Development of bottom longline underwater setting devices.

Draft Final Report

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Introduction

Estimated capture rates of at-risk seabirds by the small vessel demersal longline fleet are likely to be acceptable in the long term; both scientifically (e.g., Richard et al. 2017), and from a social 'licence to operate' perspective (e.g., RNZ, 2020), indicating the need for improvements in performance over and above that achievable using traditional mitigation measures.

The Agreement for the Conservation of Albatrosses and Petrels (ACAP) best practice guidance for bottom longline fishing includes use of the following three measures at all times: night setting, line weighting, and tori lines (ACAP, 2019). Setting lines for the 'bite time' over the change of light means many sets targeting snapper in the summer months do not meet the ACAP definition of best practice (Pierre et al., 2018). Additionally, the ACAP advice recognises that night setting may not be effective in bright moonlight, or for crepuscular/nocturnal foragers, and notes that mitigation measures need to be acceptable to fishers and not affect fish catch rates. Similarly, tori lines are often not fully effective to the prescribed aerial extent (pers. obs. DG).

The introduction of mitigation standards for demersal longliners (MPI, 2019) and subsequent changes to regulation (MPI 2021) require a hook depth of five metres at the end of the tori line aerial extent, and likely require substantial changes to gear configuration and setting speed for some of the fleet (Goad & Olsen, 2022).

Underwater setting has the potential to increase sink rates and reduce risk to birds. It is particularly relevant to meeting the latest regulations and mitigation standards, whilst maintaining flexibility of gear configuration for fishers. It also has the potential to open up daytime setting in high-risk times and places.

Efforts to reduce the availability of pelagic longline hooks to birds has focused on increasing the sink rate of the hook, either mechanically (Gilman et al., 2003, Ryan & Watkins 2002, Robertson & Ashworth 2010), or by adding weight (e.g. Robertson 2013), or protecting the barb of the hook (Oceansmart, 2011, Hookpod, 2020). These 'hook by hook' approaches are feasible for pelagic longlines where branch lines are longer than 10 m, baited as they are set, set relatively slowly (e.g. Robertson 2013, Goad et al., 2019), and the hook sinks, certainly initially, independently from the mainline (Robertson et al., 2010).

Conversely, the inshore manual baiting demersal longline fleet in New Zealand clip on pre-baited hooks with short branchlines (or snoods), typically 0.6 m length, to a stoppered mainline relatively quickly (Goad et al., 2010). Therefore, in order to set demersal longlines underwater, both the hook and the mainline have to be deployed at depth. This presents a different set of challenges, and a downward force must be applied to the mainline in order to achieve sufficient depth.

This report describes work undertaken developing two underwater setting devices. The first was initially conceived by Dave Kellian, and is described here as the 'underwater setter'. It is towed behind the vessel at depth and the longline passes under a guide. Previous work is described in Goad, 2011; Baker et al., 2013; 2016; and Goad et al., 2020. The second device was conceived by Nigel Hollands and uses a roller held under the surface by a pole fixed to the vessel, with the longline passing under the roller. It is described here as the 'line depressor' and previous work is described in Hollands et al., 2022.

Project Objectives

1. Developing a tension meter to measure and record line tension during longline sets.

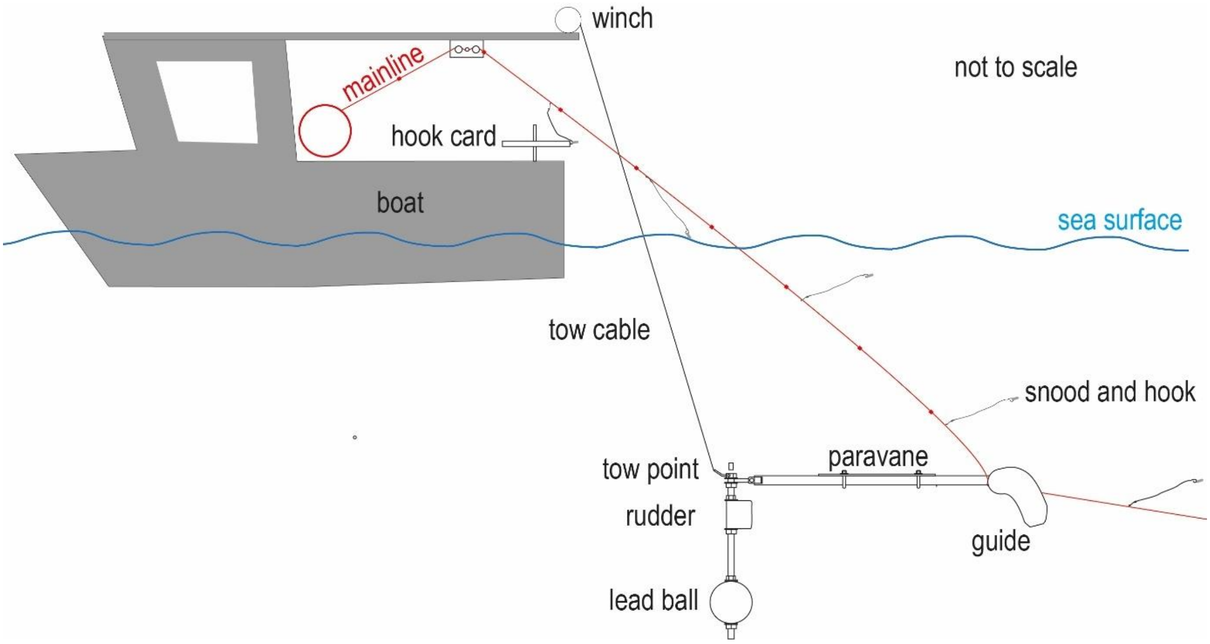
2. Develop and modify the underwater setter configuration to operate at low line tension.

