Development of an adaptive management tool for line setting

Final report for MIT2018-03 prepared by Pisces Research Ltd and Fisheries Inshore NZ for the Department of Conservation, Conservation Services Programme

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CONTENTS

EXECUTIVE SUMMARY

Ensuring that baited books deployed in surface and bottom longline fisheries sink rapidly to depths that are beyond the typical diving depths of foraging seabirds is a key strategy for mitigating seabird captures in these fisheries. Streamer lines towed behind vessels during setting aim to prevent seabirds accessing the hooks immediatedly after deployment. As a result, there is a particular focus on measuring the depths reached by hooks at the limits of the streamer line coverage.

The time that hooks remain under the streamer line after deployment is relatively short, of the order of 30 s, and measuring sink rates in this short period is challenging. Bottle tests have been used successfully in larger vessel fisheries, but are more problematic on inshore vessels which provide a lower viewing angle and generally set lines in darkness.

Electronic time-depth recorders are the preferred measuring tool, but devices designed for research deployment on animals are unsuitable for routine deployment on fishing gear. This project assessed the use of Wet Tags, robust time and depth recorders designed for use on fishing gear, for routine deployment by vessels engaged in inshore bottom longline and surface longline fisheries. A particular aim was to provide ‘real-time’ information on sink rates to fishers to allow adaptive management of fishing behaviour.

Despite the challenges of carrying out the project during the initial response to the COVID-19 pandemic, there was adequate participation in the project, especially by bottom longline fishers. The Wet Tags proved suitable for widespread, routine deployment by fishing vessels, but experience during the project indicated that data download and submission procedures would require further automation for ongoing use.

The Wet Tags typically did not start logging until the tags reached depths of 3 m to 5 m, and provided data at a coarser logging interval than the TDRs designed for wildlife deployment. Nevertheless, paired testing indicated that the estimates of line depths achieved at the streamer line extent were generally comparable. As a result, the Wet Tag data provided reasonable estimates of the sink rates and line depths achieved by a range of bottom longline vessels. Sink rates of $0.2\,\mathrm{m\,s^{-1}}$ to $0.4\,\mathrm{m\,s^{-1}}$ and estimates of 3 m to 5 m depths at the extent of streamer line coverage were typical for the participating bottom longline vessels.

Surface longline data were more limited, with the majority provided by a single vessel. Further work to refine how best to account for the initial free sink period of surface longline gear is warranted.

Overall, the project demonstrated that routine collection of line sink rate data from bottom and surface longline fishing is feasible, and the results are useful to fishers and vessel managers in monitoring and managing the risk of seabird captures in their fishing operations. Real-world data on sink rates achieved in day-to-day fishing operations sit alongside more focussed studies on the factors affecting sink rates, and the factors that affect seabird risk of capture, in assisting in the continuous improvement of approaches to mitigate seabird captures in inshore longline fisheries.

1. INTRODUCTION

Foraging seabirds are attracted to many of the baits used in longline fishing, and also to the fish caught. However, depredation of longline baits and catch items puts seabirds at risk of becoming caught on hooks or entangled in lines. Seabird captures during line setting are particularily problematic because, unless the bird is able to free itself, it will be pulled underwater by the sinking line and drowned.

Croxall et al. (2012) suggest that the issue of seabird bycatch in fisheries has only been apparent for about two decades. However, there is evidence that the issue was recognised prior to this (see, for example, Murray et al. 1992), and that captures in longline fisheries were anticipated to become more pervasive with the cessation of large-scale high seas drift netting in the 1990s (Manville 2005).

A range of technical and operational measures to mitigate seabird captures in longline fisheries were documented in the IPOA-Seabirds (FAO 1999), some of which had been proven to be effective whilst others were potential approaches of unknown effectiveness. Current measures to reduce captures during line setting remain primarily focussed on restricting seabird access to baited hooks during the period that these are within the diving range of birds.

Bentley et al. (2021) used time-depth recorders to study the diving behaviour of three albatross species breeding at Bird Island, South Georgia, noting that a number of studies had indicated that albatross diving depths reported from early studies using capillary depth guages were likely overestimated and that more meaningful ecological conclusions could be drawn from devices that recorded complete depth profiles rather than just the single deepest dive during a deployment.

On the basis of their results and other recent studies, Bentley et al. (2021) concluded that:

- all three genera of small albatrosses (*Phoebetria*, *Thalassarche* and *Phoebastria*) undertake infrequent, short and shallow dives, reaching <1.5 m on average;
- many shearwaters are far more proficient divers, attaining mean maximum depths of 10–20 m, although the *Calonectris* shearwaters only dive to mean depths of 1–2 m; and
- the *Procellaria* petrels are also proficient divers; with mean diving depths of around 3 m and maximum depths of 15–25 m.

In New Zealand, black petrels (*Procellaria parkinsoni*) are the species assessed to be at greatest risk from captures in commercial fisheries (Richard & Abraham 2020). Bell (2016) used time-depth recorders to collect dive data from 22 black petrels breeding on Great Barrier Island. While the deepest dive recorded was 34.3 m, the majority of dives were less than 5 m and dives to greater than 10 m were rare. Most dives were during the day and only males were recorded as diving at night.

Bell (2016) noted that Wanless and Waugh (2010) had indicated that if a vessel set lines at a speed of 6 knots, with a line sink rate of $0.3\,\mathrm{m\,s^{-1}}$, then 97% of hooks would reach depths of 10 m under a streamer line with an aerial extent of 100 m. While this result is indeed stated by Wanless and Waugh (2010), their Table 1 indicates that this result is only achieved if the setting speed is reduced to 3 knots, with only 49% of hooks expected to reach 10 m within a 100 m streamer line extent when setting at 6 knots.

Under the NPOA-Seabirds 2020, seabird bycatch mitigation in New Zealand fisheries combines regulatory and non-regulatory measures, applied on a vessel-specific basis (Fisheries New Zealand 2020). For bottom longlining, the regulated measures are currently defined by the Fisheries (Seabird Mitigation Measures–Bottom Longlines) Circular 2020[1] while regulated measures for surface longline fisheries are included in the Fisheries (Seabird Mitigation Measures–Surface Longlines) Circular 2019[2].

The Department of Conservation and Fisheries New Zealand have also documented 'Mitigation Standards' for bottom[3] (BLL) and surface[4] longlining (SLL) that aim to outline current best practice to reducing seabird interactions. These describe a series of standard practices (Mitigation Standards) necessary to achieve a number of desired outcomes, which are common across the two longline methods:

1. The discharge of fish waste from the vessel is managed so as not to attract seabirds to risk areas.
2. Seabirds are not able to access baited hooks during setting.
3. Seabird access to hooks during hauling is minimised.
4. The risk of deck landings or impacts against the vessel is minimised.

Line weighting and the use of streamer lines are included as mandatory measures for both BLL and SLL fishing. The mandatory measures take the form of input controls, detailing streamer line designs and the line weighting regime required. In contrast, the Mitigation Standards for bottom longlining take an outcome based approach to line sink rates, specifying that hooks set should be protected by the aerial extent of the streamer line until hooks have reached a depth of 5 m (outside of high-risk periods) or 10 m (during high risk periods).

In the Mitigation Standards for surface longlining a hook depth is only specified for vessels using hook shielding devices, which are required to remain in place until the hook reaches a depth of 10 m. For vessels that are not using hook shielding devices, vessels are directed to undertake line weighting.

In large vessel bottom longlining, line sink rates are frequently tested using bottle tests (Fenaughty & Smith 2001). The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)'s Conservation Measure 24-02[5] requires that longlines sink

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[1] https://gazette.govt.nz/notice/id/2020-go2290

[2] https://gazette.govt.nz/notice/id/2019-go5782

[3] https://www.mpi.govt.nz/dmsdocument/38009/direct

[4] https://www.mpi.govt.nz/dmsdocument/38018/direct

[5] https://www.ccamlr.org/en/measure-24-02-2014

at a rate of at least 0.3 m s^{-1}, verified using either time-depth recorders (TDRs) or bottle tests. Wienecke and Robertson (2004, Table 2) list pros and cons of bottle tests and TDRs, ultimately expressing a preference for TDRs which they suggest provide more reliable and consistent data, and an electronic copy of the data from the test.

1.1 Objectives

The overall objective of project MIT2018-03 was to mitigate seabird bycatch by providing fishers with information on realised sink rates, promoting adaptive management through optimisation of mitigation practices during individual trips. The specific objectives were to:

1. deploy time-depth recorders routinely on surface and bottom longline sets to automate the collection of data on sink rates and soak depths;
2. develop a system to provide fishers with information summaries that allow the interpretation of these data in the context of seabird exposure to hooks;
3. assess variation in sink rates achieved across the fleet, the extent of between and within vessel variation and the association with fishing practices (such as the species targeted); and
4. assess the extent to which fishers make use of real-time information on sink rates to adapt their fishing practices when necessary.

The project began in 2019, with initial at-sea testing carried out in September 2019. Fleetwide deployment of the TDRs was impacted by the COVID-19 response in 2020, which prevented the shipping of devices to fishers and limited engagement with participants. Initial deployment and data collection timelines were extended to the end of 2020.

This final report details the technology deployed, summarises the data collected, and assesses the utility of the information for fishers and fisheries managers.

2. METHODS

2.1 Time-depth recorders

Many studies of longline sink rates, both internationally (for example, Wienecke & Robertson 2004) and in New Zealand (for example, Goad et al. 2010), have used time-depth recorders originally developed for deployment on marine mammals and diving birds. These are miniaturised devices that must be connected by cable to a computer to set up recording and to download data. While suitable for research projects supervised by a technician, these devices are generally unsuitable for routine deployment on fishing gear.

This project opted to use Zebra-Tech Wet Tags[6], which are robust, low-cost depth and temperature loggers, designed specifically for deployment on fishing gear, and which operate automatically to record and offload data. Wet Tags have a battery life of 5–10 years and the batteries can be replaced by the manufacturer. The accuracy of depth data is stated as +/- 1% of the full depth range or better, with temperature accuracy +/- 0.1°C. For this project, the Wet Tags used were rated to 150 m.

Standard Wet Tags record average depth and temperature at a fixed interval, typically two minutes. For this project, a new version of the Wet Tag firmware (WetTag BLE - Line Speed Version 1.xx) was developed to log these parameters at a 5 s interval (the depth sensor sampling interval) whenever the tag was at depths shallower than 20 m.

Data logging by the Wet Tags is triggered by immersion; the tags begin recording automatically after immersion to a trigger depth of 1.2 m for a period of 30 s. The use of a trigger depth and delay is designed to prevent the tags from being activated at the surface by changes in atmospheric pressure.

The tags remain active for 2.5 minutes after the end of a dive event, during which time a bluetooth connection can be made to download the data. If the data is not downloaded immediately after retrieval, the tags must be reactivated by immersion to the trigger depth.

An initial batch of ten Wet Tags was supplied for testing; these tags were configured with an attachment plate (Figure 1). The main batch of ninety tags supplied to fishing vessels for operational use had a revised format with an attachment eye as part of the moulded sensor housing (Figure 1).

The original Wet Tag firmware was also updated after initial testing to improve memory use, following a problem where some tags became unable to communicate with the data download app.

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[6] https://www.zebra-tech.co.nz/wet-tag-data-collection-fisheries/

Figure 1: The original (left) and revised (right) Wet Tags, with a one dollar coin for scale.

2.2 Deployment schedule

The project aimed to recruit nine bottom longline and nine surface longline vessels. For each fishing method, six vessels were supplied with three tags each and three vessels with nine tags. Vessels were asked to deploy all available sensors on each line set, with the expectation that the sets with nine sensors would provide additional information on within-set variation in sink rates.

2.3 Wet Tag data retrieval and submission

Fishers were asked to download data from the Wet Tags after retrieval using the `Zebra-Tech BLE`[7] app. This is currently available for both Android[8] and iOS[9] smartphones and tablets.

During the initial testing phase of the project it was necessary to manually scan for devices ready for data offload by pressing a button in the app (Figure 2a). However, a revision to the app was available for the main deployment of Wet Tags to the fleet; this provided an ‘auto-offload’ mode (Figure 2b) that continually checked for newly retrieved Wet Tags and downloaded these automatically when they were discovered.

