Agreement on the Conservation of Albatrosses and Petrels

Twelfth Meeting of the Seabird Bycatch Working Group

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Seabird bycatch mitigation development for floated demersal longline fisheries in New Zealand

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SUMMARY

Research to improve the sink rate of baited hooks on floated demersal longlines has been recognised as a research priority by ACAP. The use of floats inherently risks reducing the sink rate of baited hooks, thus increasing their availability to seabirds which may become bycaught. Furthermore, the slow setting speeds in some operations may act to limit the aerial extent achieved by bird scaring lines, which exacerbates the risk of seabird bycatch.

This project focussed on reducing sink times to depth for externally weighted demersal longlines in primarily small vessel New Zealand fisheries targeting ling, hapuku, bass and bluenose. In these fisheries longlines are set with multiple floats attached between widely spaced weights to target fish at different heights above the sea floor.

Experimental gear configurations were developed to sink baited hooks to five metres depth within the protection afforded by the aerial extent of a bird scaring line and were tested during two commercial fishing trips. The practicality, workability, and influence on catch rates of experimental gear set ups was compared to control gear set as per the operator’s normal practice. A 'dropper float’ was developed and successfully deployed. This comprised two floats attached to the longline via a 7 m rope, and a weight on the longline to counteract the buoyancy of one of the floats. The use of increased line weight mass and reduced line weight spacing were also employed, and the aerial extent of bird scaring lines was maximised.

The use of more weight and dropper floats resulted in a marginal increase in workload for the crew but did not hinder setting or hauling operations. Dropper floats performed well, did not frequently tangle with the longline or bird scaring line, and proved simple to set and retrieve. Poor and patchy catch rates precluded firm conclusions on the potential influence of experimental gear configurations on target catch. Options were identified for fishers to further vary floatation added to lines without impairing sink times to five metres depth.

These trials have demonstrated that through the use of dropper floats, together with manipulation of line weighting regimes and bird scaring line configurations, it was possible to sink baited hooks beyond the reach of most seabirds under the protection of the aerial part of a bird scaring line. We plan further research to document the operational performance of the recommended gear configurations under a wider range of normal fishing operations by providing fishers user-friendly time depth recorders.

RECOMMENDATIONS

We recommend that SBWG:

1. note that through the use of dropper floats, together with manipulation of line weighting regimes and bird scaring line configurations, improved sink rates and adequate protection of sinking hooks by bird scaring lines can be achieved in small vessel floated demersal longline fisheries.
2. consider providing advice for best practice seabird bycatch mitigation in floated demersal longline fisheries which specifically highlights the use of dropper floats, together with manipulation of line weighting regimes and bird scaring line configurations which may differ from vessel to vessel.
3. encourage Parties and other fisheries operators to implement similar approaches to mitigate seabird bycatch in floated demersal longlines under their jurisdiction and report progress to future SBWG meetings.

Desarrollo de la mitigación de captura secundaria de aves marinas para las pesquerías de palangre demersal con flotadores en Nueva Zelanda

RESUMEN

El ACAP ha reconocido que la investigación para mejorar la tasa de hundimiento de los anzuelos cebados en palangres demersales con flotadores es una prioridad de investigación. El uso de flotadores tiene el riesgo inherente de reducir la tasa de hundimiento de los anzuelos cebados, aumentando así su disponibilidad para las aves marinas, que pueden resultar capturadas incidentalmente. Además, la lentitud de las velocidades de calado en algunas operaciones puede limitar la extensión aérea alcanzada por las líneas espantapájaros, lo que agrava el riesgo de captura secundaría de aves marinas.

Este proyecto se centró en la reducción de los tiempos de hundimiento a profundidad para palangres demersales lastrados externamente en pesquerías neozelandesas, principalmente de embarcaciones pequeñas, dirigidas a la maruca, el hapuku, la lubina y el rufo antártico. En estas pesquerías, los palangres se colocan con múltiples flotadores fijados entre pesos muy espaciados para apuntar a los peces a diferentes alturas sobre el fondo del mar.

Se desarrollaron configuraciones experimentales de artes de pesca para hundir anzuelos cebados a cinco metros de profundidad dentro de la protección que ofrece la extensión aérea de una línea espantapájaros y se probaron durante dos viajes de pesca comercial. La practicidad, la viabilidad y la influencia en las tasas de captura de los artes de pesca experimentales se compararon con los artes de control según la práctica normal del operador. Se desarrolló e implementó con éxito un flotador con peso. Esto consistía en dos flotadores unidos al palangre a través de una cuerda de 7 m, y un peso en el palangre para contrarrestar la flotabilidad de uno de los flotadores. También se empleó una mayor masa y un espaciado reducido del lastrado de brazoladas, y se maximizó la extensión aérea de las líneas espantapájaros.

El uso de más peso y de flotadores con peso dio lugar a un aumento marginal de la carga de trabajo para la tripulación, pero no obstaculizó las operaciones de calado o virado. Los flotadores con peso funcionaron bien, no se enredaron con frecuencia con el palangre o la línea espantapájaros, y demostraron ser fáciles de lanzar y recuperar. Las tasas de captura deficientes e irregulares impidieron llegar a conclusiones firmes sobre la posible influencia de las configuraciones experimentales de artes de pesca en la captura objetivo. Se identificaron opciones para que los pescadores variaran aún más la flotación añadida a las líneas sin perjudicar los tiempos de hundimiento a cinco metros de profundidad.

Estos ensayos han demostrado que mediante el uso de flotadores con peso, junto con la manipulación de los regímenes de lastrado de brazoladas y las configuraciones de las líneas espantapájaros, fue posible hundir anzuelos cebados fuera del alcance de la mayoría de las aves marinas bajo la protección de la parte aérea de una línea espantapájaros. Planeamos más investigaciones para documentar el rendimiento operativo de las configuraciones de artes de pesca recomendadas en una gama más amplia de operaciones de pesca normales, proporcionando a los pescadores registradores de profundidad y tiempo fáciles de usar.

RECOMENDACIONES

Se recomienda al GdTCS realizar las siguientes acciones:

1. Tomar nota de que mediante el uso de flotadores con peso, junto con la manipulación de los regímenes de lastrado de brazoladas y las configuraciones de las líneas espantapájaros, se pueden lograr mejores tasas de hundimiento y una protección adecuada de los anzuelos hundidos mediante líneas espantapájaros en las pesquerías de palangre demersale con flotadores de embarcaciones pequeñas.
2. Considerar la posibilidad de proporcionar recomendaciones de mejores prácticas de mitigación de la captura secundaría de aves marinas en las pesquerías de palangre demersal con flotadores, que destaque específicamente el uso de flotadores con peso, junto con la manipulación de los regímenes de lastrado de brazoladas y las configuraciones de las líneas espantapájaros, que pueden diferir de un buque a otro.
3. Alentar a las Partes y a otros operadores de pesquerías a aplicar enfoques similares para mitigar la captura secundaría de aves marinas en pesquerías de palangre demersal con flotadores bajo su jurisdicción e informen de los progresos realizados en futuras reuniones del GdTCS.

Développement de l’atténuation des captures accessoires d’oiseaux de mer pour les pêcheries palangrières démersales flottantes en Nouvelle-Zélande

RÉSUMÉ

La recherche visant à améliorer le taux d’immersion des hameçons appâtés sur les palangres démersales flottantes a été reconnue comme prioritaire par l’ACAP. L’utilisation de flotteurs risque intrinsèquement de réduire le taux d’immersion des hameçons appâtés, augmentant leur disponibilité pour les oiseaux de mer qui peuvent ainsi être capturés. De plus, les vitesses réduites de mise à l’eau dans certaines opérations peuvent limiter la superficie aérienne couverte par les dispositifs d’effarouchement des oiseaux, ce qui exacerbe le risque de captures accessoires.

Ce projet visait à réduire les temps d’immersion en profondeur pour les palangres démersales à lest externe dans les pêcheries néo-zélandaises ciblant principalement la lingue, le hapuku, le bar et le rouffe antarctique. Dans ces pêcheries, les palangres comportent plusieurs flotteurs fixés entre des lests très espacés afin de cibler les poissons à différentes profondeurs au-dessus du fond marin.

Des configurations expérimentales d’engins ont été mises au point, permettant d’immerger des hameçons appâtés à cinq mètres de profondeur, dans la zone de protection offerte par la superficie aérienne d’un dispositif d’effarouchement des oiseaux, et ont été testées lors de deux sorties de pêche commerciale. L’aspect pratique, la maniabilité et l’influence sur les taux de capture des dispositifs expérimentaux ont été comparés au dispositif témoin, conforme à la pratique normale de l’opérateur. Un « dropper float » a été développé et déployé avec succès. Ce dispositif comprend deux flotteurs fixés à la palangre par une corde de 7 m, et associés à un lest pour contrecarrer la flottabilité de l’un de ces flotteurs. L’utilisation d’un poids accru pour les lests et d’un espacement réduit entre les lests a également été mise en place, tandis que la superficie aérienne des dispositifs d’effarouchement des oiseaux a été maximisée.

L’utilisation accrue de lests et de « dropper floats » a entraîné une augmentation marginale de la charge de travail de l’équipage, mais n’a pas entravé les opérations de mise à l’eau ou de virage. Les « dropper floats » ont bien fonctionné, les enchevêtrements avec la palangre ou le dispositif d’effarouchement des oiseaux sont restés rares, et les « dropper floats » se sont avérés simples à installer et à récupérer. Á cause de taux de capture faibles et inégaux, il n’a pas été possible de tirer des conclusions définitives sur l’influence potentielle des configurations expérimentales d’engins sur les prises ciblées. Des options ont été identifiées pour que les pêcheurs varient davantage la flottaison des lignes sans nuire aux temps d’immersion jusqu’à cinq mètres de profondeur.

Ces essais ont démontré qu’en utilisant des « dropper floats », ainsi qu’en variant les régimes de pondération des lignes et les configurations des dispositifs d’effarouchement des oiseaux, il était possible d’immerger des hameçons appâtés hors de portée de la plupart des oiseaux de mer sous la protection de la superficie aérienne d’un dispositif d’effarouchement des oiseaux. Nous prévoyons d’autres recherches visant à documenter le rendement opérationnel des configurations d’engins recommandées dans un plus large éventail d’opérations de pêche normales, en fournissant aux pêcheurs des appareils de mesure de temps et de profondeur conviviaux.

