both are essential to achieving seabird conservation in tuna fisheries.

Based on previous experience in other fisheries, seabirds encountered during this cruise were not aggressive and interactions were weak. That few birds were killed during this work should not be attributed to the quality of seabird mitigation techniques, but to other factors that are difficult to identify. This experience reinforces the need to conduct mitigation research when seabird interactions are at their highest level. In the case of South Africa, this is likely to be June and July, when tuna catches peak.

Protocols

Weak seabird interactions in this study did not really provide a test of the attack rate aspect of our protocol, based on our work in Alaska demersal fisheries; however, we remain confident that we can record seabird attacks out to 200 m or more, depending on sea conditions. A proposed protocol for evaluating the effectiveness of different tori line designs was developed (see Appendix 1).

Future

Based on progress on this cruise, the establishment of a good working relationship with cooperators, and the continued need to improve seabird mitigation in pelagic tuna fisheries in South Africa and elsewhere, we proposed that this effort be expanded to a controlled study on at least two vessels operating in the South African EEZ in June and July 2009. The objective would be to compare the efficacy of select tori line and branchline designs at reducing seabird attacks on baits and reducing seabird bycatch. Continued work in the South African fishery, as well as New Zealand and perhaps other fisheries, have great potential to identify best practices for tuna longline fisheries that are safe and practical as well as effective.

Acknowledgements

We would like to thank Fishing Master — Kazuhiro Yamazaki — for his excellent hospitality, cooperation and innovation. Engineer — Yoshinari Hanada — maintained tori lines and provided innovation. Marius Kopp, the Fishery Observer, helped collect and shared data. We also would like to express our gratitude to our many collaborators: specifically Craig Smith, Don Lucas, Selwyn Roup, Hiroyuki Yoshida, Masaaki Nakamura, and Nagahide Kubota for their encouragement and cooperation. Sheila Garber and Frank Tarabochia built the Prototype tori line and provided insight on materials. Capricorn Fisheries Monitoring and the BirdLife Albatross Task Force provided extensive logistical support — we specifically thank Jan Wissema and Meidad Goren. Reviews by Barry Baker, Kim Rivera, Graham Robertson, Ben Sullivan, and Nathan Walker improved the manuscript. This project was funded by the David and Lucile Packard Foundation and Washington Sea Grant.

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Appendix 1.
Pelagic Longline Seabird Behavior and Abundance Protocol

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This protocol was designed to measure the response of seabirds to tori lines and possibly other surface mitigation technologies. It is based on our experience in the Alaska demersal longline fisheries (Melvin et al. 2001 and Dietrich et al. 2008) and observations in the New Zealand and South Africa joint venture tuna fisheries (Melvin and Walker 2008; Melvin et al. 2009). Bird Attacks on baits as a function of distance astern is a measureable behavioral index. In the absence of a deterrent, attack data tell you which seabirds are dominant and where baited hooks are most vulnerable to attack (Figure 1).

Changes in the magnitude of attacks and the peak distribution of attacks for each species can be used to determine the relative effectiveness of different tori lines or the number of tori lines (Figure 2).

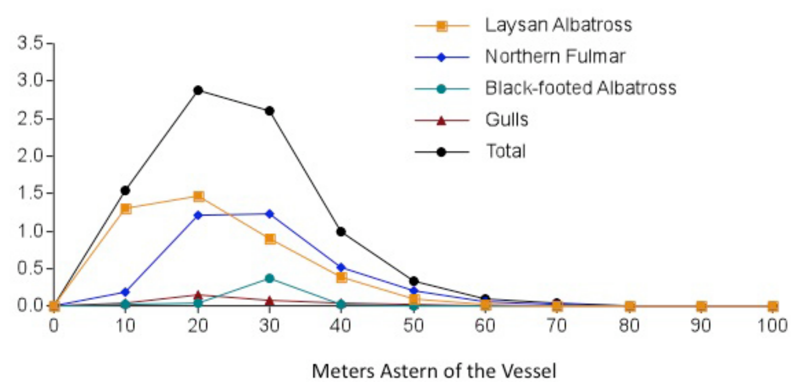


Figure 1. Seabird attacks on baits in the absence of a deterrent in the 2000 Alaska Fishery for sablefish and halibut. (from Melvin et al. 2001).