Each download of a Wet Tag resulted in a CSV data file on the device (Figure 3a). Files were initially submitted to the project using the ‘share’ function of the `Zebra-Tech BLE` app (Figure 3b) to send the files by email (Figure 3c).

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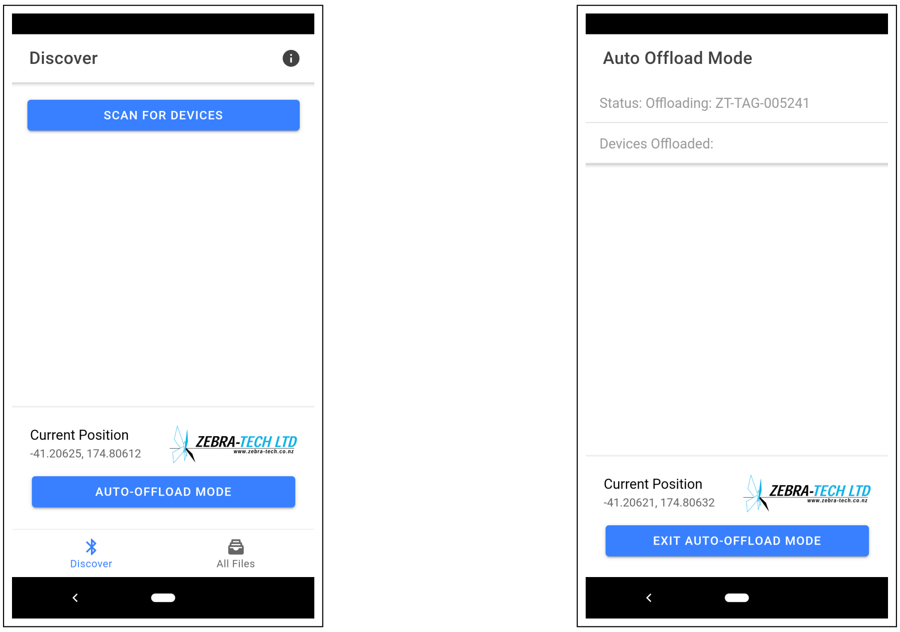
[7] Bluetooth Low Energy

[8] https://play.google.com/store/apps/details?id=com.zebratech.zebratechble

[9] https://apps.apple.com/nz/app/zebra-tech-ble/id1338544188



Current Position
-41.20625, 174.80612

Status: Offloading: ZT-TAG-005241

Devices Offloaded:

Current Position
-41.20621, 174.80632

(a) Alternative download modes **(b)** Automatic Wet Tag download

Figure 2: The `Zebra-Tech BLE` app provided the ability to manually scan for Wet Tags, or to enter an auto-offload mode that continually scanned for devices.

In the latter part of the project a separate app, `Demitto`, was introduced to assist with data transfer. The app automatically discovers Wet Tag data files that have been downloaded using the `Zebra-Tech BLE` app (Figure 4a) and submits these to the project server (Figure 4b). In addition, the `Demitto` app allows data to be submitted from multiple vessels (Figure 5) and provides access to the processed data summaries (Figure 6).

2.3.1 Data download via Deck Units

During the course of the project, Zebra-Tech developed a new temperature and depth profiling sensor for the Moana Project[10], which is focussed on using fishing vessels as vessels of opportunity for the collection of oceanographic data.

On a number of vessels, the Moana TD sensors[11] are automatically downloaded by a deck unit which then transmits the data autonomously to the project servers. In collaboration with the Moana Project, the deck units were configured to additionally download and forward data from Wet Tags.

One vessel participated in both the Wet Tag based sink-rate project and the Moana Project and tested this mechanism of data download and submission.

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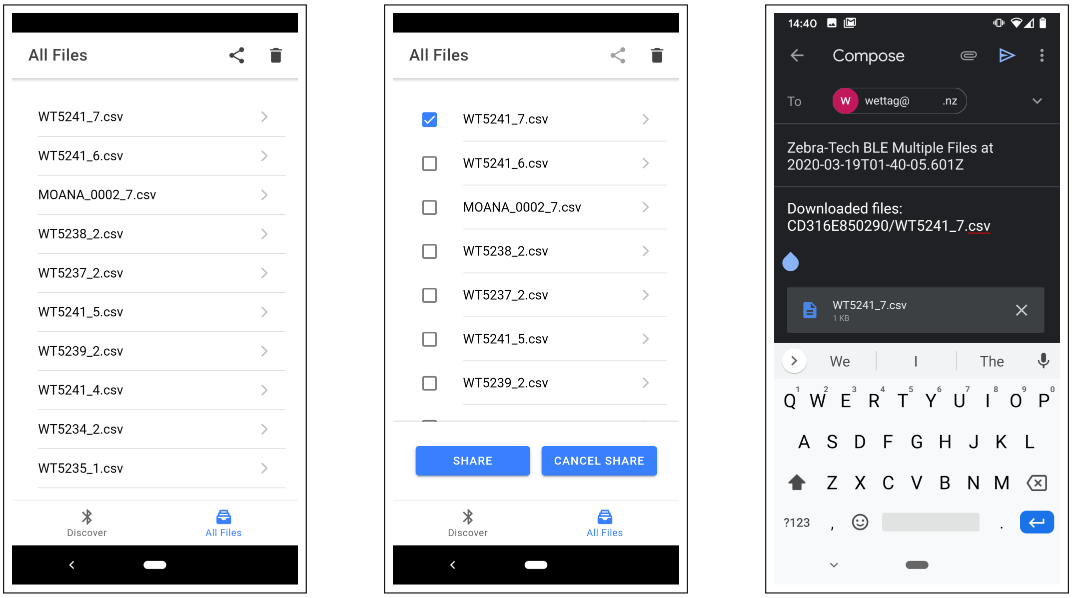
[10] https://www.moanaproject.org/

[11] https://www.zebra-tech.co.nz/moana/



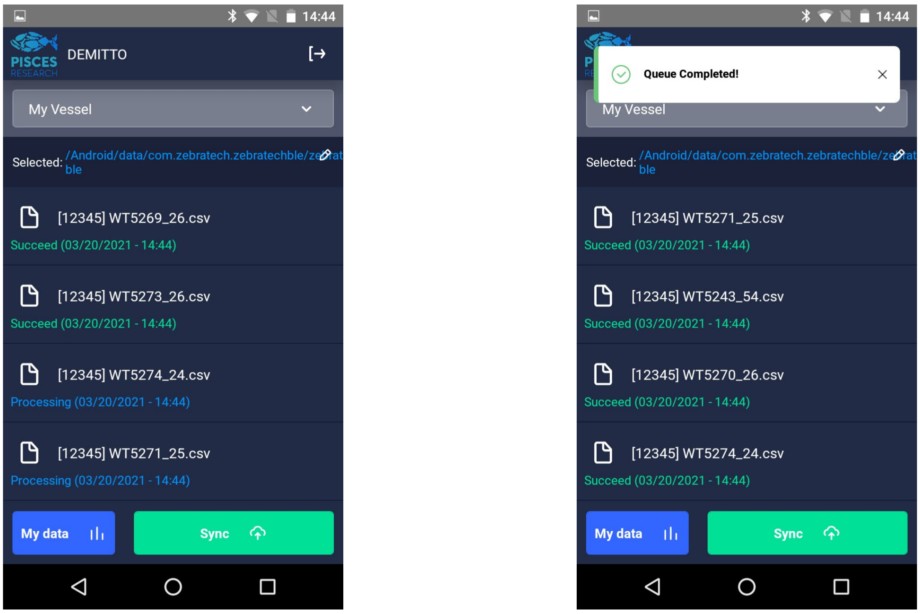
Zebra-Tech BLE Multiple Files at 2020-03-19T01-40-05.601Z

Downloaded files: CD316E850290/WT5241_7.csv

WT5241_7.csv 1 KB

(a) Downloaded files **(b)** File sharing **(c)** Email data submission

Figure 3: Submitting data by email from the `Zebra-Tech BLE` app.



Selected: /Android/data/com.zebratech.zebratechble/zebratble

[12345] WT5269_26.csv
Succeed (03/20/2021 - 14:44)

[12345] WT5273_26.csv
Succeed (03/20/2021 - 14:44)

[12345] WT5274_24.csv
Processing (03/20/2021 - 14:44)

[12345] WT5271_25.csv
Processing (03/20/2021 - 14:44)

Queue Completed!

[12345] WT5271_25.csv
Succeed (03/20/2021 - 14:44)

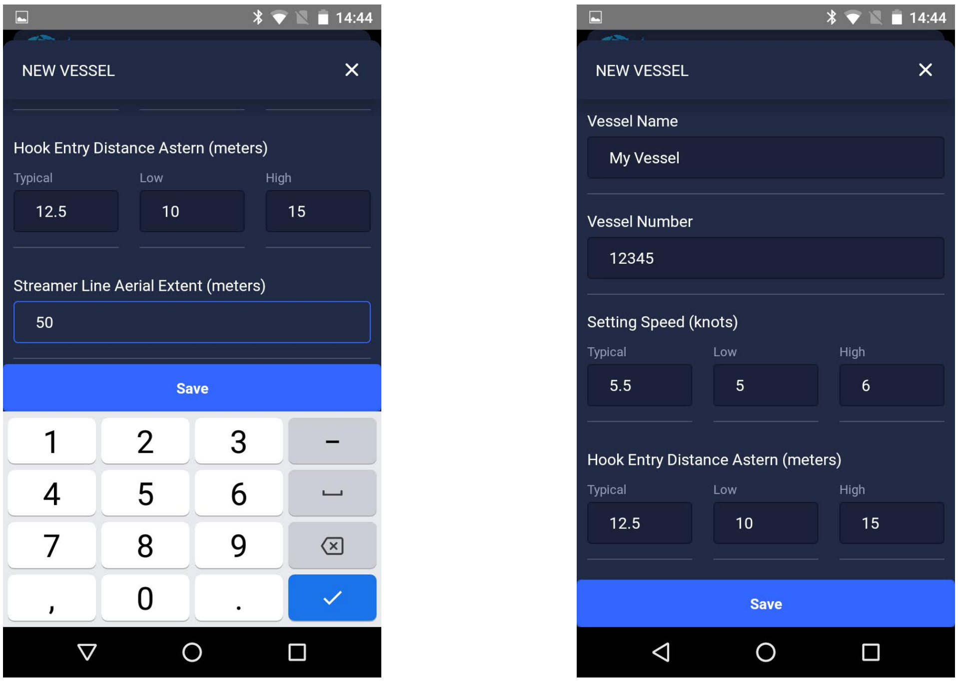
[12345] WT5243_54.csv
Succeed (03/20/2021 - 14:44)

[12345] WT5270_26.csv
Succeed (03/20/2021 - 14:44)

[12345] WT5274_24.csv
Succeed (03/20/2021 - 14:44)

(a) Processing files **(b)** All files synced to server

Figure 4: The `Demitto` app automatically discovers Wet Tag data files and submits these to the project server.



Hook Entry Distance Astern (meters)

Typical	Low	High
12.5	10	15

Streamer Line Aerial Extent (meters): 50

Vessel Name: My Vessel

Vessel Number: 12345

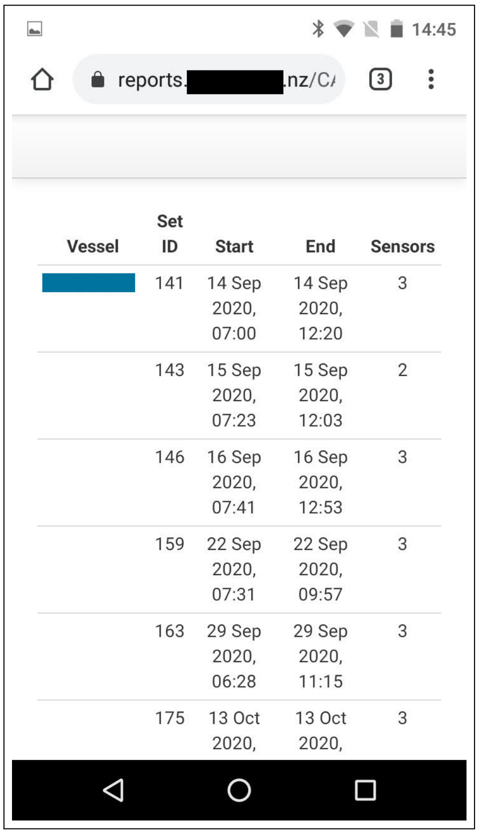
Setting Speed (knots)

Typical	Low	High
5.5	5	6

Hook Entry Distance Astern (meters)

Typical	Low	High
12.5	10	15

Figure 5: Setting up vessel information in the `Demitto` app.