3. Quantify and improve performance of the line depressor

Device descriptions

Underwater setter

A lead ball is towed behind the vessel at depth. Attached to the ball is an upside down 'U' shaped guide which is placed over the longline, forcing the longline down to the depth of the ball. In order to separate the tow cable from the longline, and to keep the device tracking in a straight line, the guide is attached behind the lead ball on an arm. A paravane holds the arm horizontal behind the tow point and the lead ball is attached below the tow point to provide roll stability. The setter is towed on a cable from one side of the vessel, and the longline enters from the other side with hooks passing beside the guide. (Figure 1). Dimensions of the towed unit are 400 mm wide by 1200 mm long by 610 mm deep.



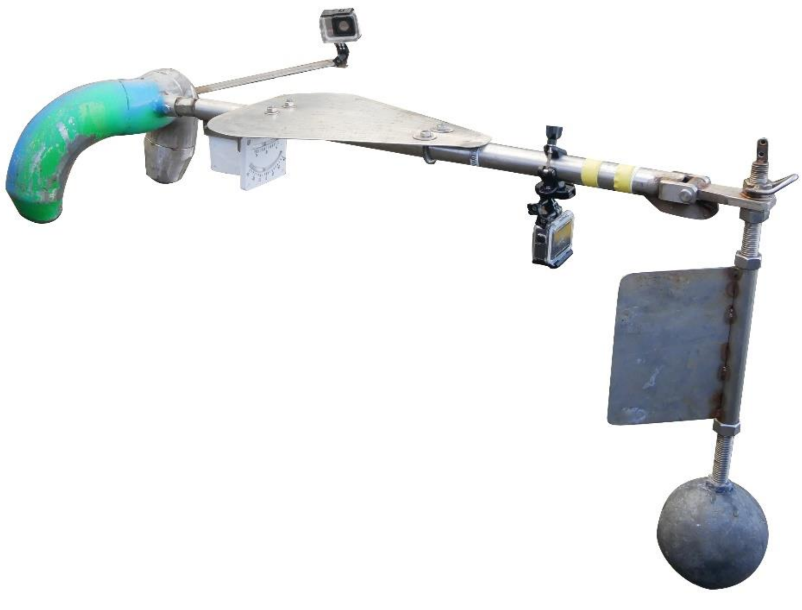


Figure 1. Schematic diagram and photograph showing the underwater setter.

Line depressor

A roller is held underwater by a pole attached to the stern of the vessel, and the longline passes under the roller. A housing shields the roller and eliminates catch points. The pole is mounted on the vessel directly above the setting station and is supported laterally by two stays (Figure 2). The longline passes straight underneath the roller. The pole is 6.8 m long and 50 mm in diameter. The roller housing unit is 650 mm long by 290 mm wide by 260 mm deep and the roller has a diameter of 50 mm.