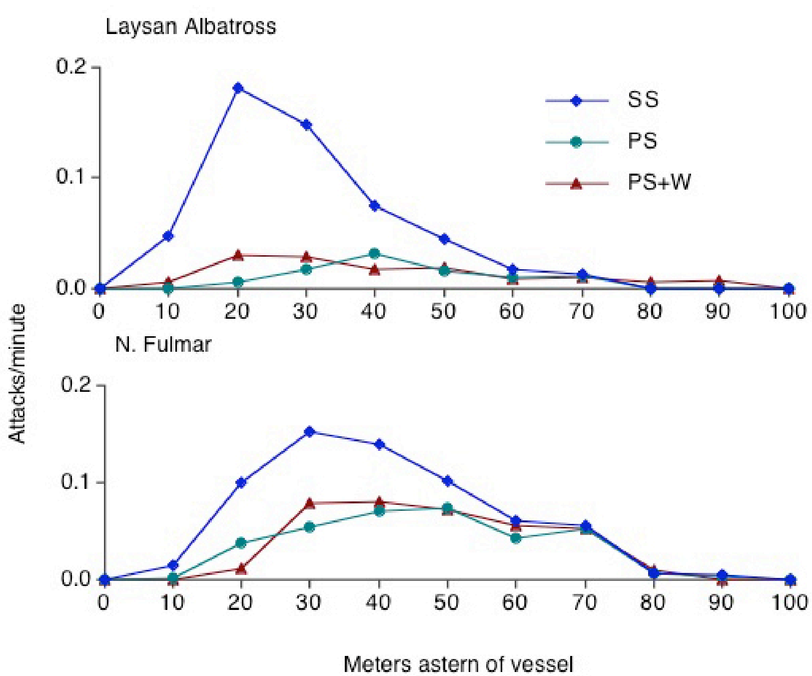


Figure 2. Attacks of Laysan albatross *(Phoebastria immutabilis)* and Northern fulmar (*Fulmarus glacialis*) in response to single streamer lines (SS), paired streamer lines (PS) and paired streamer lines plus added weight (PS+W; Melvin et al 2001; Figure 12, Page 8).

Collecting Seabird Abundance and Attack Data

Seabird counts by species tell us which species are present. Recording attacks by species tells us which of the species present are interacting with fishing gear. The distance of each attack from the stern tells us where interactions with the fishing gear occur.

An observation period includes taking 5 to 10 minutes to estimate abundance followed immediately by a timed 15 minute observation period to record attack rates by species as a function of distance astern. The number of observation periods possible in a given gear deployment will be dictated by the time available for observation during daylight sets. For example, if we estimate that only 120 minutes of daylight setting will occur, we would attempt to obtain three to four back-to-back observations. If the gear setting period was estimated to be 5 hours occurring entirely during daylight, hourly sampling would be more appropriate.

Seabird counts are made in a 250 m hemisphere centered at the stern of the vessel. To facilitate counting, the hemisphere is divided into three sections: the "wake", "starboard hemisphere" and the "port hemisphere" (Figure 3). Conducting counts by species and by section also allows us to evaluate how birds distribute themselves in response to a specific tori line design. Counts are made of birds in the air and on the water and by species in each section. Estimate the number of birds, by species and/or type, within each of the zones.

The sequence in which bird count are made by zones does not matter, but it is helpful to be consistent. Take your time to make sure you see all of the birds in the area, including those flying and those on the water. If swells are large, wait several swell cycles to make sure you are seeing birds which may be rafting a swell period beyond the vessel. Use binoculars to confirm your identifications, especially early in the season. For birds moving between or among sections assign the bird to the section it was most often observed.