Vessel	Set ID	Start	End	Sensors
[redacted]	141	14 Sep 2020, 07:00	14 Sep 2020, 12:20	3
	143	15 Sep 2020, 07:23	15 Sep 2020, 12:03	2
	146	16 Sep 2020, 07:41	16 Sep 2020, 12:53	3
	159	22 Sep 2020, 07:31	22 Sep 2020, 09:57	3
	163	29 Sep 2020, 06:28	29 Sep 2020, 11:15	3
	175	13 Oct 2020,	13 Oct 2020,	3

Figure 6: The 'My data' button in the `Demitto` app provided access to set-by-set summaries of the Wet Tag data.

2.4 Wet Tag data processing

Wet Tag data received from vessels by email, the `Demitto` app, or the Moana deck units was automatically on receipt. This involved a series of steps:

1. The individual CSV files were read and the header and data blocks contained within each file were separated. The header block contained metadata about the tag, its deployment history, and the download event, whilst the data block consisted of time-stamped depth and temperature readings accumulated since the preceding download.
2. The sensor data were associated with a particular vessel, based on the email address from which the data were submitted or metadata available from `Demitto` app submissions.
3. The data from each sensor were processed to identify tag deployments. Deployments were identified by temporal breaks in the sequence of data from a sensor, representing periods where the Wet Tag stopped logging after retrieval. Deployments less than 800 s or which did not exceed a depth of 5 m were dropped, as these typically represented instances where the tag was briefly submerged to facilitate data download, or other testing.
4. Deployments of sensors from a vessel were grouped based on overlapping deployment time ranges, in order to identify groups of sensors that were deployed on the same longline set.
5. Wet Tag deployment groups were matched to the statutory catch-effort data in order to gain information on the fish species targeted during a set.

2.4.1 Initial sink rate

For each Wet Tag deployment, the initial setting phase was identified. This was defined as the period at the start of the deployment during which depth and time were logged at 5 s intervals (i.e., until the tags reached a depth of 20 m). The mean sink rate was then calculated over all records in the initial setting phase where depths were less than or equal to 10 m.

2.4.2 Estimating hook depth at end of streamer line coverage

An estimate of the depth of baited hooks as these pass beyond the area protected by the streamer line is potentially the most useful metric to provide to fishers to assist them in adapting their line setup and setting processes.

For a streamer line with an aerial extent of 50 m, and a setting speed of 5 kn (2.57 m s^{-1}), an object deployed from the stern of the vessel will be within the aerial extent of the streamer line for 19.4 s. Hooks deployed on longlines will be in the air for a short distance behind the vessel; if this distance was 5 m then, for the same parameters as the previous example, the hooks would be in the water for 17.5 s while within the aerial extent of the longline.

In mathematical form, the covered sink period c (in seconds) is given by:

$$c = \frac{e - o}{v} \tag{1}$$

where e is the aerial extent of the streamer line, o is the distance behind the vessel where hooks enter the water, and v is the setting speed of the vessel in metres per second. The depth reached by hooks by the time they reach the limits of the streamer line coverage is

$$d = cs \tag{2}$$

for depth, d, in metres and a mean sink rate of s metres per second.

On each vessel deploying Wet Tags, the skipper (or vessel operator) provided an estimate of:

- typical setting speed, v, and the minimum, v^-, and maximum, v^+, settings speeds likely to arise in their normal fishing (estimates were given in knots);
- the typical distance astern of the vessel where the hooks entered the water, o, and the minimum, o^-, and maximum, o^+, distances likely to arise; and
- the aerial extent, e^v, achieved with their streamer line.

The minimum aerial extent for streamer lines as specified in any relevant regulations, e^r, was also considered.

The 'best estimate' of hook depths at the end of streamer line coverage, was calculated by using the vessel estimates of v, o, and e^v in equations 1 and 2, while minimum and maximum depths were estimated by substituting v^+ and o^+, and v^- and o^- respectively. Likewise the depth achieved at the minimum statutory extent of the streamer line was estimated by substituting e^r for e^v.

2.5 Standard graphics provided to fishers

Data from Wet Tags were compiled into standard graphics for distribution back to fishers. For each set, a four panel data display was provided that summarised information from all sensors deployed on the set (Figure 7).

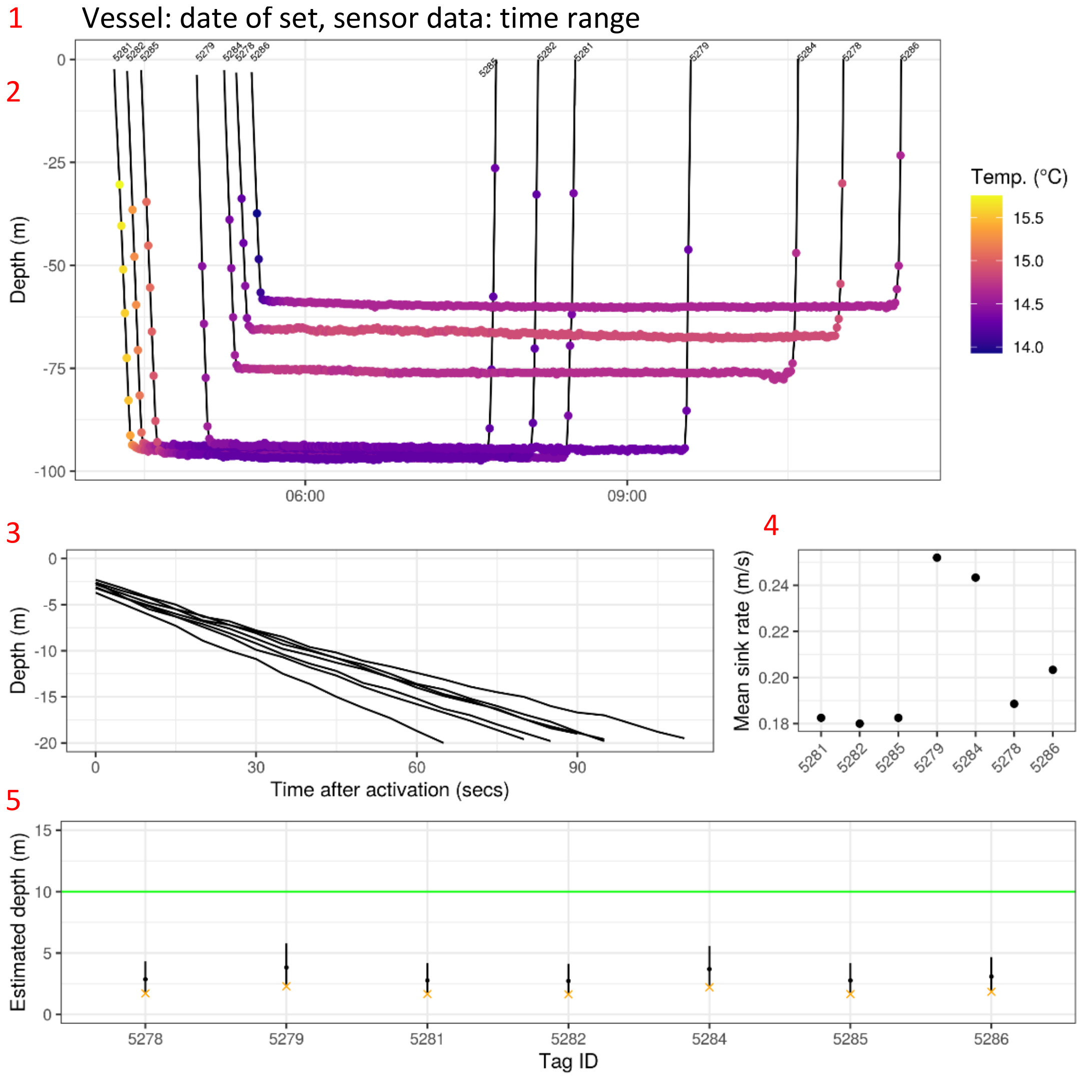


Figure 7: The set-by-set presentation of Wet Tag data provided to participating fishers, with the key areas annotated (see text for details). These data are from a bottom longline set.

The plot elements, as numbered in Figure 7, were:

1. A title identifying the vessel, the date of the set, and the time range for which sensor data were available.
2. A plot showing time/depth/temperature profiles for each sensor deployed on the line. Time and depth were indicated by the black line while temperature measurements were shown by the coloured points. Temperature measurements were only shown for depths greater than 20 m, when the sensor has a one-minute interval between data points. The temperature sensor in the tags has a slow response time and so the temperature data collected at shallower depths, when the sensor is recording at a 5 s interval, are not expected to be accurate.

3. A plot showing time-depth profiles for each tag from the time it started recording until it reached a depth of 20m. This is the high-resolution data collection phase when points are collected at a 5 s interval to allow sink rates to be calculated.

4. The plot to the right of the middle row showed the mean sink rate calculated for the deployment phase of each tag profile, restricted to data collected at depths up to 10 m.

5. A plot showing the estimated depth of hooks at the limits of streamer line aerial extents. The black points indicated the best estimate of depth using the skipper or vessel operator's estimate of the aerial extent achieved by the streamer line, the typical setting speed, and line entry distance astern of the vessel. The black line indicated the potential range on the depth estimate, using the minimum and maximum setting speeds and line entry distances. The orange cross indicated the estimated depth for the typical setting parameters, but with the minimum statutory aerial extent for the streamer line.

For each vessel, operators could also view a plot summarising estimates of the hook depth at the end of the streamer line over time; in these graphics the best estimate of hook depth at the end of the streamer line from each sensor was summarised as a per-set boxplot (Figure 8).

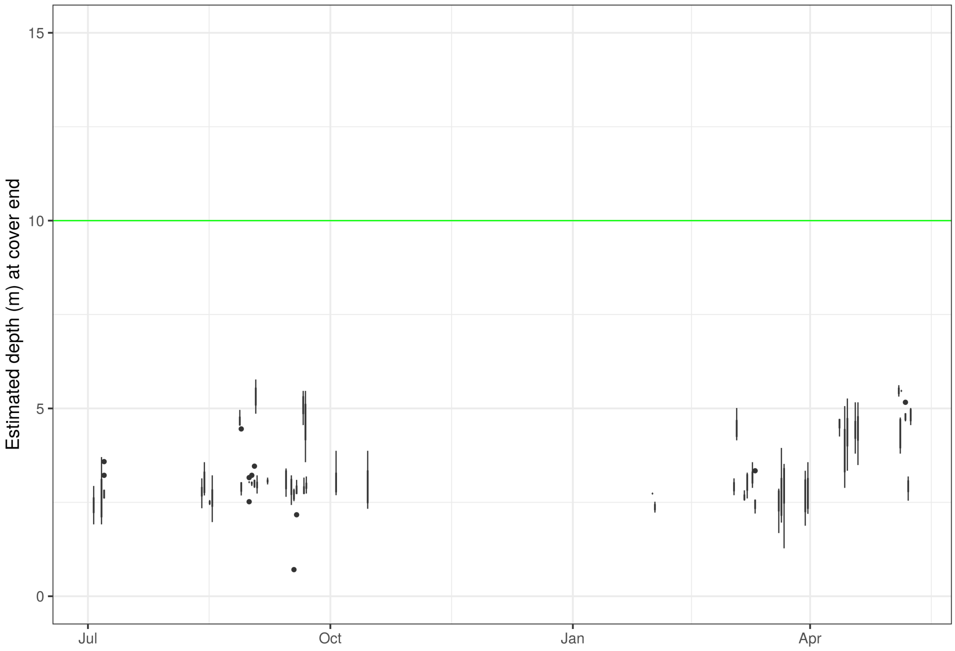


Figure 8: Example of a summary graphic showing per-vessel estimates of hook depth at the aerial extent of the streamer line, over time.