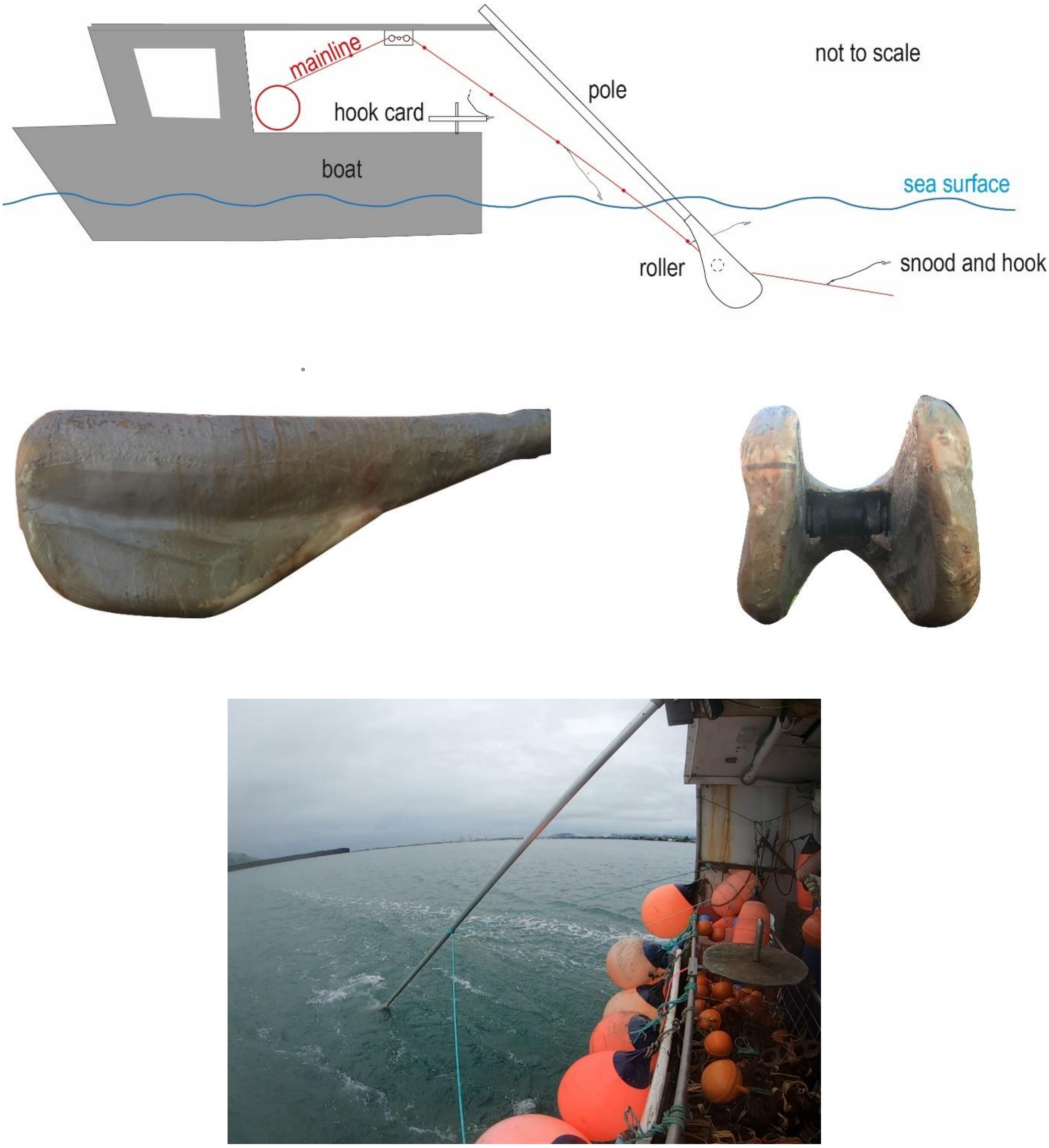


Figure 2. Detail of the line depressor (from top). Schematic diagram, side and rear view of the roller unit, and photograph showing depressor behind vessel.

Methods

Tension meter

After investigating off-the-shelf options for measuring line tension, none were deemed suitable. A purpose-built meter was designed incorporating three pulleys and a load cell. It was manufactured, trialled, and calibrated (Figure 3).

Figure 3. Photograph showing tension meter in place on the vessel, with screen in the background.

Device development – Underwater setter

To facilitate deployment and recovery a davit arm was designed and manufactured and installed on the vessel. This incorporated a high-speed electric winch and drum with a hand-held control at the setting station.

At sea testing was conducted during commercial fishing operations, deploying a portion of the line as a control, followed by a portion of the line through the underwater setter. Hooks were baited with pilchard pieces, which were salted for some trips. Line setup was consistent with droppers comprising of a 2.2 or 3.2 kg lead weight, a 3m rope and a 100 mm float every 60 m. Data were collected using a combination of methods.

Line tension was measured using the tension meter and automatically logged to a PC, throughout the set. Setter depth was measured using CEFAS G5 time depth recorders (TDRs) placed on the setter. Depth was also calculated using tow cable length and angle.

GoPro cameras were mounted on the setter to examine the passage of gear through the device. Two or three cameras were used, two to assess bait loss at the setter and one to assess the angle of the longline entering the setter. Cameras also recorded the roll and pitch of the setter using inclinometers attached within the field of view. Review of video footage was conducted at reduced speed and often rewound or re-viewed to check counts. Bait loss was classified into three categories: bait OK, bait damaged (mostly comprising of lost guts but occasionally torn pieces), and bait lost at setter.

Measurements on deck were taken of setting speed, treatment, and fish catch, usually every 30 hooks or as adjustments were made.

Iterative adjustments and modifications were made to the setter between trips, aiming to improve performance metrics, particularly bait loss. Individual trips are described in more detail in trip-by-trip progress reports (Appendix 1.)

Device development – Line depressor

At sea testing of the line depressor was conducted during dedicated trips. Sink rates of different line configurations deployed through the depressor were tested against a control of gear set normally. Sink rates were measured using CEFAS G5 TDRs placed midway between droppers consisting of a 3.5 kg steel weight, a 3.6 m rope and either a 100 or 150 mm diameter float. Gear configurations tested also included the use of small gillnet ('egg') floats, deployed midway between droppers. The passage of hooks through the depressor was examined using cardboard and pilchard baits

Line tension was measured in a similar manner to trips with the underwater setter. GoPro footage was taken from on deck and underwater using a hand-held pole.

Iterative adjustments and modifications were made to the depressor between trips, including modifying the guide shape and pole length. Individual trips are described in more detail in trip-by-trip progress reports (Appendix 2.)

Results

Securing sea time on vessels was challenging, due to several factors beyond the control of the authors. It was not practical to run trips close together as it took some time to review video footage and analyse data, and then design and complete modifications before trialling improvements.

Line tension meter

Calibration was conducted to relate load cell readings to line tension, by hanging a series of weights from the line and recording the load cell readings. The relationship was not linear, with higher line tensions producing proportionately lower load cell readings (Figure 4).

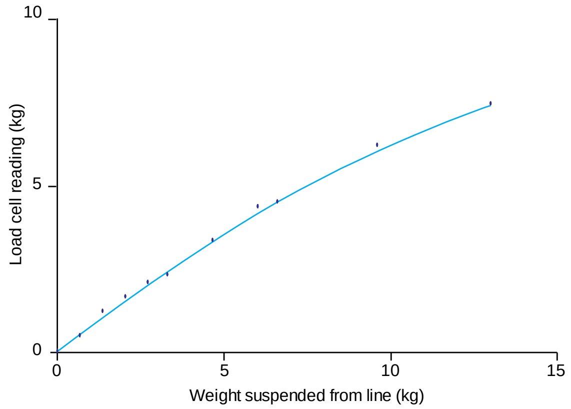


Figure 4. Relationship between line tension and tension meter load cell readings, including fitted line used to calculate line tension in table 1.

The tension meter worked well and was transferrable between vessels. Occasionally large tails on knots, particularly with thicker backbone, caught in the meter but this was rare and though it increased tension on the line momentarily it did not unduly hinder setting operations. Recording and controlling line tension in a repeatable manner was crucial to replicating settings, particularly for the underwater setter.

Underwater setter

Between all trips modifications were made to improve and measure setter performance. Inclinometers were added to measure pitch and roll. A lateral camera mount was added to better measure the vertical angle of the line entering the setter (Figure 5). The guide shape was modified to include a lip to retain the mainline when weights were added, and the whole guide was raked aft to smooth the passage of snoods.