RECOMMANDATIONS

Nous recommandons que le GTCA :

1. Note que l’utilisation de « dropper floats », ainsi que l’ajustement des régimes de pondération des lignes et des configurations des dispositifs d’effarouchement des oiseaux, permettent d’améliorer les taux d’immersion et de protéger adéquatement les hameçons immergés par les dispositifs d’effarouchement des oiseaux dans les pêches à la palangre démersale flottante sur des navires de petite taille.
2. Envisage de fournir des conseils en matière de bonnes pratiques d’atténuation des captures accessoires d’oiseaux de mer dans les pêcheries à la palangre démersale flottante, qui mettent particulièrement l’accent sur l’utilisation de « dropper floats » ainsi que sur l’ajustement des régimes de pondération des lignes et des configurations des dispositifs d’effarouchement des oiseaux, qui peuvent différer d’un navire à l’autre.
3. Encourage les Parties et les autres opérateurs de pêche à mettre en œuvre des approches similaires pour atténuer les captures accessoires d’oiseaux de mer dans les palangres démersales flottantes relevant de leur juridiction, et à rendre compte des progrès accomplis lors de futures réunions du GTCA.

Novel seabird bycatch mitigation for floated demersal longline fisheries

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Executive Summary

The introduction of mitigation standards and subsequent changes to regulations require fishers to sink demersal longlines to a depth of five metres within the aerial extent of the tori line. Previous experimental trials without hooks identified gear modifications to reduce sink times to depth for ‘floating’ demersal longlines set with multiple floats attached between widely spaced weights. In combination with tori line improvements these modifications were shown to meet regulations.

This project tested compliant gear configurations in a fishing context to examine their practicality, workability, and influence on catch rates compared to control gear set as per the skipper’s normal practice. Deployment of modified floats with a seven-metre rope between the float and the longline and a small weight on the longline was successful. Increased line weight size and reduced line weight spacing were also employed. These measures resulted in reduced times to depth and, in combination with tori lines providing coverage up to 90 m astern, met the regulated depth of five metres at the end of the tori line.

The use of more weight and modified floats resulted in a marginal increase in work load for the crew, but did not hinder setting or hauling operations. Modified floats performed well, did not frequently tangle with the longline or tori line, and proved simple to set and retrieve.

Poor and patchy catch rates precluded firm conclusions on the influence of experimental gear configurations. However, if necessary, options were identified to more precisely control the height hooks fish above the seabed whilst meeting regulations.

Background

The introduction of mitigation standards for demersal longliners (MPI, 2019) and subsequent changes to regulation (MPI 2021) require fishers to sink bottom longlines to at last five metres depth under the protection of a tori line. Previous work (Goad & Olsen, 2023) experimentally tested sink times to depth for a range of gear configurations and made recommendations for improving depths at the end of the tori line aerial extent.

The Conservation Services Programme Technical Working Group reviewed previous work in conjunction with suggested proposals arising from the social research project MIT 2033-03 (Turner, 2023), and agreed that it was useful to investigate alterations to gear configuration in a fishing context (DOC 2023a).

This project tested alterations to gear configuration under fishing conditions to assess their practicality and any impacts they may have on normal fishing operations.

Introduction

The deep-water manual baiting demersal longline fishery targets species such as ling (hokarari, *Genypterus blacodes*), hapuku (*Polyprion oxygeneios*), bass (moeone, *Polyprion americanus*) and bluenose (mātiri, *Hyperoglyphe antarctica*), generally in depths greater than 150 m. A similar fishery operates in shallower water, using lighter gear and longer branchlines. The use of a three-millimetre or larger backbone separates the 'deep' demersal longline fishery, from the 'shallow' demersal longline fishery which predominantly targets snapper (tāmure, *Pagrus auratus*).

The deep-water fishery uses a mainline or 'backbone' of either three-to-six-millimetre diameter monofilament nylon ("mono") or seven-to-nine-millimetre polypropylene rope. It deploys hooks on 500-millimetre long, two-millimetre diameter, monofilament branchlines. Baited hooks are stored either on cards containing (typically) 32 hooks, in fish bins, or on metal rods. Hooks are individually clipped onto the mainline during the set, as the line leaves the vessel. Generally, hooks are pre-baited by hand, commonly with squid (wheke, e.g. *Nototodarus spp.*) or barracouta (mangā, *Thyrsites atun*) though some vessels use automatic or random baiters which pull hooks through a pool of pre-cut baits during setting operations (DG pers. obs.).

Hooks are generally separated by regularly spaced stoppers but may be spaced by eye when using rope. The fleet employ a range of gear configurations, which vary with target species. Sets targeting ling are typically over 'clean' flat seabed with skippers aiming to add sufficient floatation to hold some hooks just above the seabed to avoid invertebrate bait stealers and lice. Bluenose configurations may be fished over 'foul' bathymetric features and generally aim to suspend some or all hooks well above the seabed by the addition of several floats between weights. Lines targeting other species tend to employ gear configurations between these two examples, at times also varying with the nature of the seabed.

Gear configuration is flexible and can be changed between and within sets. Hook spacing is dictated to some extent by stopper spacing but vessels can (for example) use lines with one-metre stopper spacing and clip hooks on every two to four stoppers to modify hook spacing. Weight spacing is, in turn, dictated by the number of hooks between weights. The height of the gear above the seabed is controlled by the length of rope between the weights and the longline and the addition of floats in combination with weights and/or directly on the mainline between weights.

For a given amount of weight per metre of longline, using smaller weights at closer spacings produces more even sink rates and shorter times to depth (Goad & Olsen, 2023). However, as described above, some species are targeted with lines set 'floating' above the sea bed and, in some instances, specific echo sounder marks will be targeted. These 'floating' lines generally involve gear configurations with multiple floats between widely-spaced weights and consequently the line between weights spends considerable time close to the surface before the following weight is attached. This project builds on previous work to test the practicality of modifying gear configuration to reduce sink times to depth for 'floating' gear, during commercial fishing trips.

Objectives

The objectives of the project were:

To identify potential novel options to mitigate seabird bycatch in floated demersal longline fishing gear.

To test one or more novel bycatch mitigation option(s) identified for floated demersal longline operations and assess the feasibility and practicality of commercial implementation.

(Conservation Services Programme Annual Plan 2023/24 (Department of Conservation, 2023b)).

More specifically the project aimed to alter gear configuration to sink hooks to five metres at the end of the tori line, and compare this with control gear set as per the skipper's normal operation. Comparisons included catch rates and an assessment of the practicality of alternate gear configurations including any extra time and/or work necessary for the crew.

Methods

Preparation

Two vessels were chosen for the trials (Figure 1). Fishing Vessel A targets ling and bluenose on the east coast of the North and South Islands. At 19 m it was typical of larger vessels in the fishery, had two longline drums, and would typically set three or four lines a day. It had a steel hull, aft wheelhouse, a fully-sheltered working deck, and is normally operated with a skipper and three crew. Fishing Vessel B targeted bluenose, hapuku, bass, school shark (kapetā, *Galeorhinus galeus*), snapper, king tarakihi (*Nemadactylus spp.*), and red snapper (*Centroberyx affinis*). Vessel B had three longline drums, and set one or two lines a day. At 15 m it is typical of the larger vessels in the 'snapper fleet', several of which also fish in deep water. It had a steel hull with a forward wheelhouse and sheltered working deck, and is operated with a skipper and two crew.

Figure 1. Vessels A and B (credit Marine Traffic).

Prior to sailing, individual one-kilogram lead weights were tied together to make six-kilogram and three-kilogram weights for use on experimental gear sections. Thirty 'modified' floats were made up which consisted of two 150 mm diameter pressure floats tied together. A 7.2 m (four fathom) long four-millimetre diameter rope was tied to the floats and wound around them. The loose end of the rope had a 1.3 kg weight and 100 mm shark clip attached, resulting in overall buoyancy equivalent to a single float (Figure 2). These 'modified floats' were designed to reduce sink times to a depth equivalent to the length of the rope, after which the floats get pulled under water and the line behaves in a similar manner to adding single floats. Both vessels typically fished with single 150 mm diameter pressure floats attached directly to the backbone, with a range of weight sizes.

Figure 2. Modified float, ready for deployment.

Tori line testing

New tori lines were taken on board both vessels and towed inside the harbour to assess aerial extent and compare with the vessel's tori line. The tori line had a three-millimetre diameter Dyneema aerial section with alternating 10 mm wide fibreglass measuring tape and six-millimetre diameter orange plastic tubing streamers, every five metres. The drag section comprised of 30 m of nine-millimetre diameter trawl braid with 50 x 83 mm gillnet floats spaced a metre apart, followed by eight metres of 52 mm diameter eight-plait polypropylene rope with 150 x 260 mm cones at two-metre spacing (Figure 3). Vessel A had two 8.3 m high tori poles, and Vessel B had a single 7.0 m high pole.

Longline configuration

Lines were deployed starting with A5 and HL3 Polyform buoys attached to eight-millimetre diameter rope downline. On both vessels the rope downline was initially set slack, often turning after deploying the floats. On Vessel A the rope downline was stored on the longline drum so setting continued without interruption. However, on Vessel B, the downline was stored in a separate bin, so at each end of the line the vessel stopped, connected the rope to the monofilament backbone on the drum, attached the grapnel, and then carried on setting. On both vessels a 20-30 kg steel grapnel was attached at the junction between the rope downline and the backbone, followed by a float, and then repeated sections of line separated by weights. Three lines were set per day on Vessel A, two with eight-millimetre three strand polypropylene rope backbone and one with a mixture of six-millimetre diameter monofilament nylon and rope backbone. On Vessel B two lines were set per day, using either five- or three-millimetre diameter monofilament nylon backbone.