3. RESULTS

Initial testing of the Wet Tags for sink rate measurement was reported by Middleton et al. (2020a). This comprised testing of tag deployments from a local wharf and two trips undertaken by project staff when the initial batch of Wet Tags configured for sink-rate measurement was tested on a bottom longline vessel.

The at-sea testing indicated that, while the Wet Tags reliably recorded line profiles, the tags did not start logging until they had reached a depth of around 5 m, sometimes deeper. On the second trip, Wet Tags were deployed alongside higher-resolution, continuously logging TDRs. The resulting data suggested that assuming the line sinks at a constant rate was appropriate.

3.1 Uptake

Wet Tags were dispatched to the operators of nine bottom and nine surface longline vessels as envisaged by the deployment schedule. However, data were ultimately received from fewer vessels (Table 1).

A total of 974 individual Wet Tag deployments were identified in the submitted data from 288 individual line sets, of which 264 were matched to the statutory catch-effort data. Realised numbers of tags per set (i.e. deployed and successfully returning data) ranged from one to eight (Figure 9).

Most of the bottom longline sets were from snapper target fishing on the east and west coasts of the northern North Island (Table 2). All the surface longline effort was targeting southern bluefin tuna, but included fishing off the east coasts of both the North and South Islands (Figure 10).

Table 1: Number of participating vessels, by fishing method. BLL indicates bottom longlining and SLL is surface longlining.

Fishing method	Vessels returning data
BLL	6
SLL	2

Table 2: The fishing method and target species for longline sets with Wet Tag deployments, matched to fishing events in the statutory catch-effort data.

Fishing method	Target species	Number of sets
BLL	GUR	1
BLL	RSN	5
BLL	SNA	193
SLL	STN	62

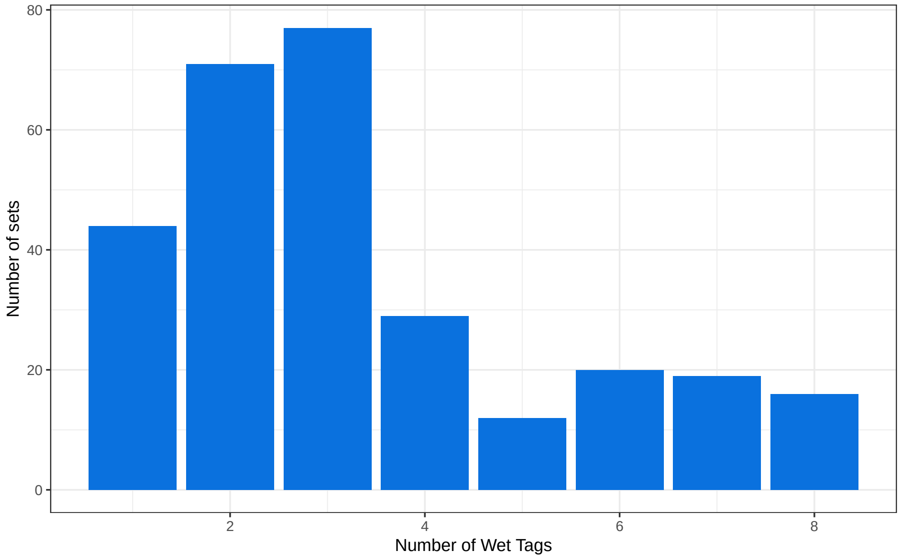


Figure 9: The number of Wet Tags providing data per set.

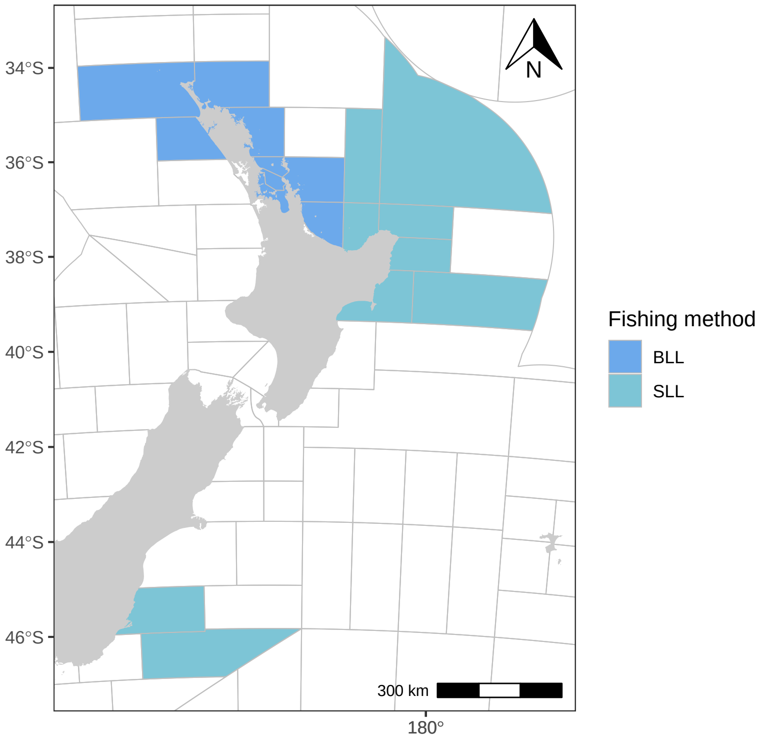


Figure 10: Statistical areas with sink rate data from bottom and surface longlining.

3.2 Recorded sink rates

Sink rates were able to be calculated for 893 deployments where sufficient data points were logged in the top 10 m of the water column.

In general, the line sink rates recorded from surface longline vessels were slower than from bottom longline vessels (Figure 11). The typical sink rates achieved by different bottom longline vessels varied by a factor of around two, although within-vessel variation was substantial.

Differences in sink rate were reflected in the estimated depths of hooks at the aerial extent of the streamer line (Figure 12), with median estimated depths for bottom longline vessels ranging from 3 m to 5.2 m. For the two bottom longline vessels that returned the greatest volume of data, there is an indication that the sink rates achieved vary with the depth in which the line was set with slower sink rates when setting in deeper water (Figure 13).

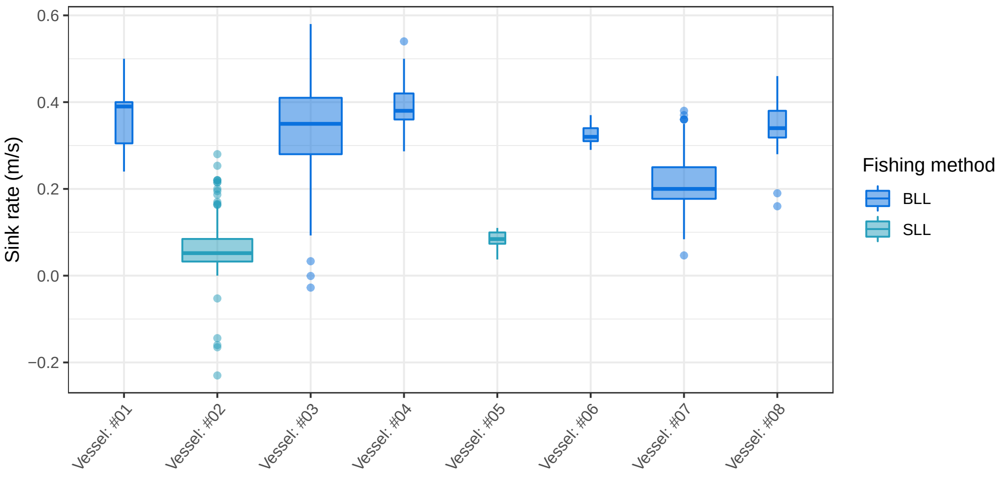


Figure 11: The distribution of mean sink rate to 10 m depth, by vessel. Boxplot widths are scaled to the square root of the number of Wet Tag deployments recorded from a vessel.

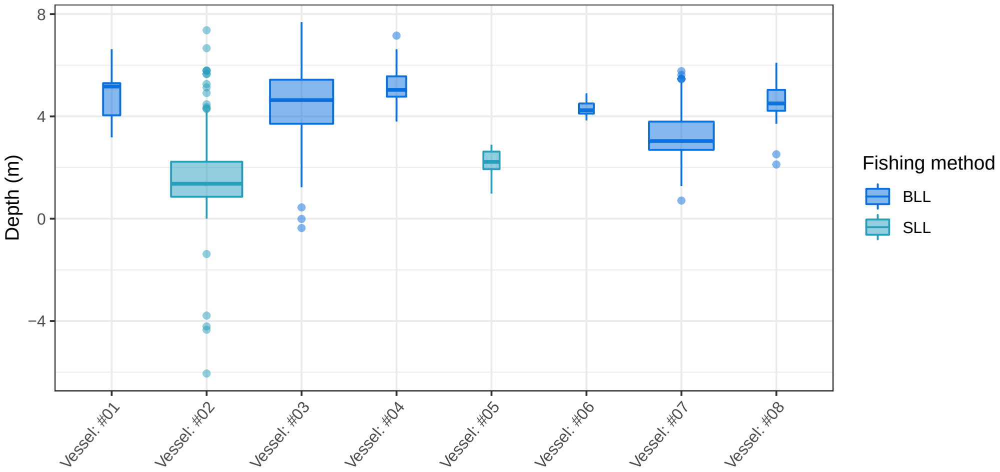


Figure 12: The distribution of estimated hook depths at the aerial extent of the streamer line, by vessel. Boxplot widths are scaled to the square root of the number of Wet Tag deployments recorded from a vessel.

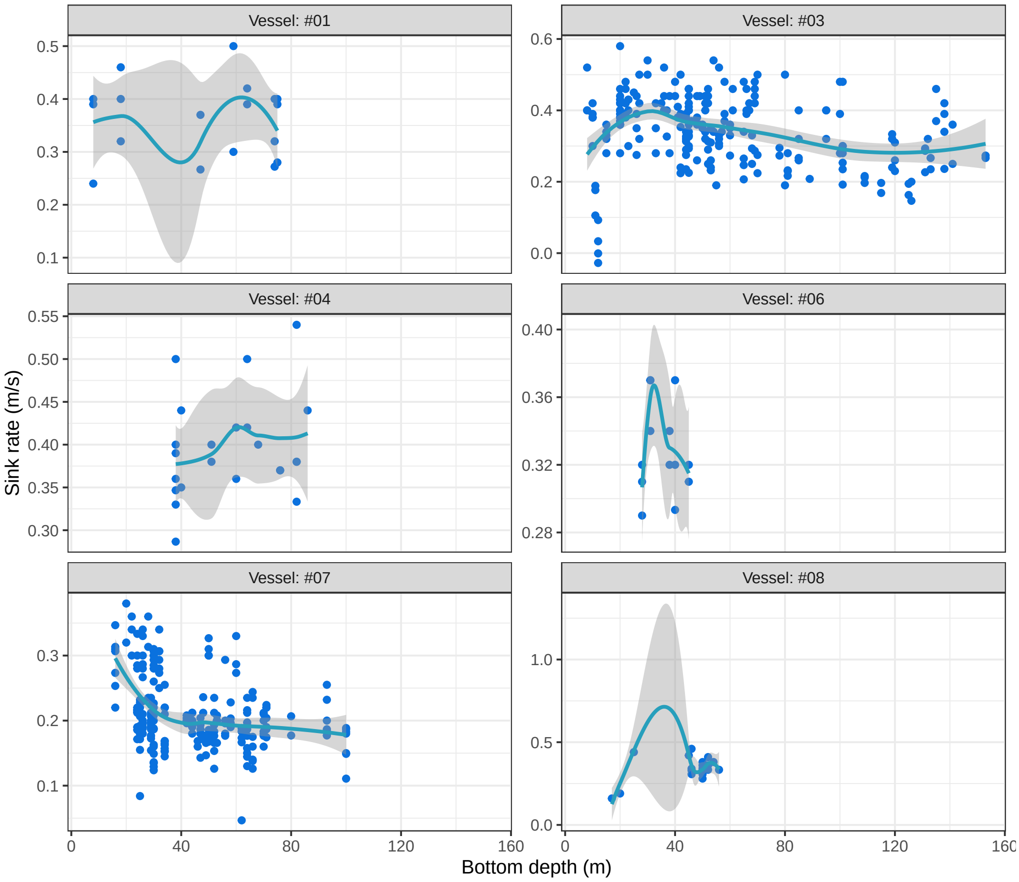


Figure 13: The relationship between mean sink rate to 10 m depth and reported bottom depth of the set, for the participating bottom longline vessels.