Adjustments were made to the setter to control the attitude and position relative to the vessel. Depth was controlled by a combination of weight of the lead ball, tow cable length, line tension, and vessel speed. The angle of the rudder influenced the lateral separation between the setter and the setting point on the vessel, and in turn the horizontal angle of the line entering the setter. The height of the rudder influenced the roll angle of the setter. Increasing line tension increased the angle of attack of the paravane and the depth of the setter. Increasing line tension also reduced the vertical angle of the line entering the setter and reduced the wrap around the guide, providing a smoother passage of hooks.

Bait retention was influenced by bait type, contact with the guide, and the angle of the line entering the setter. Pilchard baits were softest and most susceptible to loss, so trials focussed on minimising pilchard loss rate. Modifications to the setter resulted in baits rarely contacting the guide. However, pulling baits rapidly downward into the setter often resulted in loss, especially at low line tension. Increasing line tension reduced loss, but only to an acceptable rate at undesirably high tension.

Following modifications, the underwater setter was capable of deploying the line at 7+ m depth. Fresh pilchard bait retention varied with line tension and speed but was in the order of 60% undamaged baits and a further 10% damaged at a speed of 4.5 – 5 knots and a line tension of around 5 kg (Appendix 1).

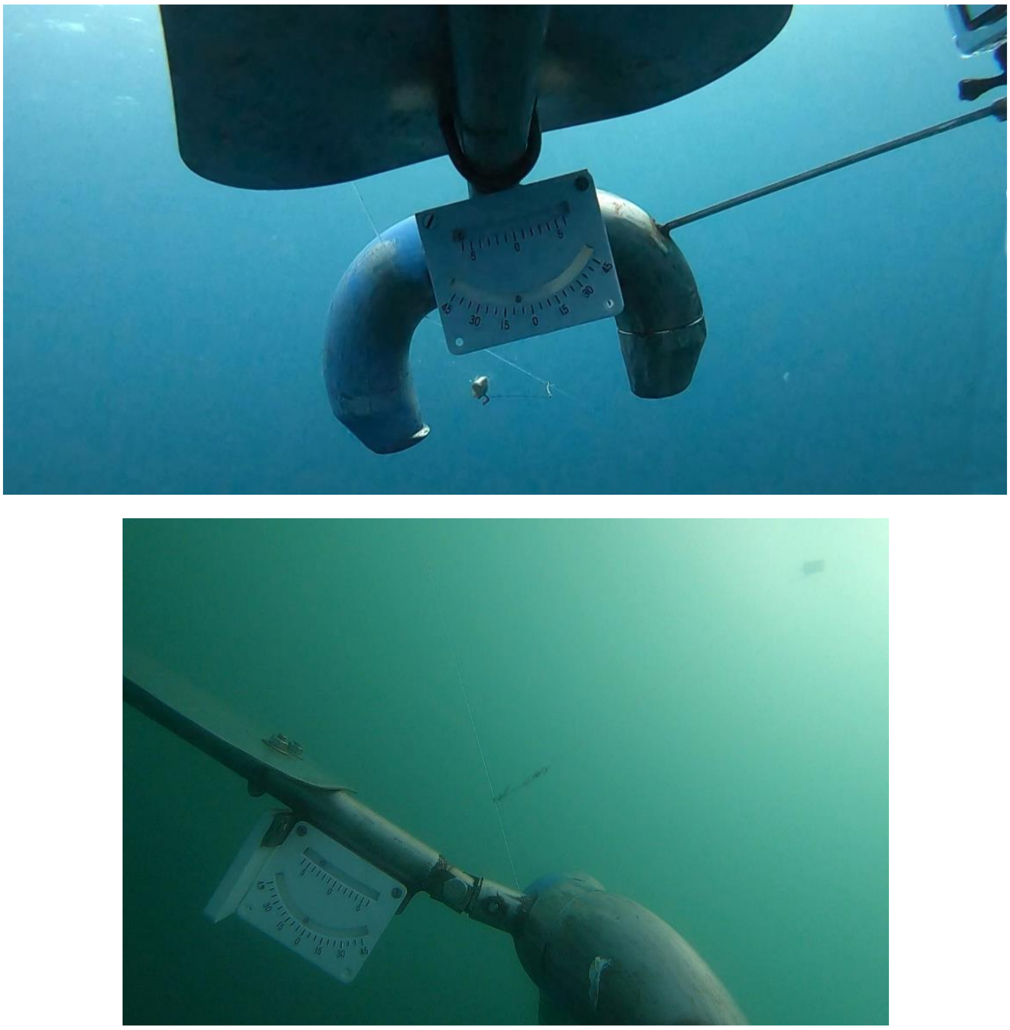


Figure 5. Stills from GoPro camera footage showing view looking aft (top) and view looking sideways (bottom)

Line depressor

Modifications to the depressor reduced catchups by altering the shape of the roller housing and adding a short strop between the float and the longline to allow the float to pass beside the housing. Extending the pole increased roller depth and hookless gear was successfully deployed a metre underwater. Load on the pole and stays increased with depth, but was manageable.

Sink profiles indicate that when operating at the surface with low line tension then increases in sink time to six metres are negligible. However, when operated a metre under the water, and with a line tension of 4.0-5.0 kg, then the depressor can decrease sink times to six metres and markedly increase hook depths in the first 15 seconds after deployment (Figure 6).

Bait retention was harder to asses due to aerated water obscuring video footage (Figure 7). Bait returns and fish counts following a single set with a short soak indicated that bait loss is probably occurring, but likely at lower rates than when using the underwater setter.