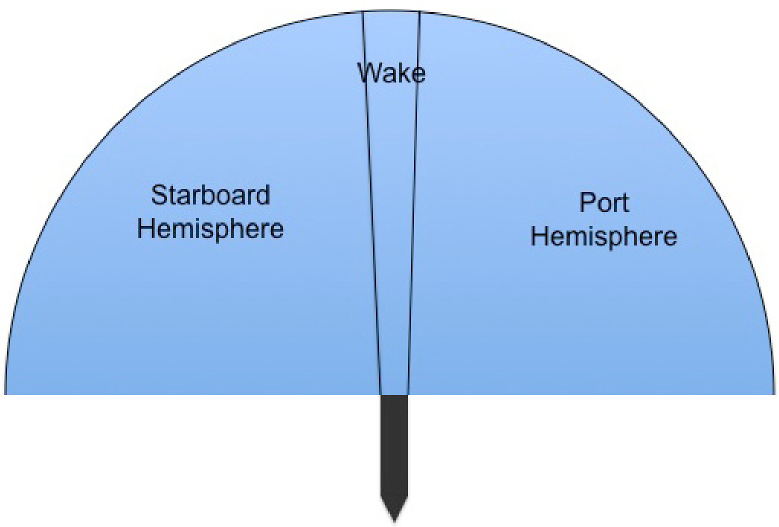


Figure 3. Seabird abundance sampling area – a 250 m hemisphere centered at the stern. Counts are made to the species or species group level for birds in the air and on the water for each section: Starboard hemisphere, wake and port hemisphere

How to Estimate Bird Abundance

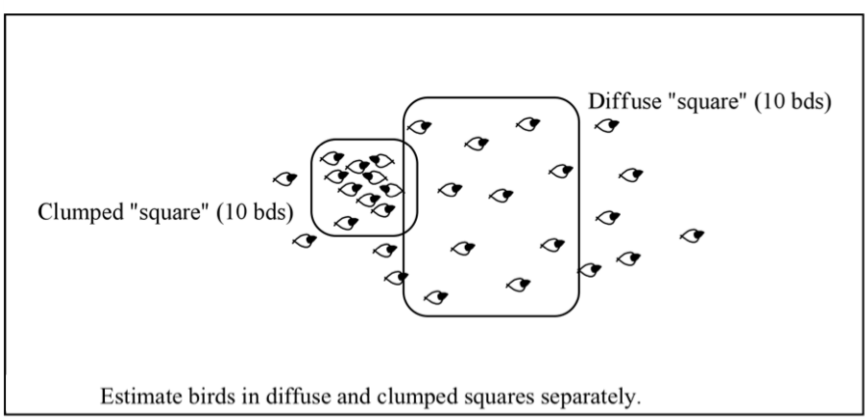
For small numbers (0-10), a species can be counted. Even though it is possible to count into the hundreds, it takes time; therefore, for larger numbers (15-infinity), you will have to estimate abundance.

Using this technique, you count a reasonable number of birds in a contiguous patch of water or air (say 5-25), visually "lock-in" on the area encompassed by those birds, and repeat that area in your mind's eye as you survey the entire area in which you need to estimate abundance (i.e., aft hemisphere). This is like imposing a grid on the water, where each square holds the number of birds you originally counted. You are then tallying the squares. Obviously, the size of the "square" will depend on the total number of birds in the area. If there are thousands of fulmars in the aft hemisphere, don't estimate by 5's. Use the following table as a guide to estimation ranges:

A complicating factor is that birds are rarely spread evenly over the surface of the water or in the air- birds are often clumped. The solution is to estimate the number of birds in a representative clump and then count the clumps (Figure 2).

Number Range	You Should:
1, 2, 3, 4, 5	count
10, 15, 20, 25	estimate by 5s (can also be counted)
30, 40, 50, 60, 70, 80, 90	estimate by 10s
100, 125, 150, 175	estimate by 25s (can also stick with 10s)
200, 250, 300, 350, etc.	estimate by 50s
500, 600, 700, etc.	estimate by 100s
1000, 1200, 1400, 1600, 1800, 2000	estimate by 200s (can also use 250s)
2000, 2500, 3000, etc.	estimate by 500s

Exercise: Estimating numbers takes practice, as does accurately identifying and counting moving targets like birds. The best thing to do is try estimating birds in a given area during gear retrieval. This will greatly help your ability to collect accurate data during deployment.



Attack Rate Sampling

An "attack" is any attempt by a bird to take a bait from a hook. If uncertain as to whether a dive or an attempt is on something other than a baited hook, be conservative and do not count it as an attack. Keep in mind, the presence of loose bait in a pelagic fishery is unlikely. If an attack leads to an aggregation of birds count it as one attack only – the initial attack has already occurred and the location of the attack that led the aggregation is the target of interest.

The distance astern at which attacks occur can be estimated from marks of known distance on the tori line and from knowing its length. We recommend marking the line at 50 m intervals and using the streamers, which should be spaced at known intervals (typically 5 m) as your guide. If you know vessel speed, you can also time the track of surface floats to judge distance. After a few observation sessions determining distances will become second nature.