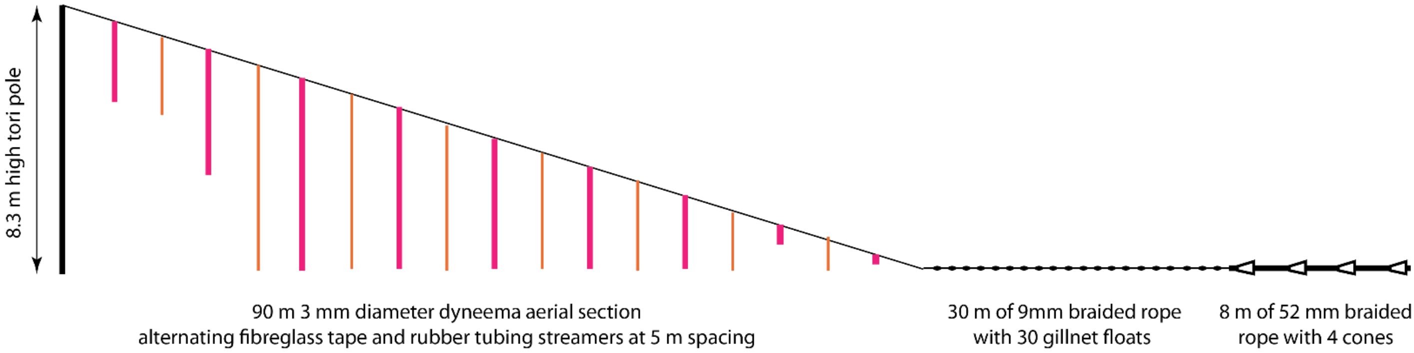

Figure 3. Tori line design

Alterations to gear configuration to reduce sink time to depth

The skippers varied gear configuration depending on backbone material, target species, and to a lesser extent seabed topography. On Vessel A control configurations employed by the skipper, as per normal fishing operations, used approximately six-kilogram steel weights at spacings of 210-360 m. On Vessel B control configurations used either six- or twelve-kilogram weights at spacings of 100-180 m.

Experimental configurations on Vessel A were iteratively developed using heavier lead weights, smaller spacings, and modified floats. This avoided making large changes to gear configuration and allowed the skipper to gradually become comfortable working more weight at closer spacing. Typically, gear was altered for three to six consecutive sections on two lines a day, with the rest of the gear set at the skipper's discretion. Results from previous sets informed subsequent gear configurations employed. On Vessel B changes did not materially alter weight size or spacing and just substituted single floats for modified floats, usually on approximately half of each line.

Time depth recorder deployment

CEFAS G5 time depth recorders (TDRs) were deployed in 80 mm long x 30 mm diameter housings, and were stored in a bucket which was filled with seawater several minutes prior to the first deployment. TDRs were programmed and data was downloaded on a set-by-set basis. Between sets TDR clocks were reset to the PC time and this was checked against the clock used on deck to manually record clip-on times. TDRs were clipped directly onto the backbone at the estimated slowest sinking part of the line. For each line with experimental sections three TDRs were attached to both control and experimental sections. Extra TDRs were deployed to examine variations in sink profile, and to estimate the slowest-sinking position within a section. A GoPro camera was used to check TDR deployment times.

Line tension was recorded using a purpose-built meter, which was calibrated by hanging a series of weights in six-kilogram increments from a length of monofilament passing through the meter.

Data processing

Data manipulation and analysis was conducted in R (R Core Team 2021). TDR depth was adjusted with an offset derived from mean readings from one to two minutes prior to deployment. Individual sink profiles and tension records were examined and compared with videos and notes made during the set to verify clip-on times, and to ensure that any records which did not represent typical conditions were removed, for example if the floats and weights were not deployed in the desired sequence. In line with previous work (Goad and Olsen 2023), to allow for potential inaccuracies in TDR-derived depths and the distance between the hook and TDR, times to six metres depth are presented.

Catch assessment.

All catch was recorded as number of each species caught on each section of line, with weights separating sections. Returned baits and empty hooks per section were also counted. Box-whisker plots were constructed of catch per hook of ling (Vessel A) and ‘all landed fish species’ (Vessel B), and the percentage of hooks (that did not catch fish) with bait remaining at the haul. Plots were split by line and by treatment (either ‘control’ or ‘experimental’ sections of line) except for lines 19 and 20 on Vessel A, which were combined. Both lines were set in the same direction, in similar depths. Line 19 had experimental gear for the majority of the line and line 20 was all control gear.

Results

Trip summaries

The sea time on Vessel A was completed between the 10th and 19th February 2024, following a few days waiting for a weather window. Conditions were generally good with less than 20 knots of wind and 1.5 m swells, except on the third day where wind speed exceed 25 knots and swells exceeded two metres. Current varied throughout the trip and maximum current coincided with the poorer weather and may have been partly driven by wave and wind action. Sets targeted ling for four days and switched to bluenose on the fifth day, all in canyons north of Lyttelton. Following poor catches of bluenose, and a southern royal albatross capture on the control gear, the decision was taken to revert to ling target sets for the final two days of the trip.

The second trip, on Vessel B, was conducted between the 12th and 17th April 2024 after waiting for the easterly wind and swell to drop and the forecast to improve. For the first day a residual 1.5 m swell was present and wind speed was 10-15 knots whilst setting and up to 20 knots during the haul. The remainder of the trip was in calmer weather conditions with swells generally less than a metre and wind speeds less than 15 knots. Current was consistently 0.3 knots to the south east offshore, when targeting school shark and bluenose east of North Cape, and minimal when fishing further inshore targeting red snapper, hapuku, king tarakihi, and snapper.

Both vessels proved to be a capable and comfortable work platforms and the skippers and crews were unfailingly helpful, keen, proactive, and efficient.

Tori line testing.

The tori line drag section tracked well behind both vessels, though it took some time to re-align following sharp turns during testing. Under fishing conditions deflection due to crosswinds was minimal up to 20 knots, above which some horizontal displacement was noticeable. The tori line produced 90 m of aerial extent at 3.5 knots on Vessel A, and 70 m at 3.5 knots on Vessel B. The tori line provided much greater aerial extent than Vessel A's tori line so was used for the trip. Vessels B's tori line, of a similar design but with a road cone on the drag section, provided slightly less drag but a similar aerial extent and this was used during the trip as the skipper was familiar with it.

Having two tori poles on Vessel A provided options for attachment but it was not practical to swap the tori line from side to side during a set. For most sets the tori line was run from the starboard side of the vessel, with the gear shot slightly to port of the centre line. The tori line was deployed and retrieved every set, immediately before and after hooks were set. Under fishing conditions aerial extent was hard to quantify due to night setting and low lighting levels. However, it appeared that sufficient drag was consistently generated to keep the 90-metre aerial section taught and out of the water. No tangles occurred during the trip.

On Vessel B the tori pole was on the centreline of the vessel. The skipper deployed the tori line once per night and left it out between sets, briefly checking it was clear of the end floats with a spotlight. No tangles occurred and the aerial extent appeared consistent. One set during the day was cut short due to birds showing interest in baits beside the tori line.

TDR data grooming

All sink profiles were checked to ensure that depth offsets corrected TDR depth to zero at the surface, prior to deployment. Notes and video footage identified six records for removal due to incorrect gear deployment, two sets cut short, a hook bin change resulting in abnormally large spacing, and two float lines not fully unwinding. Whilst some of these problems were identified during setting and extra 'replacement' TDRs were deployed, some were only identified at the data processing stage so were not replaced. Additionally, two TDRs were lost – one whilst clipping on, and one on a lost section of gear. Consequently, three repeats were available for most but not all line configuration and TDR position combinations.

Alterations to gear configuration to reduce sink time to depth

On Vessel A gear configuration was altered iteratively, to avoid making large changes to the gear which could otherwise have caused operational problems, and to understand the effect of different changes. Initially, modified floats and larger weights were employed on experimental sections and then, additionally, weight spacing was decreased by reducing the number of hooks between weights (Figure 4, Table 1). Once sink times to six metres had been achieved under the tori line, and the skipper was happy with the experimental gear, more experimental sections were deployed on later sets.

On Vessel B the skipper's normal weighting regime involved heavier weights and closer spacings and so changes to gear configuration only comprised of switching normal floats for modified floats (Figure 4, Table 1).

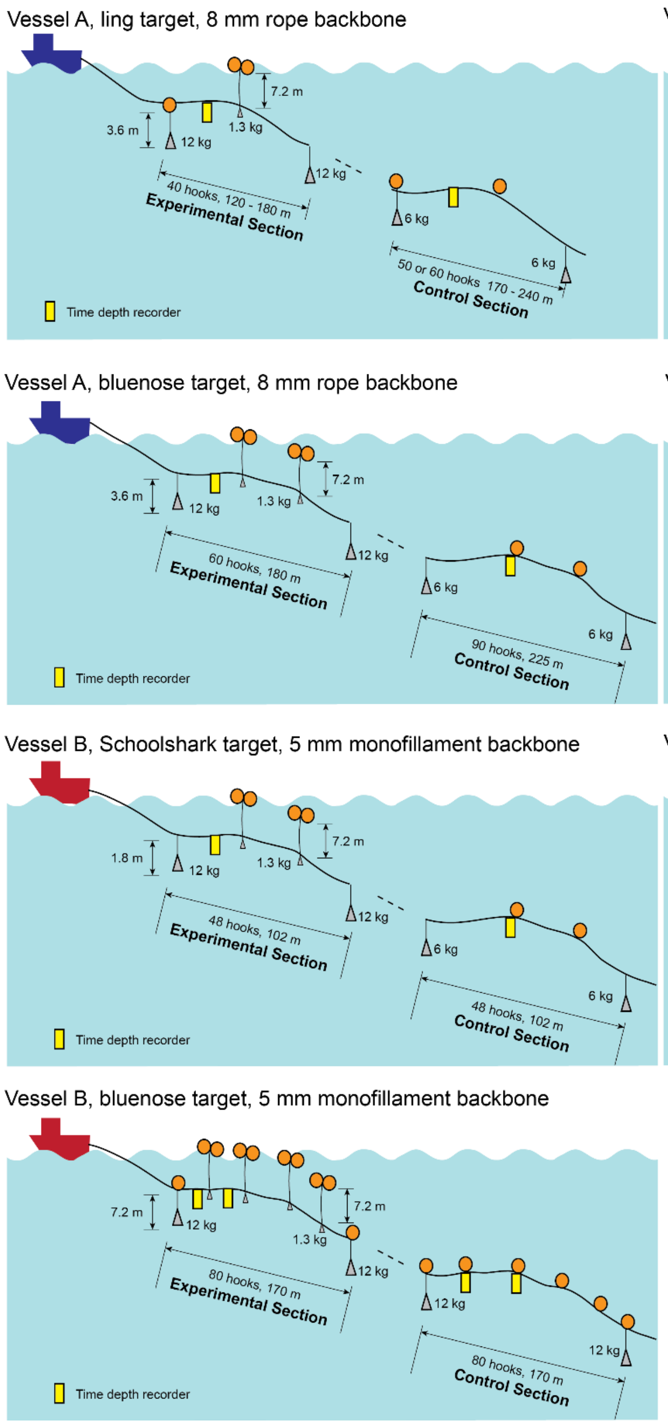

Figure 4. Summary of control and final experimental gear configurations trialled, by backbone type, target, and vessel.