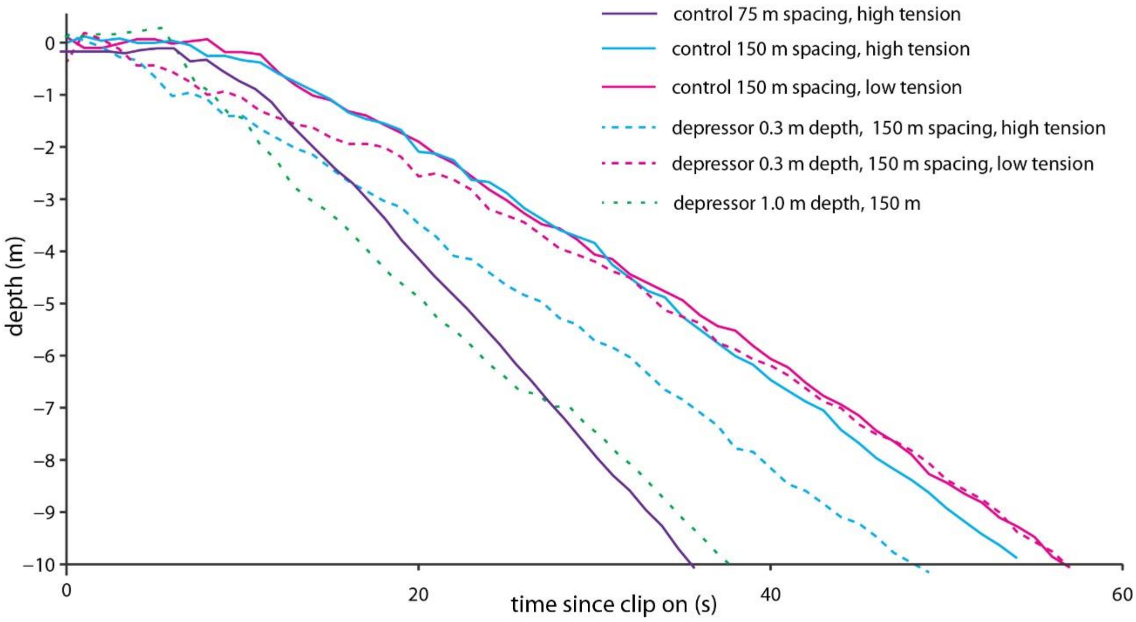


Figure 6. Composite plot of mean sink profiles showing gains in depth by deploying gear through the line depressor.

Figure 7. Still from GoPro camera mounted on a handheld pole, showing a dropper float passing beside the roller housing and limited visibility due to air bubbles.

Discussion

Underwater setter

Underwater setter refinements have resulted in a useable device, operating at depth with baits rarely contacting guide and a smooth passage of gear through the device.

Loss of fresh pilchard baits was unacceptably high, and whilst this may not affect catch rates at low fish densities, when catching a fish-a-hook for periods then bait retention in the high 90 precents is likely necessary to maintain catch rates. Given that pilchard baits were lost prior to entering the setter, as they were pulled rapidly downwards and forwards, they may not be a viable bait for deploying rapidly to depth.

Further trials should focus on teasing out the impact on catch rates of using tougher bait types and different mixes including salted pilchard, barracouta and squid, and comparing these to fish catches on a 50:50 squid and pilchard mix as typically used in the fishery, and/or straight pilchard baits.

Line depressor

Many of the lessons learnt developing the underwater setter were applicable to the line depressor and development in parallel has been beneficial.

The increase in depth of hooks provided by the depressor may open up a wider range of gear setups, including increased weight spacing, whilst remaining compliant with the regulations. Initial results show that bait loss may occur but can likely be improved via refinements of the guide design.

Having proven the concept of a guide attached directly to the vessel it seems prudent to progress with a second prototype that can be lowered over the longline and can pivot laterally to 'follow' the direction of the longline. Other potential improvements include having an interchangeable roller housing to facilitate trialling different options. Fabricating the roller housing from pipe would reduce bulk and resistance in the water.

Recommendations

Continue trials of the underwater setter, during commercial fishing operations, focussing on comparing the use of tougher baits through the setter and gear set with more typical 50:50 squid and pilchard mixes and/or straight pilchard.

Continue trials of the line depressor focussing on building a second prototype, setting baited hooks at depth, deploying intermediate floats, and making turns. Working camera mounts into the second prototype may provide for assessment of bait loss via video footage review.

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Zak Olsen and Dave Kellian for advice and support.

Appendix 1. Trip reports for work on the underwater setter.

Trip 1u

Aim

To test the tension meter during a longline set, and compare setter performance at different line tensions.

Methods

A total of 1200 hooks were deployed, all baited with pilchard pieces salted for several days. The first 420 hooks were deployed without the setter to record some baseline catch rate data. The setter was then deployed over the longline using progressively less line tension and more tow cable. Setter parameters were recorded in a similar manner to previous trips using a combination of measurements from on deck, video footage, two cameras, and time depth recorders (TDRs) mounted on the setter.

Results

It took three attempts to lower the setter onto the longline, as it was not stable until the paravane was lowered into the water. Following deployment, the longline stayed in the setter throughout the set. Floats and weights passed through the setter reasonably smoothly, occasionally with some hesitation and momentary increases in line tension. The setter operated at 9.2 m depth with 15 m of cable, at 12 m depth with 20 m of cable and at 14 m depth with 25 m of cable (Figure 1u).