Wet Tags were deployed in the bottom longline fishery attached by short rope tethers to standard clips. Thus the Wet Tags essentially sank at the same rate as the backbone, and the same assumption applies to baited hooks. For BLL, snoods are short and so this assumption is reasonable. However, in the case of SLL fishing snoods are longer and are initially cast from the vessel, with hooks sinking freely to a depth determined by the snood length, before transitioning to sink at the same speed as the backbone.

Initially surface longline fishers opted to deploy the Wet Tags on snoods without baited hooks, due to a concern over sensor loss due to 'bite offs'. However, this imples that the initial sink rate will be the sink rate of the Wet Tag, which may differ from that of a baited hook. Therefore, in the 2021 season, SLL fishers were encouraged to deploy snoods with Wet Tags and with/without baited hooks. The increased sink rate due to the baited hook is evident in density plots of sink rate from the two seasons (Figure 14).

Seabirds were reported captured on three bottom longline sets and one. Given the low number of events, any conclusions are necessarily tentative but Wet Tags deployed on bottom longline sets with seabird captures tended to be at the lower end of the range of recorded sink rates (Figure 16).

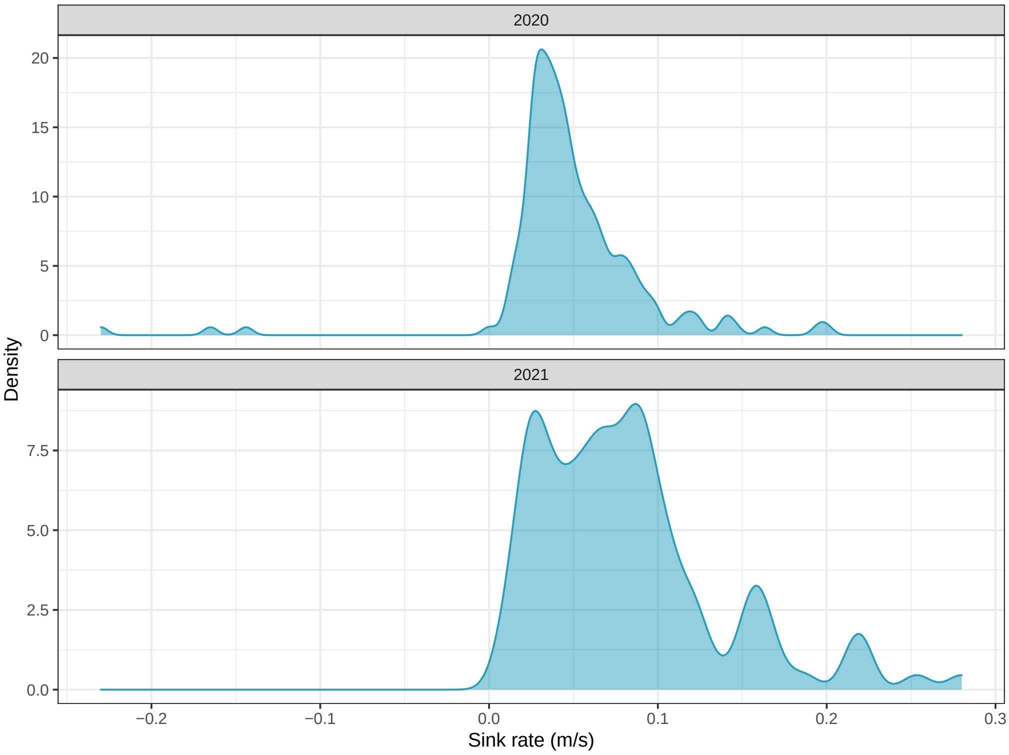


Figure 14: The distribution of mean sink rate to 10 m depth, for Wet Tags deployments from a surface longline vessel in the 2020 and 2021 fishing years (Oct–Sep).

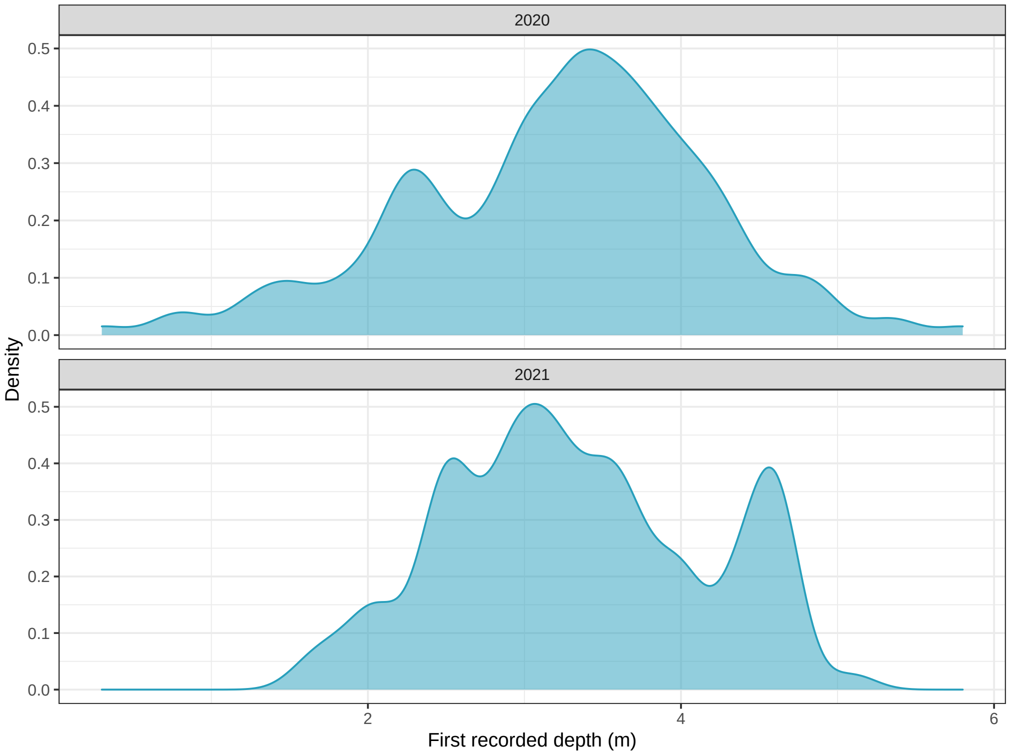


Figure 15: The distribution of first recorded depth, for Wet Tags deployments from a surface longline vessel in the 2020 and 2021 fishing years (Oct–Sep).

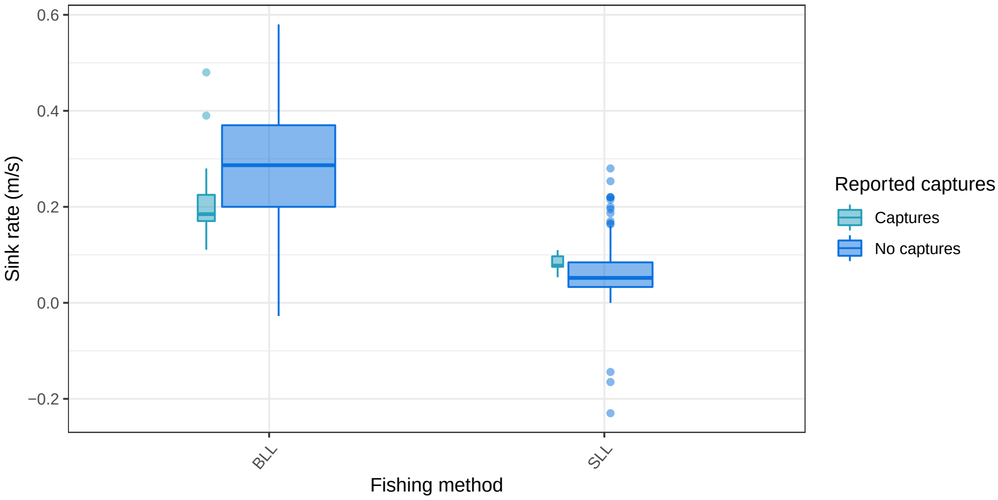


Figure 16: The distribution of mean sink rate to 10 m depth, for Wet Tags deployments on sets with and without fisher-reported seabird captures.

3.3 Fisher feedback

At the end of the project, debriefs with participants aimed to gather feedback on the value of the project and the challenges encountered. Discussions were guided by the following questions:

- Did you find the Wet Tags useful?
- Do you feel that knowing the actual sink rates of your gear would make you change the sink rates?
- Did you add weight/take weight away/adjust setting speed as a result of knowing your sink rate? If not, why not?
- What were the biggest challenges in using the Wet Tags?
- How did you find connecting the Wet Tags to your phone?
- How did you find using the app?
- How did you find sending the data?
- Did you find the way the sink rates were presented informative?
- What is your key recommendation for improving the Wet Tag programme?

Three participants (one SLL skipper and two BLL vessel managers) have provided the majority of the feedback; their views are those of the most engaged participants in the project and so do not reflect the views of those vessel operators that were provided with Wet Tags but ultimately did not submit any data.

In general, the active participants were enthusiastic about the project and the information generated. They recognised the importance of data that verified/checked their gear performance, but were more focussed on detecting longer term drift in performance away from the expected norms (e.g. due to crew changes) than set-by-set modifications. On the water changes in weighting regime are already made in response to known seasonal variations in risk of seabird interaction, and in response to observed seabird behaviour. One participant was strongly in favour of continued use of TDRs rather than bottle tests, noting that the latter were considered unreliable in the conditions prevailing in the inshore BLL fishery.

The Wet Tag data is primarily seen as useful in confirming that the expected gear performance is maintained, although it would be expected to be used more intensively in any situation where gear modification or initial setup to meet a performance standard was required. Vessels managers have noted between trip differences in sink rates from the Wet Tag data to-date and have used these as a basis for discussions with crew.

In addition to the data from the initial line sink phase, the active participants reported that the depth and temperature profiles from the whole set were useful.

With one exception, participants found data download and submission challenging. The challenges included:

- compatability issues that limited the platforms where the apps functioned (e.g. the `Zebra-Tech BLE` app was unable to function on recent iOS devices for most of the project);
- varying familiarity with the required smartdevices. For example, one fisher did not use a smartphone, while others were more basic users. One skipper, while a highly competent smartphone user, found the 'auto-offload' function of the `Zebra-Tech BLE` app too intrusive. It required to be in the foreground to be operational, and was therefore interrupted by incoming calls etc.;
- maintaining the engagement of the crew that might be best placed to download data using the apps, but not key users of the data. In one case, the vessel manager chose to download the data periodically from vessels, rather than delegate this task to crew.

Overall, the feedback indicated a strong desire to see the data download and submission process improved, both for any continuation with current participants and any expansion of the programme. Investing in improving and 'beta' testing a new download regime was recommended as a key next step for the programme. Autonomous download as sensors are retrieved (removing the need for any later sensor re-activation to download) and automatic data submission were strong recommendations.

Improvements in the data collection regime would provide the opportunity for a renewed focus on the best approaches for presenting near real-time data summaries back to vessel operators. One operator noted the need to be able to correct the parameters used in calculating expected hook depths. While the `Demitto` app provided the opportunity for different setting to be configured, automomous download generally does not provide the opportunity for these to be entered on a set-by-set basis, and it was suggested that an interactive interface should be provided for these to be corrected subsequently.

The BLL fishery participants, in particular, noted the need to obtain representative data across the fleet which would entail expanding the programme to other fishers, including those not normally at the forefront of new data collection initiatives.