Assuming you are on the upper deck of a vessel, record all attacks within 200 m astern. If you are on the setting deck near the water, adjust the sampling distance to one that you can reliably monitor. Record each attack by species, distance astern and location relative to tori lines – inside, port or starboard (Figures 4 and 5). Within 100m, record distance to the nearest 10m increment along the tori line. Normal rounding rules apply, but when in doubt, round up. Beyond 100 m record attacks in the 25 m blocks – for example, 100 to 125m, 126 to 150m, 151 to 175 m and 176 to 200 m. Adjust distance blocks with your ability to reliably record these data from set to set. Be alert to secondary interactions where a diving bird brings a bait to the surface which in turn creates a seabird aggregation fighting for the bait.

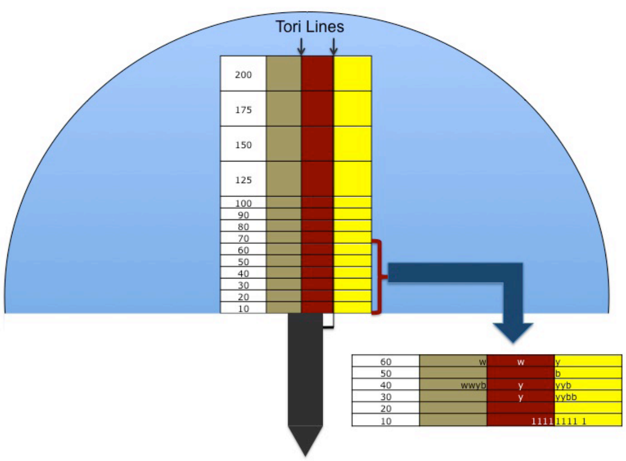


Figure 4. Illustration of zones used to record seabird attack rate using two tori lines (hypothetical field data notations included). Seabird attacks are recorded by species or species group as a function of distance from the stern within and on either side of two tori lines. The cut out is a close up of hypothetical data where w= white chinned petrel; Y = Atlantic yellow-nosed albatross; and b = black-browed albatross. Opposite the 10 m mark are ticks for the number of baits that fell inside and outside the port tori line.

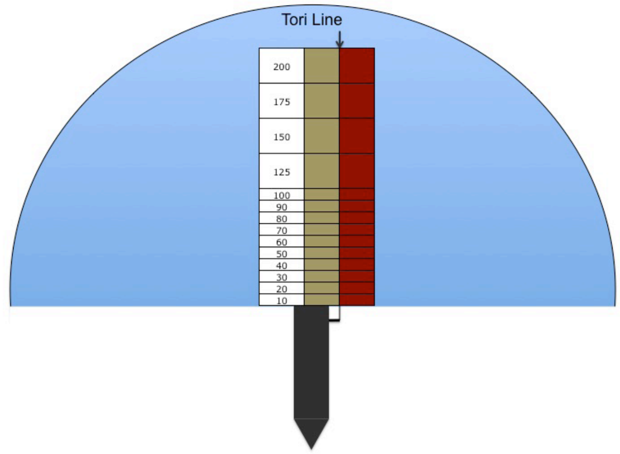


Figure 5. Illustration of zones used to record seabird attack rate using one tori line. Seabird attacks are recorded by species or species group as a function of distance from the stern on either side of the tori line.

Other Data

Before each observation session record the following:

- Vessel speed and course (from GPS or Bridge)
- Latitude and longitude
- Barometric pressure (in millibars)
- Time (digital wrist watch - to the nearest minute)
- Where baits land relative to the wake and the tori line(s). This is best done by observing at least 10 baits in succession and whether they are outside or inside the wake and within the protection of a tori line. In the case of two tori lines the bait should land somewhere between the two and not outside either line.
- Wind speed (from Bridge or hand-held anemometer if available or Beaufort sea state)
- Wind direction relative to the vessel (using the face of a clock centered at the stern)
- Swell height to the nearest 0.5 m
- Cloud cover: clear to 100%
- Weather (rain, fog, clear…etc)
- Other vessels in the area and type (longliner, trawler, freighter, etc.)
- Tori Line Specifics
    - Number
    - Port of starboard
    - Length
    - Aerial extent
    - Streamer number/materials
    - Distance of first streamer to the stern
    - Frequency of foulings with surface floats

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