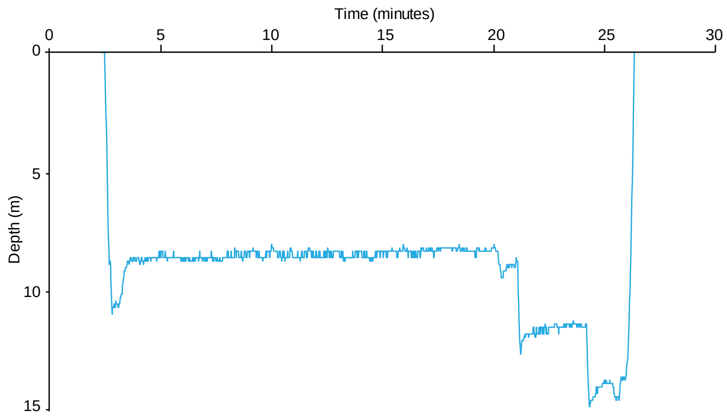

Figure 1u. Setter depth over time.

The line entered the setter from ahead, and at slightly higher angles with less tension. These settings produced reasonable bait retention and similar catch rates to gear set normally (Table 1u).

Line tension was controlled using the vessel's drum brake and was set slightly higher than normal when deploying the control gear. It was then increased when the setter was deployed, and adjusted downwards during the remainder of the set (Table 1u).

Discussion

Bait retention was high (Table 1u) at the high tensions however bait returns were also high. Fishing was not particularly consistent spatially, but a noticeable difference in bait return rates suggests tension was maybe set too high.

Table 1u. Setter performance indicators with different configurations

<table>
<tr><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th colspan="8">Per 100 hooks</th></tr>
<tr><th>Treatment</th><th>Clips</th><th>Speed (knots)</th><th>Depth (m)</th><th>Tension (kg)</th><th>Hooks set</th><th>Line angle (degrees)</th><th>SNA</th><th>GUR</th><th>KAH</th><th>TRE</th><th>baits returned</th><th>bait ok</th><th>bait lost</th><th>unclipped snoods</th></tr>
<tr><td>Control</td><td>B</td><td>5.2</td><td>-</td><td>3</td><td>420</td><td>-</td><td>8.8</td><td>1.7</td><td>0.2</td><td>0.0</td><td>11.7</td><td>-</td><td>-</td><td></td></tr>
<tr><td>Setter</td><td>JVI</td><td>4.5</td><td>9</td><td>11.4</td><td>90</td><td>45</td><td rowspan="2">8.6</td><td rowspan="2">0.7</td><td rowspan="2">0.0</td><td rowspan="2">0.0</td><td rowspan="2">8.1</td><td>84.4</td><td>15.6</td><td>21.1</td></tr>
<tr><td>Setter</td><td>B</td><td>4.5</td><td>9</td><td>11.4</td><td>330</td><td>43</td><td>89.7</td><td>10.3</td><td>0.0</td></tr>
<tr><td>Setter</td><td>B</td><td>4.6</td><td>9</td><td>8.3</td><td>90</td><td>50</td><td>10.0</td><td>2.2</td><td>0.0</td><td>0.0</td><td>31.1</td><td>96.7</td><td>3.3</td><td>1.1</td></tr>
<tr><td>Setter</td><td>B</td><td>4.6</td><td>9</td><td>7.5</td><td>90</td><td>57</td><td>11.1</td><td>0.0</td><td>0.0</td><td>1.1</td><td>32.2</td><td>96.7</td><td>3.3</td><td>1.1</td></tr>
<tr><td>Setter</td><td>B</td><td>4.3</td><td>12</td><td>9.2</td><td>120</td><td>60</td><td>9.2</td><td>0.0</td><td>0.0</td><td>0.0</td><td>30.8</td><td>97.5</td><td>2.5</td><td>0.0</td></tr>
<tr><td>Setter</td><td>B</td><td>4.3</td><td>14</td><td>8.9</td><td>60</td><td>65</td><td>8.3</td><td>0.0</td><td>0.0</td><td>0.0</td><td>no data</td><td>96.7</td><td>3.3</td><td>0.0</td></tr>
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Trip 2u

Aim

To test setter at lower line tensions than the previous trip, with minor modifications to improve data collection.

Modifications

Between trips camera mounts were modified to increase the field of view, and two inclinometers were attached to measure the pitch and roll of the setter.

Methods

A total of 1500 hooks were deployed, all baited with overnight-salted pilchard pieces. The first 690 hooks were deployed without the setter to record some baseline catch rate data. The setter was then deployed over the longline using progressively less line tension and more tow cable. Setter parameters were recorded in a similar manner to previous trips using a combination of measurements from on deck, video footage, two cameras and time depth recorders (TDRs) mounted on the setter.

Results

Line tension was recorded onto a PC and with TDR results allowed for a plot of depth and tension over time (Figure 2u).

Catch rates were poor for both normal gear and gear deployed through the setter (Table 3u). When further broken down to card by card (60 hook) sections they were also somewhat patchy. Reducing line tension resulted in the setter running at shallow depths, compared to the previous trip. During the set the longline broke at the drum, necessitating the retrieval and re-deployment of the setter. This was also necessary following a line tangle on the setter as a weight passed the 'wrong' side of the tow cable.

Bait return rates were high from the normal gear, but considerably lower for gear deployed through the setter.

Measuring pitch and roll of the setter was informative, and it appears that the sideways pressure exerted by the rudder overcomes the off-centre force exerted by the longline, resulting in a reasonably consistent six degrees roll to starboard. Pitch angle is slightly nose-down, showing that waterflow over the paravane is holding the guide downwards. This angle is expected to increase with increasing line tension.