4. DISCUSSION

The Wet Tag programme successfully put robust time-depth recording technology into the hands of fishers for routine use in fishing operations. Uptake and participation in the programme was lower than anticipated due, at least in part, to the impact of the COVID-19 response in 2020 which limited interactions with participants, and disrupted their fishing operations requiring a focus on re-defining their normal business at the expense of involvement in new initiatives. However, the active participants in the programme have been generally positive about the technology, valuing the data summaries and the fact that these provide rich information about time/depth profiles rather than simply verifying initial sink rates.

The key technological challenge for the programme has been data download and submission. Initial problems with the sensor firmware that led to difficulties in communicating with the Wet Tags were identified and addressed, but variations in the hardware and operating system software of the smart devices used for app downloading persisted throughout the project. There was significant variation between participants in the degree of comfort with smartphone apps for data retrieval and viewing of results. It is likely that workshops with participants would have assisted in increasing the level of comfort with the apps, but this was not feasible due to COVID-19 restrictions. In future, alternative means of providing instructions and assistance, such as video tutorials, should be considered.

Automatic and autonomous download of Wet Tags was tested on one vessel, as an additional development in the capabilities of Deck Units deployed for the Moana Project. This was largely successful, although did limit the ability for fishers to input different parameters relevant to estimation of hook depths. Improvement of the data download and transmission process is a key requirement for continuation or expansion of the programme.

Feedback on the data summaries compiled from the Wet Tag data submissions was positive. Estimation of hook depths at the limits of the streamer line aerial coverage required fishers to supply estimates of setting speed, streamer aerial coverage, and line entry point astern of the vessel. For the most part these were constructed using fixed estimates of these parameters, albeit with ranges on setting speed and the distance astern that the line entered the water. The `Demitto` app provides the opportunity for these parameters to be updated by fishers as part of the data submission process but, given the clear preference for autonomous data retrieval in future, other mechanisms for setting these parameters need to be considered. In the case of setting speed, the vessel tracking data from the statutory Geographic Position Reporting (GPR) system[12] would probably provide the best option for calculating setting speeds on a set-by-set basis. Another option is to allow fishers to enter these parameters retrospectively; this would also provide the opportunity for the outputs to be used in an exploratory manner.

A disadvantage of the Wet Tags for measuring initial sink rate is the delay in the start of data logging imposed by the trigger depth/time approach. The consequence

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[12] https://legislation.govt.nz/regulation/public/2017/0155/latest/DLM7330540.htm

of this delay has been investigated by logging parallel data from a number of sets using high-resolution TDRs with logging manually initiated when the units are still on deck (Middleton et al. 2020a, Goad 2021).

Additional analyses of the data collected by Goad (2021) is included in Appendix A. The period when hooks are sinking under the cover provided by a steamer line is relatively short, and the Wet Tags were typically not starting logging data until the end of this period (see, for example, Figure A-4). In addition, there is evidence that there can be a period of reduced sink rates immediately after deployment, rather than the constant sink rate assumed. Nevertheless, the estimates of line depth at streamer line extent made using Wet Tag data are broadly in line with those made using continuously logging TDRs (Figure A-6). Thus, for inshore bottom longline, the Wet Tag data gathered in this project are considered to support reasonable estimates of line depths achieved within the coverage provided by the streamer lines. These show between-vessel differences, and within-vessel variation resulting from different gear setups and weather conditions. Few seabird captures were reported during the project but, for bottom longline, there is an indication that these were associated with slower sink rates.

For surface longlining, the use of longer snoods/traces results in a period where hooks are sinking freely before becoming aligned to the sink rate of the backbone. Sink rates in this initial period are generally faster. While static tests (Goad 2021) indicated that much of this initial sink period occured before Wet Tags activated, data from Wet Tags deployed on surface longline sets indicate that the two phases of line sinking are nevertheless evident in real-world Wet Tag data (Figure 17). The key challenge for surface lining deployments is to collect data that accounts for the faster sink rates of traces with baited hooks, without an unacceptable loss of Wet Tags due to bite-offs by sharks.

This project used tags that were rated to depths of 150 m. There is a trade off between maximum depth rating and the resolution of the data available from the sensors; the decision to use 150 m rated sensors was made in order to provide the highest resolution data possible, while accepting that this would limit the target fisheries that could be investigated. For example, bluenose target bottom lining was not able to be included because a significant part of the bluenose target effort is in depths below 150 m.

The selected depth rating was found to be a problem for the Wet Tags deployed in some surface longline sets. Although the target fishing depths were shallower than 150 m, some parts of the line with attached sensors went on ‘excursions’ to deeper depths as a result of the catch of fish (possibly blue sharks) that dived when they became hooked (see, for example, Figure 18). The pressure sensors in two Wet Tags were overpressurised and damaged by this process. A 250 m rated tag has been sourced and will be tested in the SLL fishery, with the aim of determining whether the resolution of the resulting data is still adequate for estimating initial sink rates.

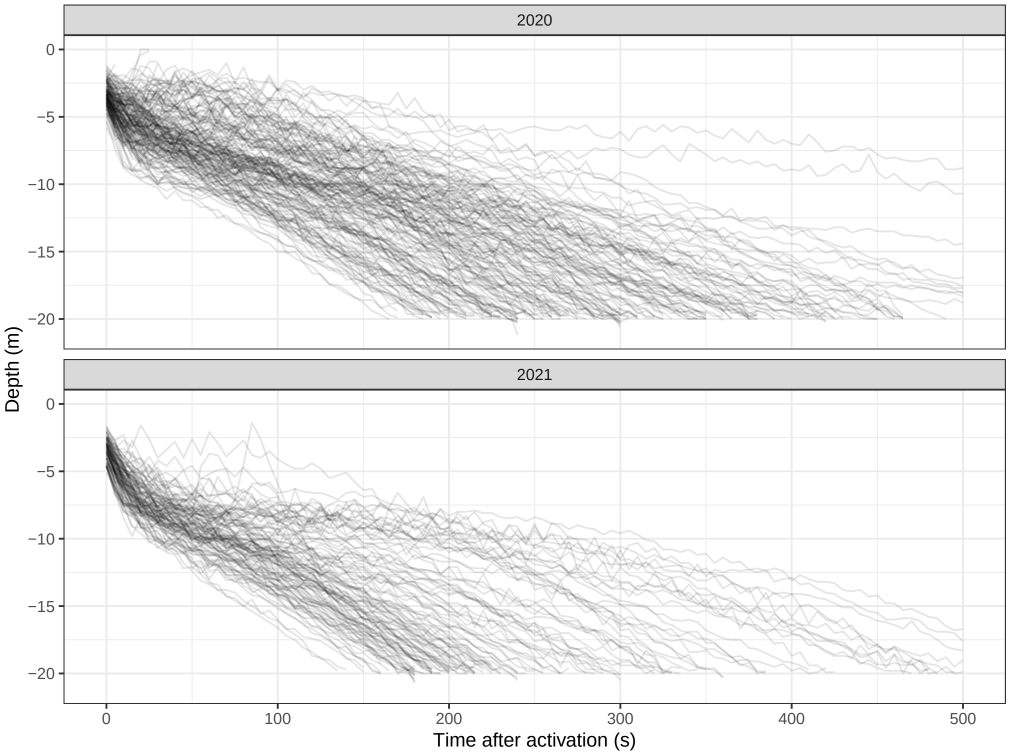

Figure 17: Depth profiles from the main SLL vessel in the 2020 and 2021 fishing years. In 2020 all Wet Tags were deployed on snoods without hooks. In 2021, every second tag was deployed on a snood with a baited hook.

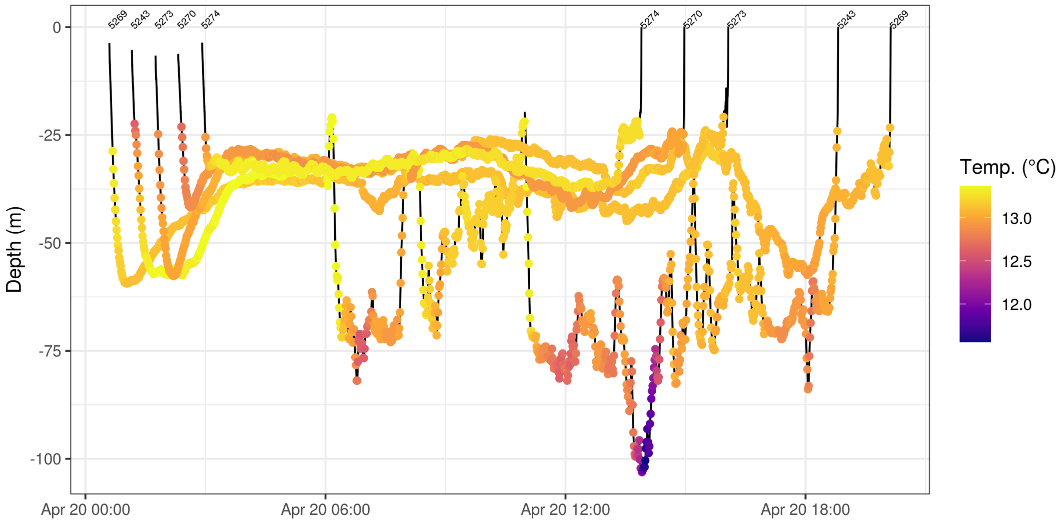

Figure 18: Example time-depth profiles from Wet Tags on a surface longline deployment. A 40 kg blue shark was caught on the trace with Wet Tag number 5243.

Overall, we conclude that the Wet Tag data are useful for monitoring of line sink rates in both bottom and surface longline and that the routine collection of these data across the fleet is useful to understand the variation in sink rates achieved within and between vessels. Further refinement of the Wet Tags to focus on earlier activation of data logging, potentially in conjunction with a simple manual switch-on that would indicate deployment from the vessel, would potentially provide more data from the immediate post-deployment period. This would assist in finer scale investigation of variation in sink rate arising from different weighting regimes, in particular the variation in initial sink rate that arises on bottom longline vessels as a result of distance between weights.

4.1 Summary of recommendations

1. Continue the deployment of Wet Tags (or similar robust, fisher-friendly TDRs, ideally with reduced trigger delays) to provide vessel operators with ongoing information on line setting speeds.
2. Hold method-specific fisher workshops to share results to-date and secure ongoing engagement, including from the sectors of the fleet that have not participated.
3. Focus on autonomous data retrieval solutions for both current and additional participants.
4. Consider use of statutory GPR data for estimating setting speeds on a set-by-set basis.
5. Adopt standardised approaches for deployment of Wet Tags in BLL and SLL fisheries.
6. Provide fishers with interactive tools for exploring the impacts of different parameters (i.e. sink rate, setting speed, distance astern, streamer line aerial extent, gear setup) on the hook depths achieved within the streamer line coverage.
7. Further investigate the relationship between line entry point astern of the vessel and weighting regime.
8. Continue to work with fishers to refine the reporting of sink rate results in a manner that supports best practive vessel operations. Potentially include baseline gear testing and trip-by-trip monitoring for deviations from expected performance, rather than set-by-set feedback.

5. ACKNOWLEDGEMENTS

This work was funded by the Department of Conservation's Conservation Services Programme project MIT2018-03. Fisheries New Zealand supplied the statutory data that was linked to the Wet Tag deployment information. We are grateful to the participating fishing companies and skippers. The contributions of Darrin Fabricus, Mike Te Pou and Zak Olsen were particularly notable. Feedback from members of the CSP Technical Working Group, especially Igor Debski and Dave Goad was helpful in refining the use of the Wet Tag data. Additional testing of multiple TDRs by Dave Goad, funded by the Department of Conservation, was valuable in determining the limits of the Wet Tag data.

6. REFERENCES

Bell, E. A. (2016). Diving behaviour of black petrels (*Procellaria parkinsoni*) in New Zealand waters and its relevance to fisheries interaction. *Notornis*, *63*, 57–65.

Bentley, L. K.; Kato, A.; Ropert-Coudert, Y.; Manica, A., & Phillips, R. A. (2021). Diving behaviour of albatrosses: implications for foraging ecology and bycatch susceptibility. *Marine Biology*, *168*, 36. doi:10.1007/s00227-021-03841-y

Croxall, J. P.; Butchart, S. H. M.; Lascelles, B.; Stattersfield, A. J.; Sullivan, B.; Symes, A., & Taylor, P. (2012). Seabird conservation status, threats and priority actions: A global assessment. *Bird Conservation International*, *22*, 1–34.