Identifying slowest sinking positions

TDR placement was different on control and experimental gear, and different TDR positions in the repeated sequence were trialled to identify and measure the slowest sinking hook for any given configuration. Depending on the configuration and weight spacing, TDRs either three-quarters of the way after a weight, on the last float in a sequence, or after the last one or two modified floats in a sequence sank slowest (Appendix 2).

On Vessel A, hook spacing was variable and partially dependent on the aptitude of crew members clipping on hooks as well as skipper instructions. Rope backbone had no stoppers so spacing was by eye, and although the monofilament was supplied with regularly spaced stoppers these were sometimes missing, inconsistently counted, or missed. Weight spacing was estimated at the set using vessel speed and time between weights, and by estimates of hook spacing at the haul; by eye and by counting stoppers on monofilament backbone. The number of hooks per section relied on counts by the crew as branchlines were set from fish bins, however these were found to be accurate when checked daily. A combination of increasing weight size from six to twelve kilograms, reducing weight spacing by a third, and the use of modified floats provided sufficient reductions in sink times to sink hooks to six metres within the protection provided by the tori line, for lines targeting ling (Table 1). Environmental conditions and variations in hook spacing can account for variation between and within sets.

On Vessel B, hook spacing was determined by stopper spacing and crew very rarely missed stoppers. Weight or floats were deployed twice per card and spacings were accurate within 1-2 hooks, with small variations when changing cards. The use of modified floats generally provided sufficient reductions in sink times to sink hooks to six metres within the protection provided by a 75 m tori line (Table 1).

Table 1. Summary of control and experimental sections deployed, by line and vessel. Note: 1 float is a 150 mm diameter pressure float and 1M (modified) float comprises two 150 mm diameter pressure floats and a 1.3 kg weight per Figure 2, bns = bluenose, sch = schoolshark, rsn = red snapper / king tarakihi / hapuku, max distance at 6 m = maximum distance astern the slowest sinking TDR repeat reached six metres depth.

				Control sections				**Experimental sections**			
Vessel	**line**	**target**	**backbone**	**weight (kg)**	**spacing (hooks / m)**	**floats**	**max 6 m distance**	**weight (kg)**	**spacing (hooks / m)**	**floats**	**max 6 m distance**
A	1	ling	rope (8)	6	60 / 240	1	189	12	60 / 240	1	151
A	2	ling	rope (8)	6	60 / 240	1	263	12	60 / 240	1M	128
A	4	ling	rope (8)	6	60 / 240	1	196	6	40 / 160	1M	105
A	4	ling	rope (8)					12	40 / 160	1M	85
A	7	ling	rope (8)	6	50 / 150	1	187	12	30 / 90	1M	79
A	10	ling	rope (8)	6	50 / 180	1	198	12	40 / 120	1M	99
A	16	ling	rope (8)	6	50 / 200	1	122	12	40 / 160	1M	86
A	19,20	ling	rope (8)	6	50 / 180	1	124	12	40 / 140	1M	85
A	3	ling	mono (6)	6	90 / 360	2	399	12	90 / 360	2M	144
A	6	ling	mono (6)	6	90 / 315	2	196	12	60 / 210	2M	94
A	9	ling	mono (6)	6	75 / 225	2	166	12	45 / 135	2M	85
A	18	ling	mono (6)	6	75 / 375	2	167	12	60 / 300	2M	92
A	21	ling	mono (6)					12	60 / 200	2M	79
A	14	bns	rope (8)	6	75 / 190	2	235	12	60 / 150	2M	124
A	15	bns	mono (6)	6	75 / 225	2x2	178	12	60 / 180	2M	65
B	1,2	sch	mono (5)	6	48 / 102	2	129	6	48 / 102	2M	81
B	3	bns	mono (5)	12	80 / 180	4	115	12	80 / 180	4M	75
B	4	bns	mono (5)	12	80 / 180	4	111	12	80 / 180	4M	89
B	5	bns	mono (5)	12	80 / 180	4	102	12	80 / 180	4M	68
B	9	rsn	mono (3)	6	50 / 100	1	111	12	50 / 100	1M	73
B	11	bns	mono (5)					12	96 / 210	5M	76

Plots of sink profiles over time show marked increases in depth with experimental gear configurations (Figure 5). The relatively small 1.3 kg weight on the modified floats was sufficient to sink the line below the surface, markedly reducing the period of time hooks spent close to the surface (Figure 5).

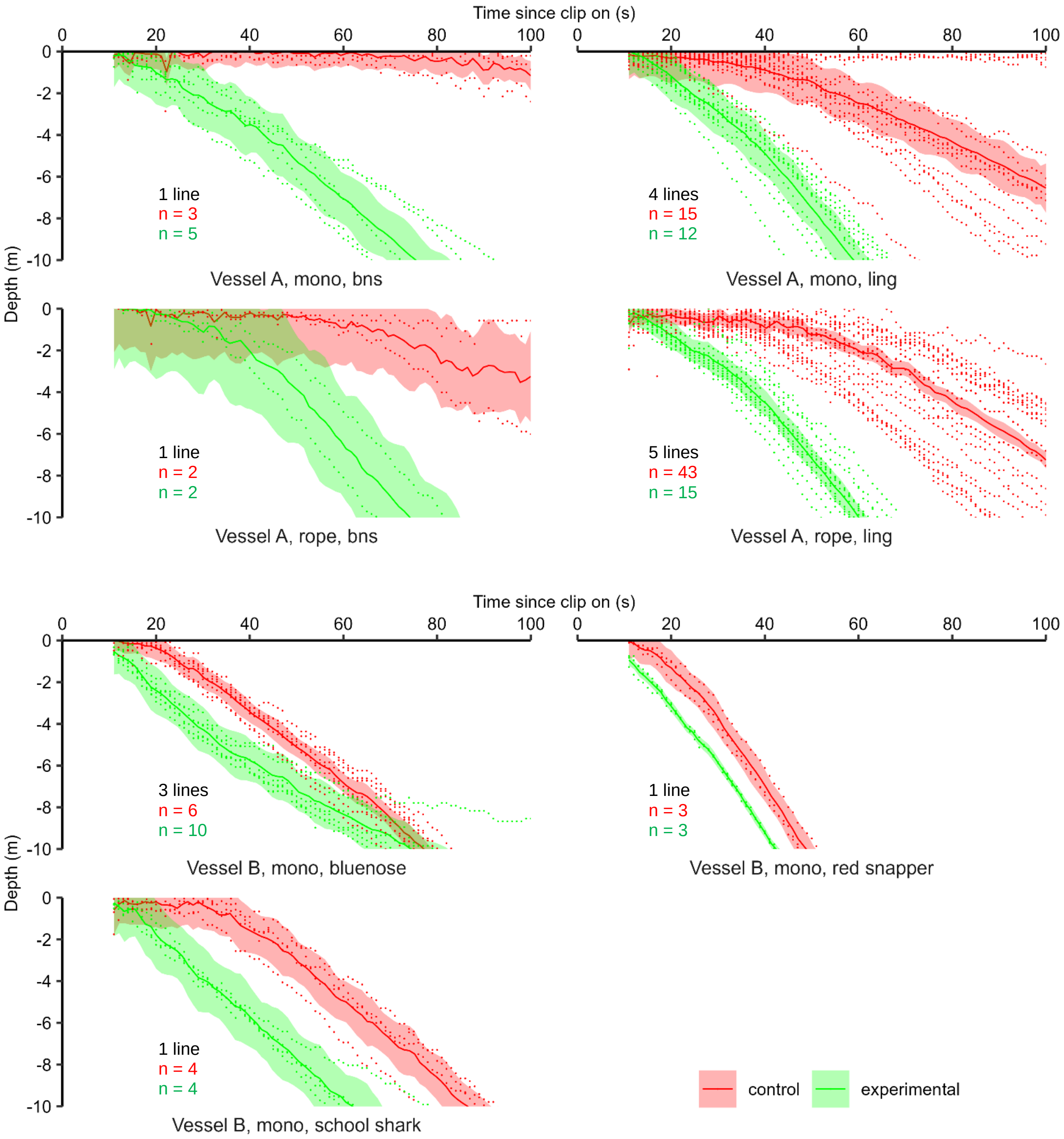

Figure 5. Depth over time for TDRs deployed on control and experimental sections by vessel, target and backbone type. Points show individual records with lines plotting smoothed mean depth and shaded areas showing +/- s.d..

Practicality of using modified floats.

Whilst setting, the gear modified floats were clipped onto the backbone without causing delays. Slightly more care and time was needed as the clip had to be un-clipped from the float rope prior to deployment. However, this was easily achievable as one crew dealt with floats, weights, anchors, and the tori line. If some vessels work with less, or less-experienced, crew then it may marginally slow setting operations. Modified floats tangled with the longline on two occasions out of 165 deployments and this may have been related to the line being stuck on the seabed during hauling. Two modified floats failed to unwind fully and on one occasion one was caught in the propellor whilst hauling. For multiple float configurations, it may not be necessary to use modified floats for floats deployed shortly after a weight (Appendix 2) but this requires further confirmation.

The crew and skippers were unphased by the marginal extra time and hassle involved in using modified floats, and storage space was not an issue. However, different attitudes and circumstances may be encountered on different vessels.