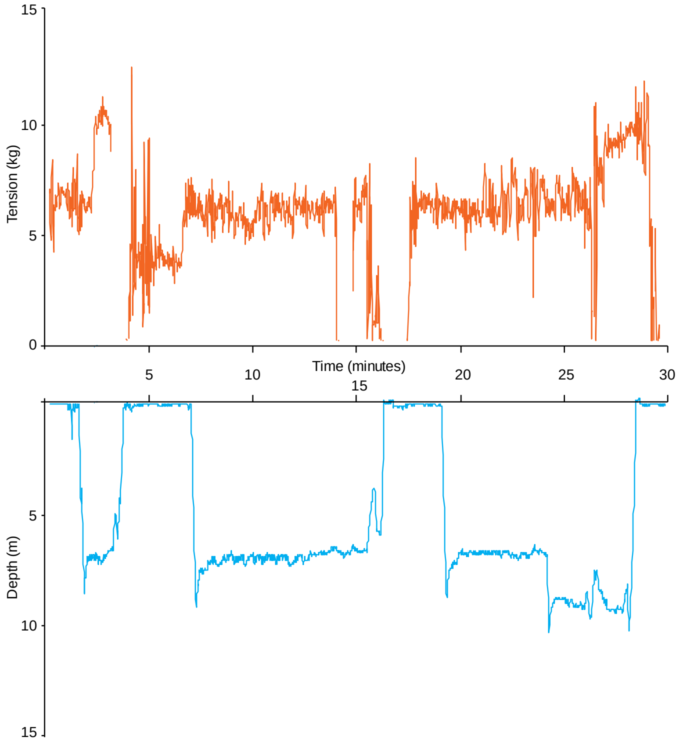

Figure 2u. Line tension and setter depth over time

Discussion

Low and patchy catches preclude firm conclusions of setter performance. However, bait damage and loss, and consequently low returns on the gear deployed through the setter, require improvement. The fact that bait damage and loss did not appear to impact catch rates may be attributable to variable fish abundance along the line. Additionally, the 'berley' effect of bait damage may attract fish, and low bait retention resulting in less baited hooks per metre of line may not have impacted baited hook encounter rate for mobile fish at low densities.

Further considerations for improvements include:

- Increasing the size of the vent hole to remove air from the legs faster
- Fixing the hinge – it does not appear to move much and this would help with handling
- Sweeping the guide back further
- Varying bait type and salting time

Table 2u. Setter performance metrics. † measured from the longitudinal axis of the setter, * starboard side down, ^ front down.

Treatment	Clips	Speed (knots)	Setter depth (m)	Tension (kg)	Hooks set	Line angle (degrees)†	roll angle (degrees)*	pitch angle (degrees)^
Control	B	4.7 - 5.0	-		690	-	-	-
Setter	JVI / B	4.7 - 5.0	7	10	54	40	6.00	5
Setter	JVI / B	4.7 - 5.0	7	6	589	55	6.00	3
Setter	B	4.7 - 5.0	9	9	113	70	6.00	5

Table 3u. Catches, fate of baits, and lost clips per 100 hooks for different treatments

	Per 100 hooks													
Treatment	SNA	GUR	KAH	TRE	EMA	KIN	EGR	baits returned	bait ok	bait damaged	bait lost prior	bait lost at setter	lost JVI clips	lost B clips
Control	3.0	1.4	1.4	0.1	0.1	0.1	0.0	52	-		-	-	-	-
Setter	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0	24	44	6	20	5.6	0.0
Setter	7.5	0.4	0.0	0.0	0.0	0.0	0.0	2	29	52	5	16	10.4	0.5
Setter	3.0	0.0	0.0	0.0	0.0	1.5	1.5	3	36	45	8	10	-	0.7

Trip 3u

Aim

To test setter at slightly higher line tension than the previous trip, and to aim for 10 m depth.

Modifications

Between trips the hinge was fixed so that the setter was one rigid piece, and the vent hole size was increased.

Methods

A normal set comprising 1860 hooks was deployed, with 560 hooks through the setter. Hooks were baited the previous day and were mostly pilchard pieces, with approximately 20 squid baits set through the setter. The first section of the line was set without the setter to record some baseline catch rate data. The setter was then deployed over the longline with setting speed and tow cable increased for the last part of the set. Setter parameters were recorded in a similar manner to previous trips using a combination of measurements from on deck, the line tension meter, video footage, two cameras and time depth recorders (TDRs) mounted on the setter.

Results

Deploying the setter was simpler with the hinge fixed, and with the air venting faster it was deployed on the line reasonably swiftly, and the gear was deployed through it with no catchups. One float/weight was felt momentarily catching on the setter and this was also apparent in the video footage, as the float was pulled forwards and under the setter. During hauling of the last section of the line set through the setter the line was tangled and broken, likely due to a shark bite off. Catch rates were reasonably consistent throughout the gear set normally and, subject to variation and low sample sizes, catch rates were maintained with gear deployed through the setter at 4 knots at 10 m depth (Table 4u, Figure 3u).

Faster speeds reduced the depth and the angle of the line entering the setter but bait loss rates were higher. Increasing tow cable length for the last section of line improved bait retention whilst maintaining similar depths to slower speeds (Tables 4u and 5u). Higher tension increased the pitch angle of the setter, resulting in the paravane exerting more force (Table 5u).

Catch rates on gear deployed through the setter were reasonably similar to those on the control section of the line, despite bait loss and damage as snoods passed around the setter. Most bait loss appeared to occur as baits were pulled swiftly down and forwards against the water flow, just prior to entering the setter. Snoods passed around the guide, with only occasional baits touching the guide.

Discussion

To further improve bait retention, it seems necessary to not only avoid baits hitting the setter but also limit the force exerted on them as they are pulled against the water flow into the setter. Options to achieve this include adjusting the angle of the guide, running the setter further from the centre of the boat so that baits enter at more of an angle, and continuing to trade off tension, depth, and setting speed to control the angle of the line entering the setter.