FAO (1999). *International Plan of Action for reducing incidental catch of seabirds in longline fisheries. International Plan of Action for the conservation and management of sharks. International Plan of Action for the management of fishing capacity.* 26 p. Rome: FAO. Retrieved from http://www.fao.org/3/x3170e/x3170e.pdf

Fenaughty, J. M. & Smith, N. W. M. (2001). A simple new method for monitoring longline sink rate to selected depths. *CCAMLR meeting paper*, *WG-FSA-01/46*.

Fisheries New Zealand (2020). *National Plan of Action – Seabirds 2020. Supporting document.* Retrieved from https://www.mpi.govt.nz/dmsdocument/40658-national-plan-of-action-seabirds-2020-supporting-document

Goad, D. (2021). *Longline sink rate verification. Draft report for Department of Conservation project BCBC202011c.* Department of Conservation. 21 p. Wellington.

Goad, D.; Temple, S., & Williamson, J. (2010). *MIT 2009/01 Development of mitigation strategies: Inshore fisheries.* Department of Conservation. 62 p. Wellington. Retrieved from https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/fishing/twg/2009-01-mit-inshore-fisheries.pdf

Manville, A. M., II (2005). Seabird and waterbird bycatch in fishing gear: next steps in dealing with a problem. *USDA Forest Service Gen. Tech. Rep. PSW-GTR-191*, 1071–1082.

Middleton, D. A. J.; King, B., & Wilson, O. (2020a). *MIT2018-03: Setting mitigation for small longline vessels. Development of an Adaptive Management tool for line setting: progress report.* Department of Conservation. 33 p. Wellington. Retrieved from https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/draft-reports/mit2018-03-setting-mitigation-for-small-longline-vessels.pdf

Murray, T. E.; Taylor, P. R.; Greaves, J.; Bartle, J. A., & Malloy, J. (1992). Seabird bycatch by Southern Fishery longline vessels in New Zealand waters. *New Zealand Fisheries Assessment Research Document*, *92/22*. 21 p. Retrieved from https://fs.fish.govt.nz/Doc/17782/1992%20FARDs/92_22_FARD.pdf.ashx

Richard, Y. & Abraham, E. R. (2020). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2016–17. *New Zealand Aquatic Environment and Biodiversity Report 237*. 61 p. Retrieved from https://www.mpi.govt.nz/dmsdocument/39407/direct

Wanless, R. M. & Waugh, S. (2010). Technical description of hookline sink rates and protection offered by streamer lines. *Collect. Vol. Sci. Pap. ICCAT*, *65*, 2297–2304. SCRS/2009/088.

Wienecke, B. & Robertson, G. (2004). Validation of sink rates of longlines measured using two different methods. *CCAMLR Science*, *11*, 179–187.

APPENDIX A Bottom longline paired deployments

Additional comparisons (to those reported by Middleton et al. 2020a) between Wet Tags and CEFAS G5 TDRs were carried out under Department of Conservation project BCBC202011c (Goad 2021). Paired sensor deployments were made from a BLL vessel on three days in May 2021 (Table A-1).

Raw data from the setting phase of the deployments is shown for the three days in Figure A-1 to Figure A-3, which illustrate a number of relevant features of the data:

- data were not retrieved for all Wet Tag deployments. This was due to a low-battery condition on the vessel's Moana sensor disrupting the autonomous download of the devices. Data was not retrieved from four Wet Tags on each of day two and three of the trial, and short data files were retrieved for some tags on day one. These were included after reducing the minimum time threshold for useful deployments.
- the deployment of a Moana sensor is included as the first set of points in Figure A-1 and Figure A-3. Because the Moana sensor adapts to the prevailing atmospheric pressure when on the surface, these devices have a quicker activation than the Wet Tags allowing set profiles to be recorded from around 1 m depths.
- the pressure sensors of the CEFAS G5 devices are not well calibrated, resulting in considerable variation in the recorded depth when at the surface. Comparison with the maximum depths recorded suggests this is a constant offset.
- the CEFAS sensor data has a fine temporal resolution, but can be quite noisy particularily as the tags are deployed (Figure A-4, Figure A-5).

Estimates of depth at the aerial extent of the streamer line

For each of the paired TDR deployments, a clip on time and setting speed was manually recorded (Table A-1). Using an assumed aerial extent for the vessel's streamer line of 70 m, the time that the sensors pass the end of the streamer line can be estimated. The depth recorded by the CEFAS G5 sensors at this point, after adjusting for the pressure sensor offsets, can then be compared with the depth estimates made using the Wet Tag data, as detailed in the body of this report.

Because the depth readings from the CEFAS sensors appeared to become more noisy with handling prior to deployment, the depth offset for a profile was chosen as the depth recorded one minute before the recorded clip-on time, when depth readings were generally more stable. Estimates of the line depth at the extent of the streamer line are shown for individual sensor pairs in Figure A-4 and Figure A-5.

An overall comparison of estimated line depths from the G5 sensors and Wet Tags is provided in Figure A-6, for sensor pairs in different positions relative to the weights deployed on the line. In general, estimated depths from Wet Tag measurements were somewhat deeper than those from the G5 sensors.

Table A-1: Paired deployments of CEFAS G5 time-depth recorders and Wet Tags on a bottom longline vessel. Clip on and water entry times were recorded manually, with the placement code indicating the clip on point as a proportion of the between-weight distance.

Pair	Speed	G5 tag	Wet Tag	Clip on	Water entry	Placement
1	6	A17237	5321	2021-05-07 02:53:20	2021-05-07 02:53:24	0.50
2	6	A17041	5322	2021-05-07 02:56:01	2021-05-07 02:56:06	0.75
3	6	A17042	5324	2021-05-07 02:57:22	2021-05-07 02:57:29	0.50
4	6	A17044	5320	2021-05-07 02:58:52	2021-05-07 02:58:57	0.75
5	6	A17050	5285	2021-05-07 03:00:16	2021-05-07 03:00:22	0.50
6	6	A17048	5280	2021-05-07 03:03:31	2021-05-07 03:03:37	0.75
7	6	A17052	5279	2021-05-07 03:05:15	2021-05-07 03:05:20	0.50
8	6	A17046	5284	2021-05-07 03:06:50	2021-05-07 03:06:57	0.75
9	4	A17046	5284	2021-05-08 04:03:17		0.00
10	4	A17048	5280	2021-05-08 04:04:29		0.00
11	4	A17052	5279	2021-05-08 04:06:10	2021-05-08 04:06:19	0.50
12	4	A17050	5285	2021-05-08 04:07:09		0.50
13	4	A17041	5322	2021-05-08 04:08:29	2021-05-08 04:08:36	0.75
14	4	A17044	5320	2021-05-08 04:09:36	2021-05-08 04:09:43	0.75
15	4	A17237	5321	2021-05-08 04:10:38	2021-05-08 04:10:48	0.75
16	4	A17042	5324	2021-05-08 04:11:32		0.50
17	6	A17046	5284	2021-05-09 02:48:32		0.00
18	6	A17048	5280	2021-05-09 02:49:47	2021-05-09 02:49:54	0.50
19	6	A17052	5279	2021-05-09 02:50:24		0.75
20	6	A17050	5285	2021-05-09 02:51:23	2021-05-09 02:51:24	0.00
21	6	A17041	5322	2021-05-09 02:52:12	2021-05-09 02:52:17	0.33
22	6	A17044	5320	2021-05-09 02:53:16	2021-05-09 02:53:21	0.75
23	6	A17237	5321	2021-05-09 02:56:37	2021-05-09 02:56:41	0.50
24	6	A17042	5324	2021-05-09 02:57:13	2021-05-09 02:57:19	0.75

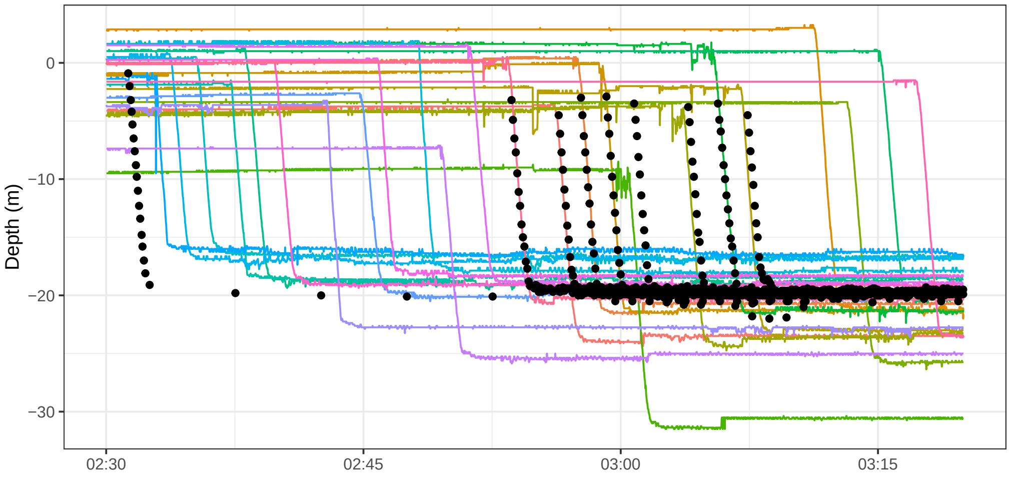

Figure A-1: Paired deployments of CEFAS G5 TDRs (coloured lines) and Wet Tags (black points) on a bottom longline on 7 May 2021. Deployment of a Zebra-Tech Moana TD sensor is evident as the earliest set of black points.

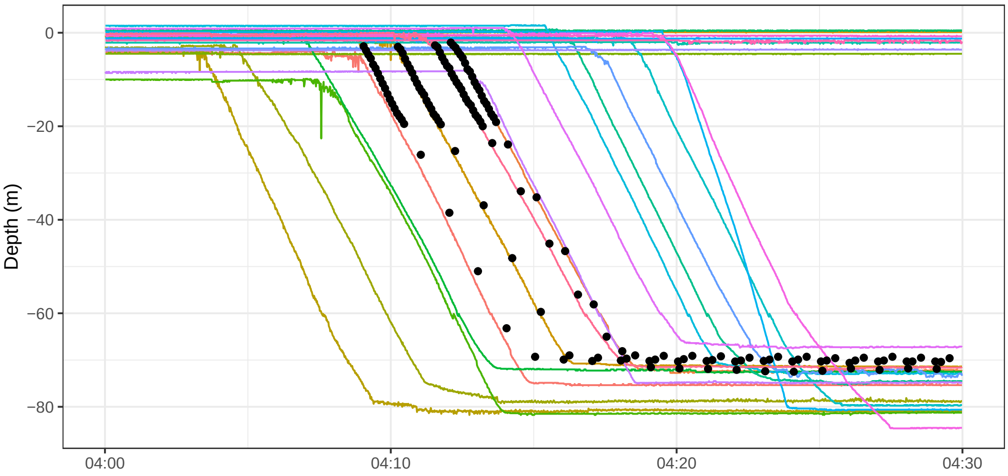

Figure A-2: Paired deployments of CEFAS G5 TDRs (coloured lines) and Wet Tags (black points) on a bottom longline on 8 May 2021.