Line tension

Line tension was measured for the first four days on Vessel A and found to be reasonably consistent, in a range of 25-32 kg, for both monofilament and rope lines. Two catchups occurred on the tension meter, due to spliced loops on rope longlines catching around a pulley. These catch ups were dealt with quickly and efficiently by the crew. However, because line tension was not changed through the trip, it was decided to not run the line through the meter for the remaining sets. On Vessel B line tension was measured during two sets with five-millimetre diameter backbone. Tension was initially 18 kg and then gradually increased through the setting process as the diameter of the drum reduced. The skipper monitored line tension by feel, and reduced the brake on the drum in stages, resulting in maximum tension of 25 kg.

Catch comparison

On Vessel A catch rates were reasonably low when targeting ling and poor when targeting bluenose. Ling was targeted on the side of canyons in depths between 150 and 500 m. Variation in depth within lines appeared to drive catch rate and catch composition more than gear configuration. On rope lines experimental sections with increased weight size, closer weight spacing, and modified floats fished comparably to control gear for both ling and all landed fish (Figure 6). Bait return rates were also similar (Appendix 3).

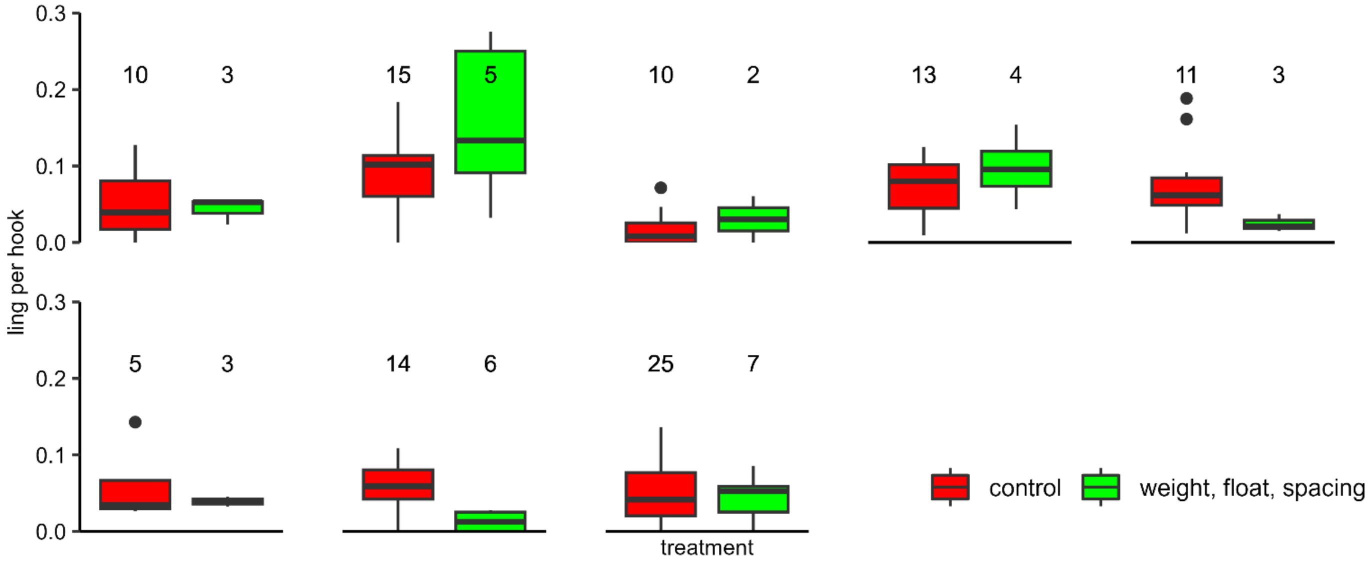

Figure 6. Catches of ling on rope lines from Vessel A, by line and treatment (control vs increased weight size, closer weight spacing and modified floats). Numbers above boxes show number of line sections in each treatment.

On monofilament lines catches between treatments were similar initially, but ling catches were lower on experimental sections during the latter days of the trip (Figures 15 and 16).

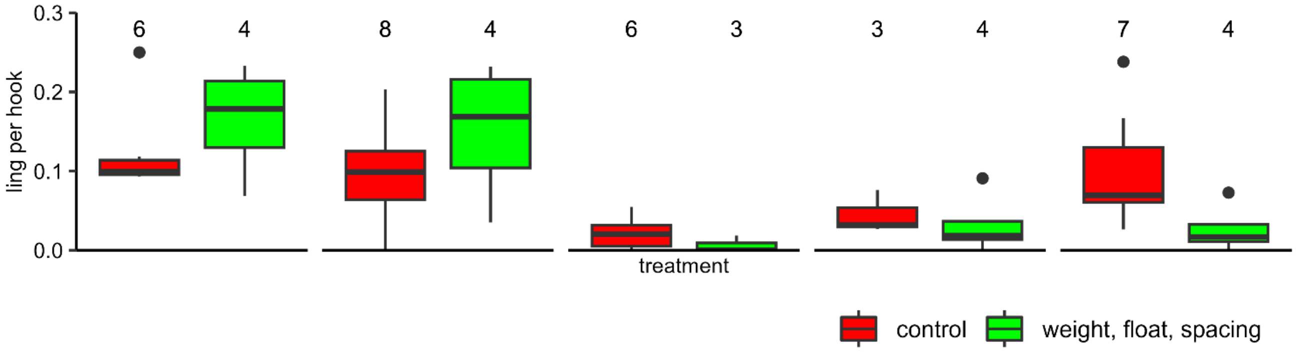

Figure 7. Catches of ling on monofilament lines from Vessel A, by line and treatment (control vs increased weight size, closer weight spacing and modified floats). Numbers above boxes show number of line sections in each treatment.

On Vessel B catch rates were poor on the first two lines, but otherwise catch rates were again driven largely by topography and often only a few sections of the line would catch the majority of the fish. Generally, the ends of a line caught less as the skipper aimed to set the middle of the line over the target area. Catches were comparable between control gear and gear set with modified floats (Figure 8). On one line, poorer catches were noticeable on the experimental gear however, this coincided with lower bait returns (Appendix 3) and a ‘bait fish’ mark on the echo sounder during the set.

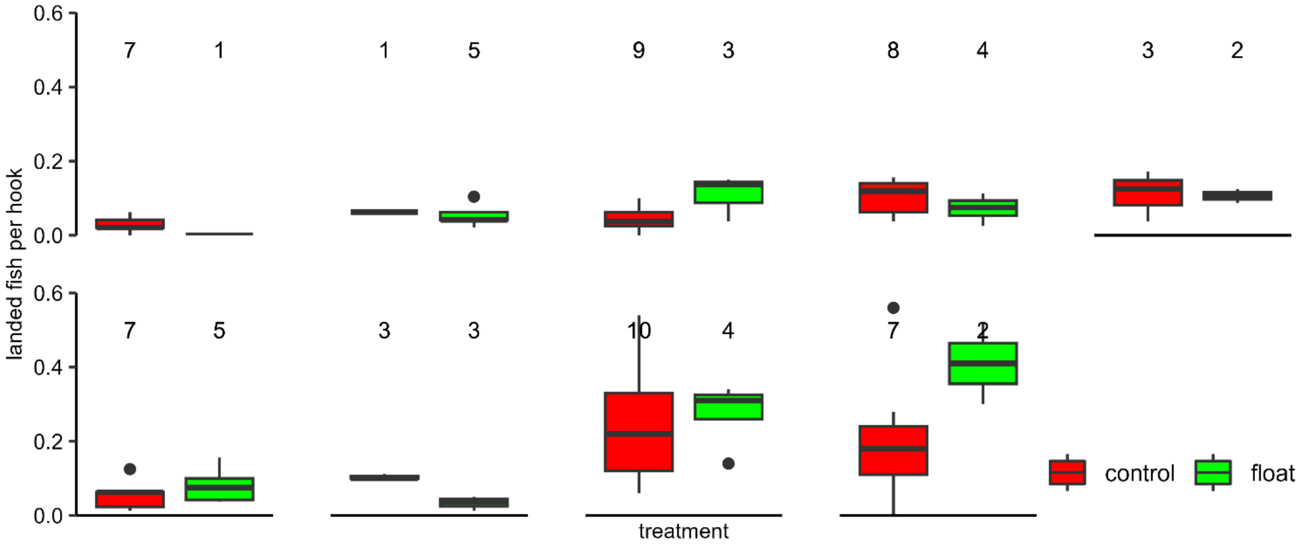

Figure 7. Catches of all landed fish from Vessel B, by line and treatment (control vs modified floats). Numbers above boxes show number of line sections in each treatment.

Discussion

Tori lines

An 8.3-metre-high tori pole on Vessel A produced 90 m of aerial extent compared to 70 m from a 7.0-metre-high pole on Vessel B. However, with faster sinking lines, Vessel B still largely achieved protection of hooks to six metres depth. Arguably, this is more desirable as longer tori lines are not necessarily as effective for the full aerial extent.

In terms of meeting target hook depths at the end of the tori line longer aerial extents are a relatively easy option for the skipper as it minimises changes required to gear configuration. Following the trips both skippers are planning improvements to tori lines, including higher and adjustable attachment points.

The gains in hook depth close to the vessel provided by experimental gear configurations (Figure 5) are arguably more effective than a longer tori line. They sink hooks down to one to two metres relatively quickly, reducing the time baits are in the air or close to the surface and visible and attractive to birds. This is supported by birds targeting baits beside the tori line, relatively close to the vessel, during the set cut short on Vessel B. This highlights that, especially during daylight, single tori lines do not fully exclude birds. In this instance multiple tori lines, which the skipper is planning on installing, may have allowed more hooks to be set before birds showed interest in baits.

Gear alterations

Modified floats provided consistent reductions in sink time to depth. They also had no influence on how the gear fishes at depth, other than a longer rope and the float being above, rather than on, the longline. By varying the compensating weight at the clip, they also allow floatation added to the line to be infinitely adjusted to compensate for weight spacing changes. Winding the rope around paired floats was reasonably practical. However, for some operations, having a separate bin of ropes with weights attached may be more practical. This would eliminate the problem of ropes not unwinding fully and allow fishers to add whatever floatation was desired and simply add an extra float to compensate for the weight. Further, for multi-float configurations, modified floats may only be required on later floats in a section i.e. those deployed furthest from the preceding weight. Overall, where fishers do need to improve sink times, modified floats are an attractive first option.

Weight spacing was also key to reducing sink time to depth on Vessel A. Skippers and crew tend to think in terms of the number of hooks between weights, however hook spacing was intentionally and unintentionally variable. This highlighted the importance of skippers and crew being aware of weight spacing in terms of metres of backbone as this is what drives sink times. Where interruptions to setting hooks, such as changing cards or hook bins, adjusting tori lines, or missing weights may result in larger hook spacings, crew need to be proactive and add ‘extra’ weights as appropriate.

Slowest sinking positions

Comparing different positions on the line showed that positions after a modified float sank slower than those on a modified float. This identified that previous work (Goad and Olsen 2023) may have indicated optimistic maximum sink times to depth by placing TDRs on modified floats. Although this difference in sink time is relatively small compared to the gains delivered by modified floats, it should be addressed in any material and advice supplied to fishers.

Vessel A had the downline (between the anchor and the surface float) wound onto the longline drum so that the anchor could be clipped on without interruption. However, Vessel B had to stop and connect a separate downline stored in a drum, resulting in slower sink rates at the end of the line. In terms of risk to birds, and meeting regulations which specify the slowest sinking hook, it is important to identify such 'abnormally' slow sinking hooks and adjust operations to rectify these. In order to examine the efficacy of changes to gear configuration, and to make sensible comparisons, this work focussed on sink rates on the main part of the line away from such 'end effects'. Consequently, it assumes that skippers can find work-arounds for abnormally slow sinking sections, such as paying out some line without hooks or attaching anchors before slowing down to attach separate downlines.

Backbone type.

Rope backbone required more weight as, all other things being equal, it sinks slower (Goad & Olsen 2023). However, because it is buoyant it requires less added floatation than monofilament. The rope backbone has less stretch than monofilament so is likely to behave differently once the gear has sunk to fishing depth. As well as increasing the sink times to depth the addition of extra weight, particularly without reducing spacing, will sink the line in more of an 'm' shape, increasing the amount of slack in the line once it reaches the seabed (Goad & Olsen, 2023). Because the line is under some tension during setting, and so will stretch to some extent, more of this slack will be taken up by monofilament compared to rope back bone.

Practicality

The modified floats (barring the minor hassle factor) provide a 'free' sink time reduction as they do not materially alter gear configuration or how the line fishes. Additionally, the ability to adjust the amount of buoyancy added to the line, by adjusting the size of the compensating weight in some ways gives skippers more flexibility. No marked differences in catch rates were apparent during these trips and it is likely that skippers will alter gear configuration to maximise catches as they are used to doing between and within sets.

Catch comparisons

Occasionally low catch rates and variable bait returns precluded firm conclusions on the effect of altering gear configuration on catch rates. However, there were no major concerns from the skippers. On Vessel A the skipper elected to reduce spacing from 30 to 25 hooks between weights/floats on the control gear after the first set, based on bait returns and fish caught close to floats. Experimental monofilament lines on Vessel A targeting ling did catch less fish, and had higher bait returns in the latter part of the trip. This indicates that changes may have floated the gear too high above the seabed, away from both the target species and benthic bait stealers. No large differences were apparent between control and experimental sections on Vessel B.

Further comparisons with more consistent and higher catch rates would help tease out differences between experimental and control gear configurations. However, in practice, catches are often patchy, especially when fishing floating gear on foul ground, and the skipper's judgement is most important. Providing skippers are happy to use modified floats, options exist to modify floatation to fish different depths above the seabed whilst meeting regulations.

Line tension

Line tension was not altered during these trials as it was deemed desirable to change as few variables as possible to understand the effect of changes made, especially in a dynamic environment. However, it should be noted that gear configuration may influence the amount of slack in lines once they are at fishing depth, and that line tension can also control this, as well as influencing sink rate. For some operations, increasing line tension may be an attractive option to reduce the sink times of slowest sinking hooks.

Promoting uptake

Whilst the results here provide an illustration of the workability and useability of experimental gear configurations, it is important to recognise that fishers are likely to need to 'feel' their way into altering gear configurations to reduce sink times to depth. Consequently, the results here, and from previous work, should not be used prescriptively, rather as an example of how to achieve reduced sink times to depth. Skippers can assess catch rates and bait return rates to iteratively alter their gear.

A good starting point would be maximising tori line aerial extent and the use of modified floats, with the option of changing the weight (and/or float size) on the modified floats to control the distance gear settles above the seabed. Floats may be used directly on the backbone at the beginning of multi-float sections, followed by modified floats, though this would need to be tested further to confirm it does not impede the slower-sinking latter part of the section. If additional reductions in sink time are required then increases in weight size, and reductions in weight spacing such as those employed on Vessel A are likely to be necessary.

This approach assumes that skippers have robust mechanisms for measuring sink times to depth and estimating depth at the end of the tori line, which is likely not the case across the whole fleet (DG pers. obs.).

Conclusions

Whilst experimental trials can relatively quickly and easily compare sink times to depth for different gear configurations and provide guidance for fishers it is important to trial recommendations in a fishing context on a 'normal' trip.

The results presented here show that modifying 'floating' demersal longline to achieve a hook depth of five metres under the protection afforded by a tori line is possible and workable. Catch rate comparisons could be extended but it is likely that skippers will further alter gear configuration to maintain or improve catch rates before large differences are apparent. Most importantly, these trips provide an example of a process through which fishers can be supported to greatly improve sink times to depth.

Recommendations

Translating results from trips with a dedicated researcher on board measuring sink times to depth into normal fishing operations across the fleet could be facilitated by providing fishers with user-friendly TDRs to estimate depth at the end of the tori line.

Trips to sea with fishers are extremely productive, not only for quantifying performance of mitigation measures, as described above, but also supporting fishers to make changes with minimal impact on operations. All opportunities should be taken to join fishers at sea and, if fishers have particular concerns with meeting regulations, then demonstrating options at sea, on a commercial trip, can be hugely productive.

Further refinement of this approach, particularly regarding line tension and use of floats directly on the backbone at the start of multi-float sections should be considered. However, this will not necessarily translate between vessels and skippers so should be part of supporting individual vessels in the fleet to improve sink times to depth, where necessary.

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Appendix 1. Tables showing time taken for TDRs to reach to a depth of six metres, and estimated distance astern

Gear configuration codes show repeated line sequence: w = weight, f = float, d= dropper (a combination weight and float), g = beside anchor, with brackets denoting TDR position in sequence. NV = not valid.

Treatment codes: w = increased weight size, f = modified floats, s = reduced weight spacing

Target codes: bns = bluenose, sch = school shark, rsn = red snapper / king terakihi / hapuku

Vessel A

line #	TDR order	speed (knots)	time to 6 m depth (s)	distance at 6 m depth (m)	weight spacing (m)	weight (kg)	backbone type	gear configuration and TDR placement	target	treatment
1	1	3.5	87	157	240	6	rope	wf()	ling	control
1	2	3.5	96	173	240	6	rope	wf()	ling	control
1	3	3.5	105	189	240	6	rope	wf()	ling	control
1	4	3.5	84	151	240	12	rope	wf()	ling	w
1	5	3.5	63	113	240	12	rope	wf()	ling	w
1	6	3.5	79	142	240	12	rope	wf()	ling	w
2	1	3.5	125	225	240	6	rope	wf()	ling	control
2	2	3.5	146	263	240	6	rope	wf()	ling	control
2	3	3.5	106	191	240	6	rope	wf()	ling	control
2	4	3.5	69	124	240	12	rope	wf()	ling	w_f
2	5	3.5	64	115	240	12	rope	wf()	ling	w_f
2	6	3.5	71	128	240	12	rope	wf()	ling	w_f
3	1	3.5	222	399	360	6	mono	wf(f)	ling	control
3	2	3.5	210	378	360	6	mono	wf(f)	ling	control
3	3	3.5	198	356	360	6	mono	wf(f)	ling	control
3	4	3.5	186	335	360	6	mono	wf(f)	ling	control
3	5	3.5	45	81	360	12	mono	wf(f)	ling	w_f
3	6	3.5	79	142	360	12	mono	wff()	ling	w_f
3	7	3.5	51	92	360	12	mono	wf(f)	ling	w_f
3	8	3.5	80	144	360	12	mono	wff()	ling	w_f
3	9	3.5	45	81	360	12	mono	wf(f)	ling	w_f
3	10	3.5	67	121	360	12	mono	wff()	ling	w_f
4	1	3.6	83	154	240	6	rope	df()	ling	control
4	2	3.6	106	196	240	6	rope	df()	ling	control
4	3	3.6	57	105	160	6	rope	df()	ling	f_s
4	4	3.6	49	91	160	6	rope	df()	ling	f_s
4	5	3.6	51	94	160	6	rope	df()	ling	f_s
4	6	3.6	46	85	160	12	rope	df()	ling	w_f_s
4	7	3.6	42	78	160	12	rope	df()	ling	w_f_s
4	8	3.6	39	72	160	12	rope	df()	ling	w_f_s
4	9	3.6	70	130	240	6	rope	df()	ling	control
6	1	3.5	50	90	210	12	mono	dff()	ling	w_f_s
6	2	3.5	47	85	210	12	mono	dff()	ling	w_f_s
6	3	3.5	52	94	210	12	mono	dff()	ling	w_f_s
6	4	3.5	93	167	315	12	mono	df(f)	ling	control
6	5	3.5	71	128	315	12	mono	dff()	ling	control
6	6	3.5	100	180	315	12	mono	df(f)	ling	control
6	7	3.5	76	137	315	12	mono	dff()	ling	control
6	8	3.5	109	196	315	12	mono	df(f)	ling	control
6	9	3.5	87	157	315	12	mono	dff()	ling	control
7	1	3.5	104	187	150	6	rope	wf()	ling	control
7	2	3.5	84	151	150	6	rope	wf()	ling	control
7	3	3.5	79	142	150	6	rope	wf()	ling	control
7	4	3.5	44	79	90	12	rope	wf()	ling	w_f_s
7	5	3.5	44	79	90	12	rope	wf()	ling	w_f_s
7	6	3.5	-40	-72	180	12	rope	wf()_NV	ling	w_f_s
7	7	3.5	44	79	90	12	rope	wf()	ling	w_f_s