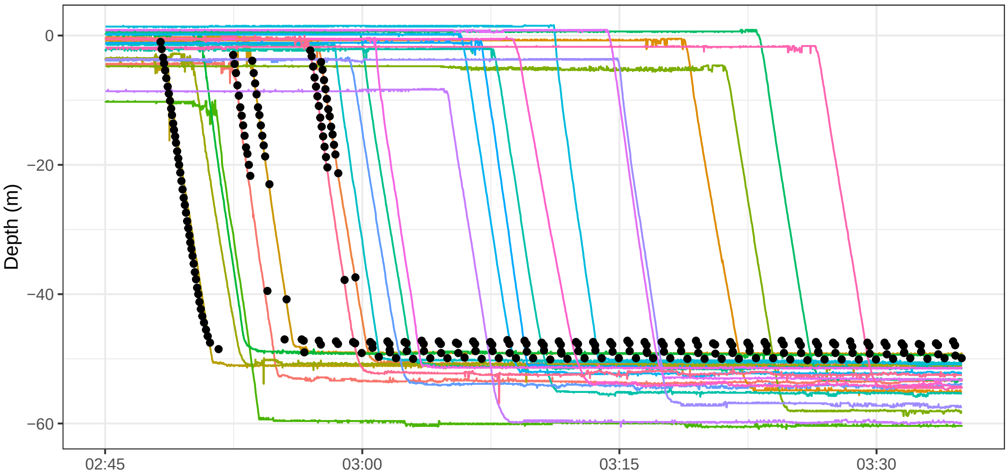

Figure A-3: Paired deployments of CEFAS G5 TDRs (coloured lines) and Wet Tags (black points) on a bottom longline on 9 May 2021. Deployment of a Zebra-Tech Moana TD sensor is evident as the earliest set of black points.

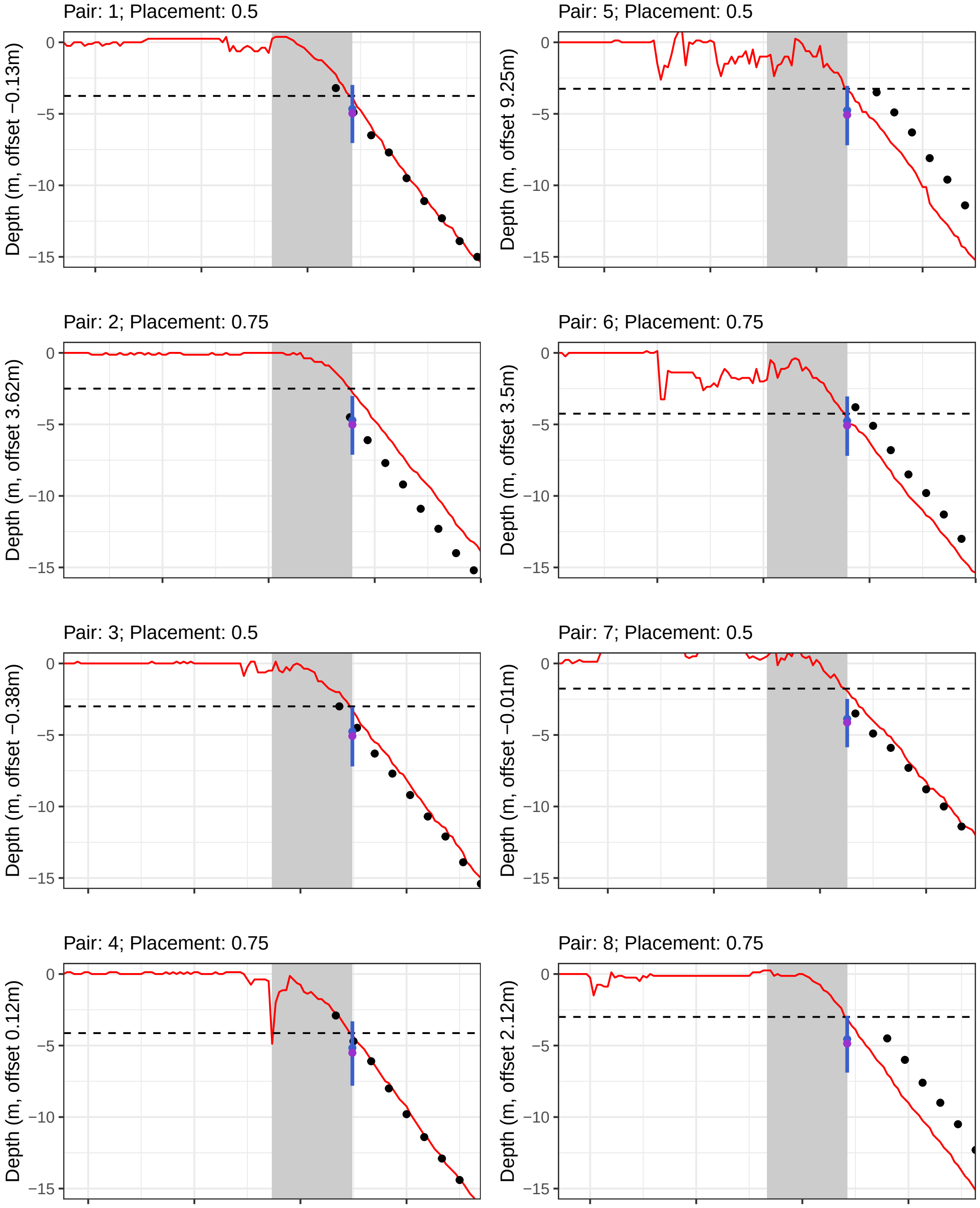

Figure A-4: Pair by pair comparisons of the CEFAS G5 TDR data (red line) and Wet Tag data (black points) for one minute before and after the recorded clip-on time, for paired deployments on 7 May 2021. The CEFAS tag data have been adjusted so that the first recorded depth is zero; the relevant offset is noted in the axis label. The grey rectangle denotes the time period from clip on until the sensors pass out from under the streamer line. Estimated depths at the end of the streamer line from the Wet Tag data are shown as a blue point and linerange, using the standard parameters for the vessel, and as a purple point when calculated using the set-specific recorded speed.

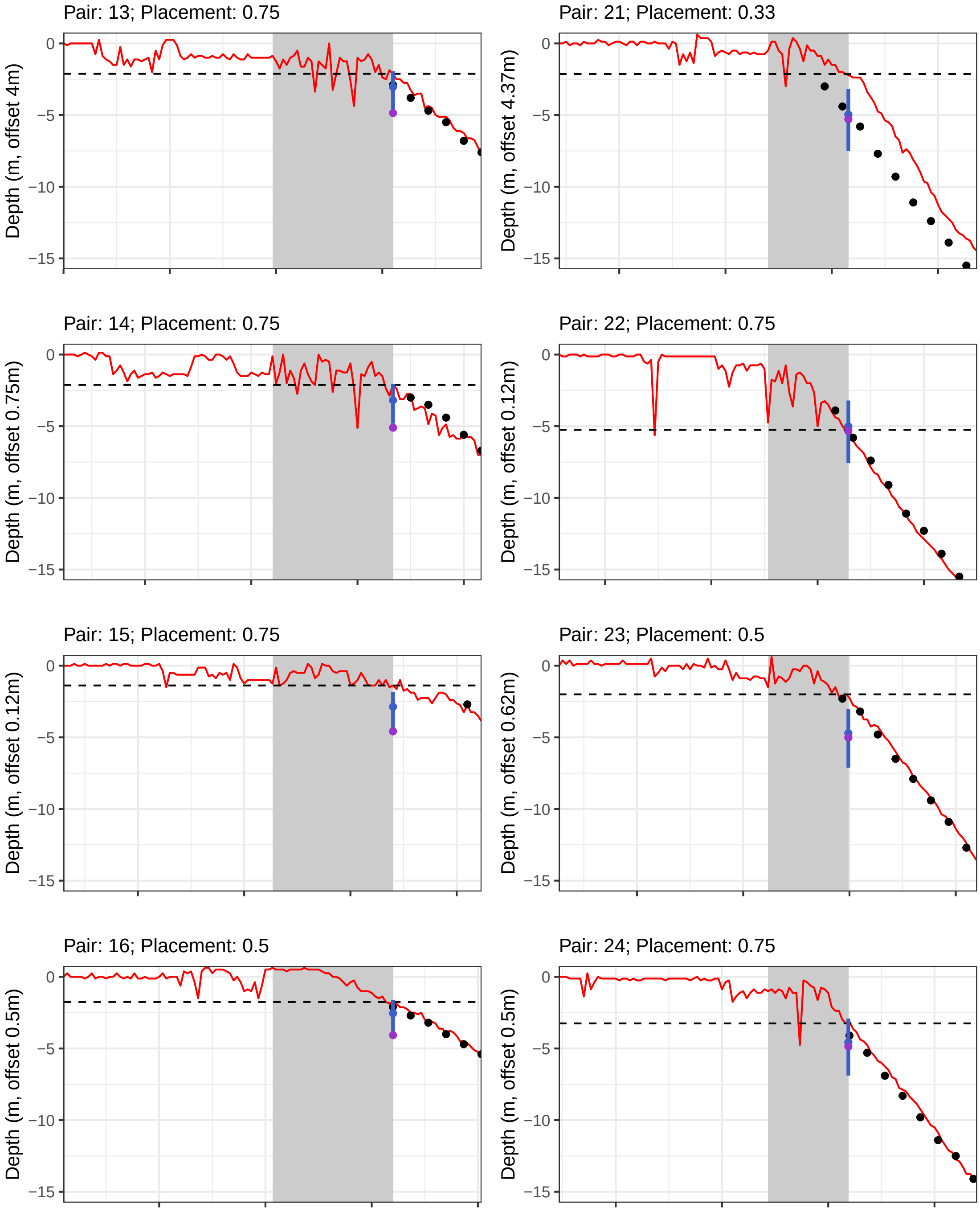

Figure A-5: Pair by pair comparisons of the CEFAS G5 TDR data (red line) and Wet Tag data (black points) for paired deployments on 8 and 9 May 2021. See Figure A-4 for details.

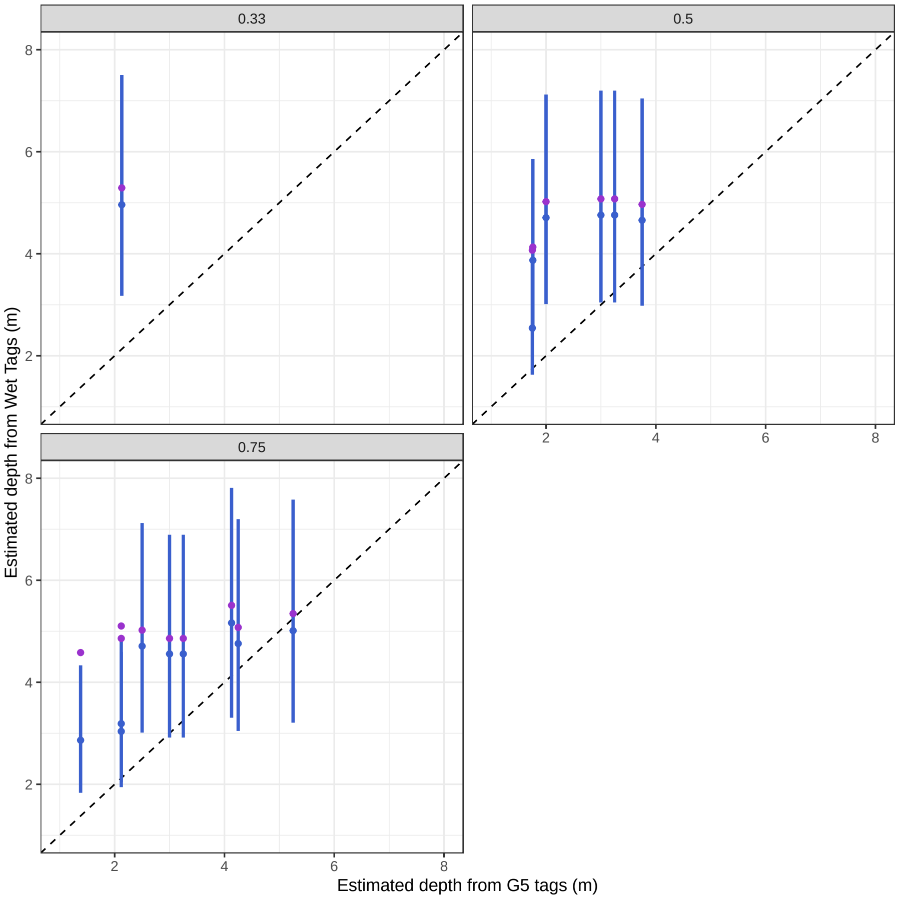

Figure A-6: Comparison of sensor depth estimates at the aerial extent of the streamer line, for different tag placements between weights.