line #	TDR order	speed (knots)	time to 6 m depth (s)	distance at 6 m depth (m)	weight spacing (m)	weight (kg)	backbone type	gear configuration and TDR placement	target	treatment
9	1	3.5	53	95	225	6	mono	wf(f)	ling	control
9	2	3.5	92	166	225	6	mono	wf(f)	ling	control
9	3	3.5	42	76	135	12	mono	wff()	ling	w_f_s
9	4	3.5	47	85	135	12	mono	wff()	ling	w_f_s
9	5	3.5	47	85	135	12	mono	wff()	ling	w_f_s
9	6	3.5	76	137	225	6	mono	wf(f)	ling	control
10	1	3.5	109	196	150	6	rope	wf()	ling	control
10	1	3.5	56	101	180	12	rope	wf()_NV	ling	w_f_s
10	1	3.5	51	92	120	12	rope	wf()	ling	w_f_s
10	1	3.5	55	99	120	12	rope	wf()	ling	w_f_s
10	1	3.5	51	92	120	12	rope	wf()	ling	w_f_s
10	1	3.5	110	198	150	6	rope	wf()	ling	control
14	1	3.5	133	239	190	6	rope	wf(f)	bns	control
14	2	3.5	52	94	190	12	rope	wf()f	bns	w_f_s
14	3	3.5	53	95	190	12	rope	wff()	bns	w_f_s
14	4	3.5	69	124	150	12	rope	wf()f	bns	w_f_s
14	5	3.5	65	117	150	12	rope	wff()	bns	w_f_s
14	6	3.5	42	76	150	12	rope	wf()f	bns	w_f_s
14	7	3.5	74	133	100	12	rope	wfw()_NV	bns	w_f_s
14	8	3.5	100	180	190	6	rope	wf(f)	bns	control
14	9	3.5	251	452	190	6	rope	wf(f)_NV	bns	control
15	1	3.5	137	246	225	6	mono	wf(f)	bns	control
15	2	3.5	178	320	225	6	mono	wf(f)	bns	control
15	3	3.5	136	245	225	6	mono	wf(f)	bns	control
15	5	3.5	50	90	180	12	mono	wff()	bns	w_f_s
15	6	3.5	65	117	180	12	mono	wf(f)	bns	w_f_s
15	7	3.5	56	101	180	12	mono	wff()	bns	w_f_s
15	8	3.5	46	83	180	12	mono	wf(f)	bns	w_f_s
15	9	3.5	65	117	180	12	mono	wff()	bns	w_f_s
18	1	3.5	81	146	375	6	mono	df(f)	ling	control
18	2	3.5	93	167	375	6	mono	df(f)	ling	control
18	3	3.5	51	92	300	12	mono	dff()	ling	w_f_s
18	4	3.5	48	86	300	12	mono	dff()	ling	w_f_s
18	5	3.5	48	86	300	12	mono	dff()	ling	w_f_s
16	1	3.5	48	86	160	12	rope	wf()	ling	w_f_s
16	2	3.5	47	85	160	12	rope	wf()	ling	w_f_s
16	3	3.5	54	97	160	12	rope	wf()_NV	ling	w_f_s
16	4	3.5	45	81	160	12	rope	wf()	ling	w_f_s
16	5	3.5	68	122	200	6	rope	wf()	ling	control
16	6	3.5	73	131	200	6	rope	wf()	ling	control
19	1	3.5	48	86	140	12	rope	wf()	ling	w_f_s
19	2	3.5	47	85	140	12	rope	wf()	ling	w_f_s
19	3	3.5	47	85	140	12	rope	wf()	ling	w_f_s
19	4	3.5	66	119	180	6	rope	wf()	ling	control
20	1	3.5	69	124	180	12	rope	wf()	ling	control
20	2	3.5	69	124	180	12	rope	wf()	ling	control
21	2	3.5	44	79	200	12	mono	wff()	ling	w_f_s
21	3	3.5	30	54	200	12	mono	wf()f	ling	w_f_s
21	4	3.5	33	59	200	12	mono	wff()	ling	w_f_s
21	5	3.5	32	58	200	12	mono	wf()f	ling	w_f_s
21	6	3.5	37	67	200	12	mono	wf()f	ling	w_f_s
21	6	3.5	39	70	200	12	mono	wff()	ling	w_f_s

Vessel B

line #	TDR order	speed (knots)	time to 6 m depth (s)	distance astern at 6 m depth (m)	weight spacing (m)	weight (kg)	backbone type	gear configuration and TDR placement	target	treatment
1	1	3.5	69	124	100	6	y	df(f)	sch	control
1	2	3.5	57	103	100	6	y	df(f)	sch	control
1	3	3.5	72	130	100	6	y	df(f)	sch	control
1	4	3.5	67	121	100	6	y	df(f)	sch	control
1	5	3.5	126	227	100	6	y	dff()g	sch	f
1	6	3.5	28	50	100	6	y	df(f)	sch	control
1	7	3.5	42	76	100	6	y	df()f	sch	f
1	8	3.5	31	56	100	6	y	dff()	sch	f
1	9	3.5	41	74	100	6	y	df()f	sch	f
1	10	3.5	39	70	100	6	y	dff()	sch	f
1	11	3.5	41	74	100	6	y	df()f	sch	f
1	12	3.5	45	81	100	6	y	df()f	sch	f
1	13	3.5	32	58	100	6	y	dff()	sch	f
1	14	3.5	127	228	100	6	y	df()g	sch	f
3	1	3.5	55	99	180	12	y	dff(f)f	bns	control
3	2	3.5	54	97	180	12	y	dfff(f)	bns	control
3	3	3.5	58	104	180	12	y	dff(f)f	bns	control
3	4	3.5	56	101	180	12	y	dfff(f)	bns	control
3	5	3.5	56	101	180	12	y	dff(f)f	bns	control
3	6	3.5	48	86	180	12	y	dfff(f)	bns	control
3	7	3.5	60	108	180	12	y	dff(f)f	bns	control
3	8	3.5	64	115	180	12	y	dfff(f)	bns	control
3	9	3.5	51	92	180	12	y	dff(f)f	bns	control
3	10	3.5	50	90	180	12	y	dfff(f)	bns	control
3	11	3.5	42	76	180	12	y	dff(f)f	bns	f
3	12	3.5	50	90	180	12	y	dfff(f)	bns	f
3	13	3.5	40	72	180	12	y	dff(f)f	bns	f
3	14	3.5	32	58	180	12	y	dfff(f)	bns	f
3	15	3.5	51	92	180	12	y	dff(f)f_NV	bns	f
4	1	3.5	49	88	180	12	y	dff(f)f	bns	control
4	2	3.5	51	92	180	12	y	dfff(f)	bns	control
4	3	3.5	62	112	180	12	y	dff(f)f	bns	control
4	4	3.5	53	95	180	12	y	dfff(f)	bns	control
4	8	3.5	54	97	180	12	y	dfff(f)	bns	control
4	5	3.5	29	52	180	12	y	d(f)fff	bns	control
4	6	3.5	42	76	180	12	y	df(f)ff	bns	control
4	7	3.5	61	110	180	12	y	dff(f)f	bns	control
4	9	3.5	40	72	180	12	y	dfff()f	bns	f
4	10	3.5	1	2	180	12	y	dffff()	bns	f
4	11	3.5	37	67	180	12	y	dff()ff	bns	f
4	12	3.5	37	67	180	12	y	dfff()f	bns	f
4	13	3.5	35	63	180	12	y	dffff()	bns	f
4	14	3.5	40	72	180	12	y	dff()ff	bns	f
4	15	3.5	38	68	180	12	y	dffff()	bns	f
4	16	3.5	50	90	180	12	y	dfff()f	bns	f
4	17	3.5	33	59	180	12	y	dffff()	bns	f
5	1	3.5	57	103	180	12	y	dff(f)f	bns	control
5	2	3.5	56	101	180	12	y	dfff(f)	bns	control
5	3	3.5	38	68	180	12	y	dffff()	bns	f
5	4	3.5	37	67	180	12	y	dfff()f	bns	f
9	3	4.6	45	106	100	6	y	d(f)	rsn	control
9	4	4.6	40	95	100	6	y	df()	rsn	control
9	5	4.6	47	111	100	6	y	d(f)	rsn	control
9	6	4.6	36	85	100	6	y	df()	rsn	control
9	7	4.6	45	106	100	6	y	d(f)	rsn	control
9	8	4.6	37	87	100	6	y	df()	rsn	control
9	9	4.6	20	47	100	6	y	d(f)	rsn	f
9	10	4.6	31	73	100	6	y	df()	rsn	f
9	11	4.6	21	50	100	6	y	d(f)	rsn	f
9	12	4.6	31	73	100	6	y	df()	rsn	f
9	13	4.6	22	52	100	6	y	d(f)	rsn	f
9	14	4.6	31	73	100	6	y	df()	rsn	f

Appendix 2. Identifying the slowest sinking position for different gear configurations

TDR positions after modified floats sank slower than those on modified floats. However, for the control gear, with floats directly on the backbone, the float positions sank slowest (Figure A1).

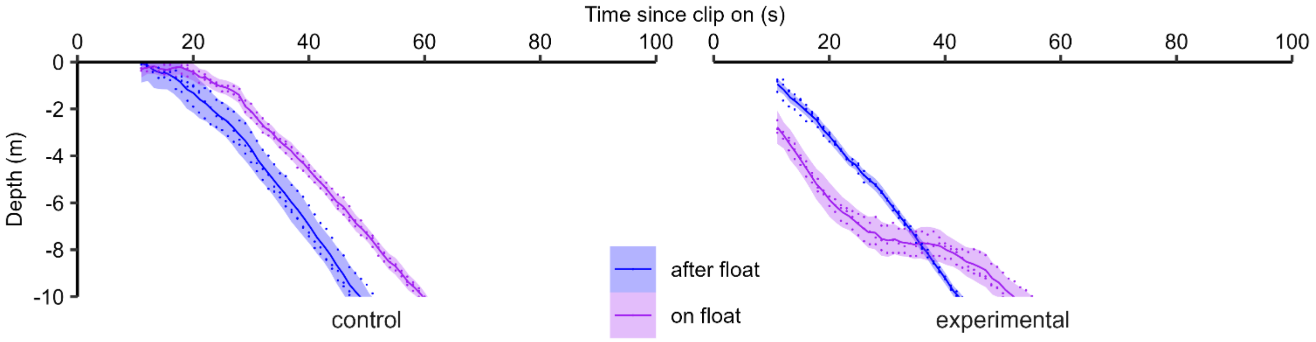

Figure A1. Depth over time for TDRs deployed from Vessel B with one float between weights. Different colours denote different TDR positions and different plots show control and experimental gear with modified floats. Points show individual records with lines plotting smoothed mean depth and shaded areas showing +/- s.d.. Three repeats were collected for each treatment.

For gear configurations with multiple floats between weights the last float in a sequence will sink initially slowly but once the following weight is clipped on it will sink faster. This may result in the previous float sinking slowest to six metres, as was the case on Vessel B with a four-float configuration. In this case TDR positions on the third float, or after the third modified float, sank slowest (Figure A2).

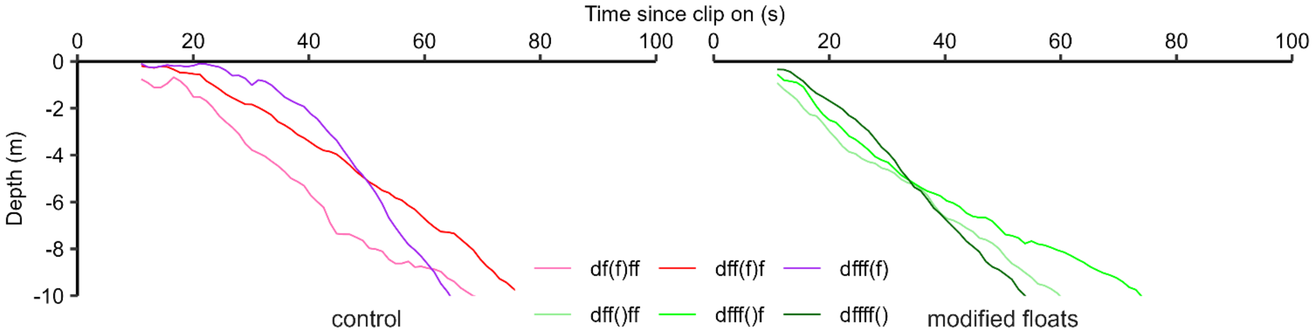

Figure A2. Depth over time for TDRs deployed on control and experimental sections targeting bluenose with monofilament backbone from Vessel B. Separate plots show different treatments. Different colours denote different TDR positions where d = weight, f = float, and () indicates TDR position. Lines plot smoothed mean depths from three repeats on the same line.

TDRs placed close to the end of the line on Vessel B sank slowly due to having to stop the vessel to attach anchor and downline before completing the set (Figure A3)

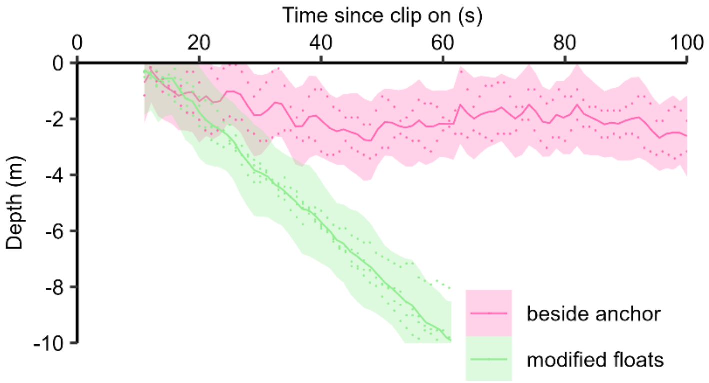

Figure A3. Depth over time for TDRs deployed from Vessel B on the slowest-sinking portion of the experimental gear, after modified floats (n = 4), and on the last section prior to deployment of the anchor (n = 2). Different colours denote different TDR positions. Points show individual records with lines plotting smoothed mean depth and shaded areas showing +/- s.d..

For multiple float configurations, floats directly on the backbone immediately after a weight may sink fast enough that modified floats are not required on (in this case) the first two floats (Figure 4).

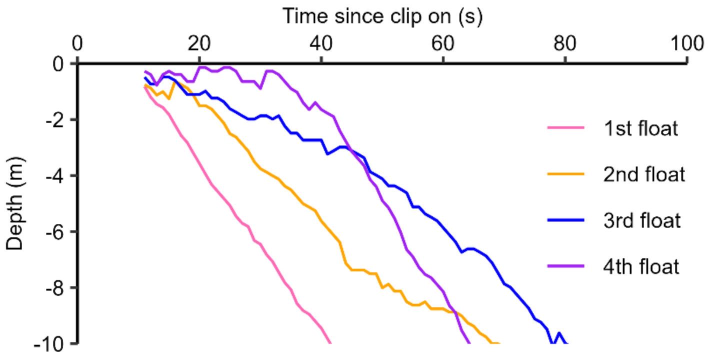

Figure A4. Depth over time for TDRs deployed on floats 1, 2, 3 and 4 in a control section of a line targeting bluenose on Vessel B.

Appendix 3. Bait returns by vessel and line.

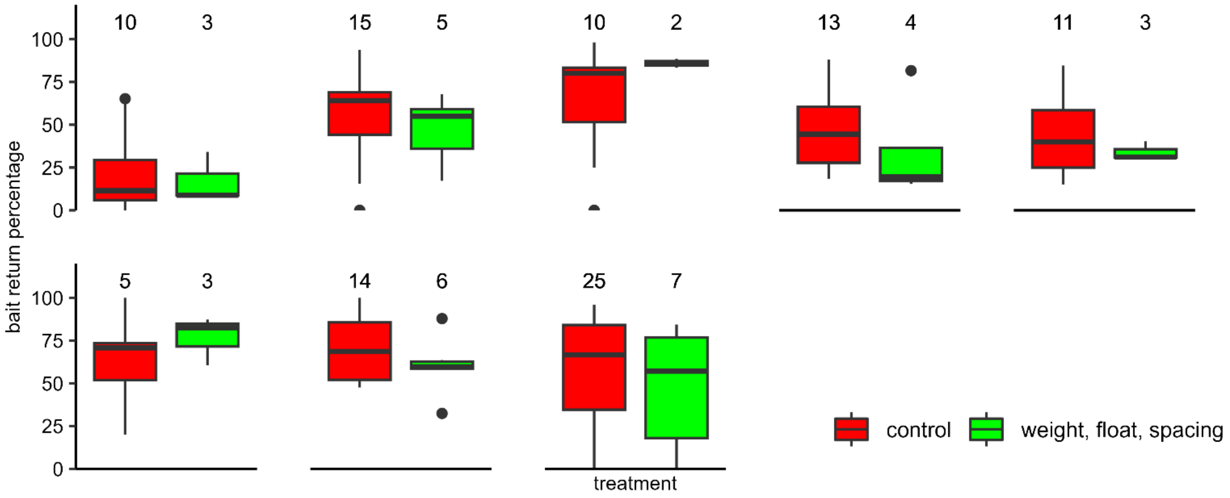

Figure A5. Bait returns on rope lines from Vessel A, by line and treatment. Numbers above boxes show number of line sections in each treatment.

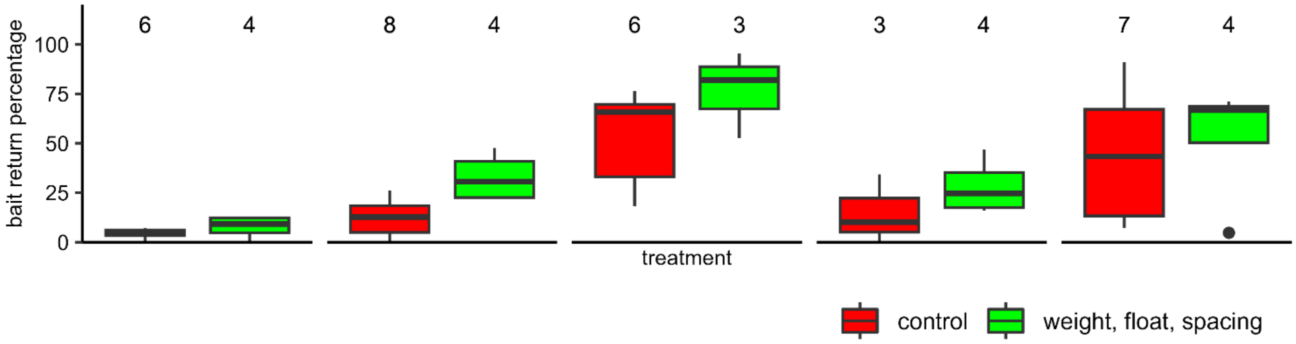

Figure A6. Bait returns on monofilament lines from Vessel A, by line and treatment. Numbers above boxes show number of line sections in each treatment.

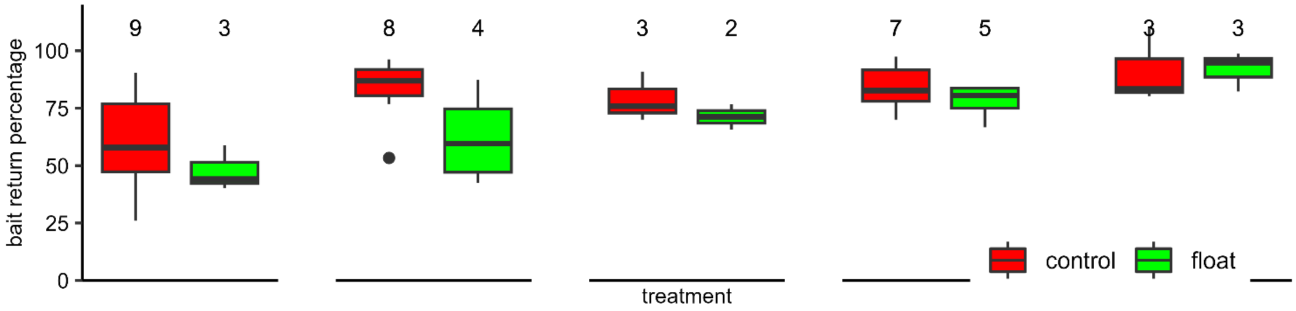

Figure A7. Bait returns on lines targeting bluenose from Vessel B, by line and treatment. Numbers above boxes show number of line sections in each treatment.