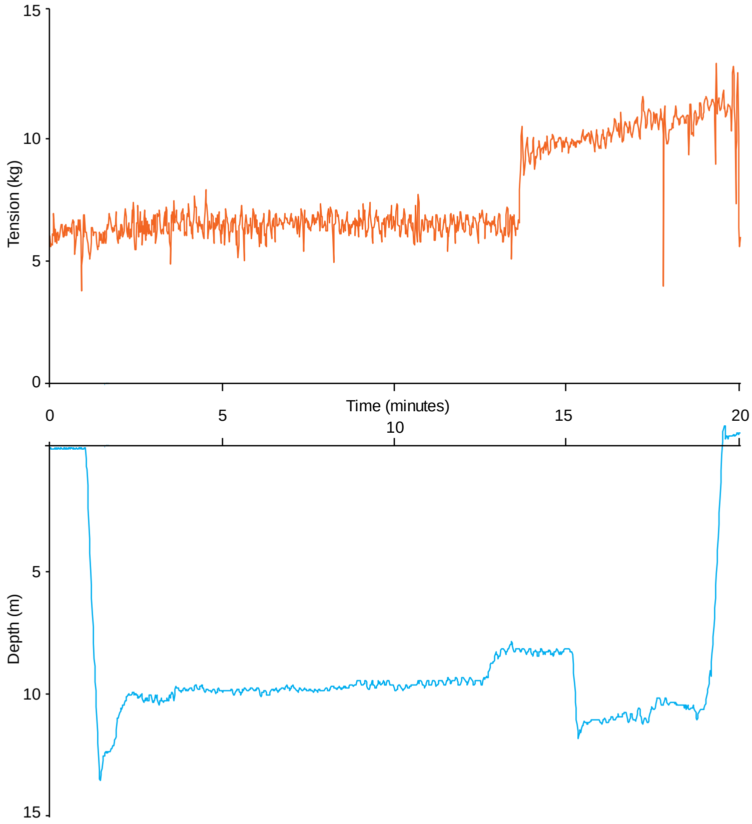

Figure 3u. Line tension and setter depth over time

Table 4u. Catches, fate of baits, and lost clips per 100 hooks for different treatments *This section of line was tangled and bitten off by a shark.

Treatment	Speed (knots)	Hooks	Per 100 hooks									
			SNA	KAH	TRE	KIN	GUR	JDO	bait ok	bait damaged	bait lost	lost snoods
Control	4.8	390	24.4	0.3	0.5	0.0	0.0	0.0	-	-	-	-
Control	4.8	360	26.1	1.1	0.6	0.3	0.0	0.0	-	-	-	-
Control	4.8	300	23.7	0.0	0.3	0.0	0.3	0.0	-	-	-	-
Control	4.8	270	20.4	0.0	0.0	0.0	0.0	0.4	-	-	-	-
Setter	4.0	120	35.8	0.8	0.0	0.0	0.0	0.0	61	13	24	7
Setter	4.0	300	19.0	2.3	1.0	0.0	0.0	0.0	64	15	20	1
Setter	4.8	60	16.7	3.3	0.0	0.0	0.0	0.0	47	23	30	0
Setter *	4.8	60	8.3	0.0	0.0	0.0	0.0	0.0	58	12	25	8

Table 5u. Setter performance metrics. † measured from the longitudinal axis of the setter,* starboard side down, ^ front down.

Treatment	Speed (knots)	Setter depth (m)	Tension (kg)	Line angle (degrees)†	Roll angle (degrees)*	Pitch angle (degrees)^
Control	4.8	-		-	-	-
Setter	4	9.5-10	5.5 - 6.5	58 - 75	3	6 - 7
Setter	4.8	8.0 - 8.5	8.5 - 9.5	53 - 60	3	7 - 8
Setter	4.8	10.5 - 11.5	9.5 - 10.0	57 - 67	3	8 - 9

Trip 4u

Aim

To test setter modifications at five metres depth, aiming to minimise bait loss

Modifications

A new rudder was fabricated, aiming to push the setter sideways more, and to increase lateral separation between the setting point and the setter. The guide was angled back further to smooth passage of baits.

Methods

Trials were conducted on Matakana Bank in 20 plus metres of water, with reasonably poor visibility. 240 hooks were set normally, then 240 hooks were set through the setter on 12 m of cable with guide swept back by 124 degrees, and then a further 240 hooks were set with the guide at an angle of 132 degrees. Previous deployments had a guide angle of 112 degrees. Line tension was set at approximately eight kilograms. The new rudder had a larger area and was set at 45 degrees.

Results

The setter operated at approximately four metres depth, with a roll angle greater than previous deployments, of around 15 degrees (Figure 4u, Table 6u). Increasing the angle of the legs resulted in hooks passing consistently beside the guide, without contacting the setter. The second deployment at a guide angle of 132 degrees from horizontal resulted in losing the line, indicating that this angle may be too large, at this line tension.

Bait loss occurred above the setter as baits were pulled swiftly downwards. Those labelled lost at the setter were within view of the camera and occurred as clips passed around the guide. Baits lost 'prior' to the setter were lost before the snood was in view of the camera. Snoods almost always passed around the guide, with only occasional baits touching the guide. Much lower rates of bait damage were recorded than in previous trips, though this could have been due to poorer visibility (Table 7u).

Discussion

Bait loss was higher than the previous trip, however this could be due to the faster setting speed than trip 3, and indeed loss rates were lower than trip 2, with a similar speed. The swept back guide did appear to reduce damage to baits. The new rudder increased separation between the setter and the longline, but did increase the roll angle considerably. This did not seem to negatively affect performance, and may have contributed to reduced bait damage. Operating with a roll angle results in the paravane pushing the setter away from the longline, which may further increase lateral separation between the setting point and the setter.

Further options for reducing bait loss include increasing tension, salting pilchard bait and trialling tougher baits such as squid and barracouta.

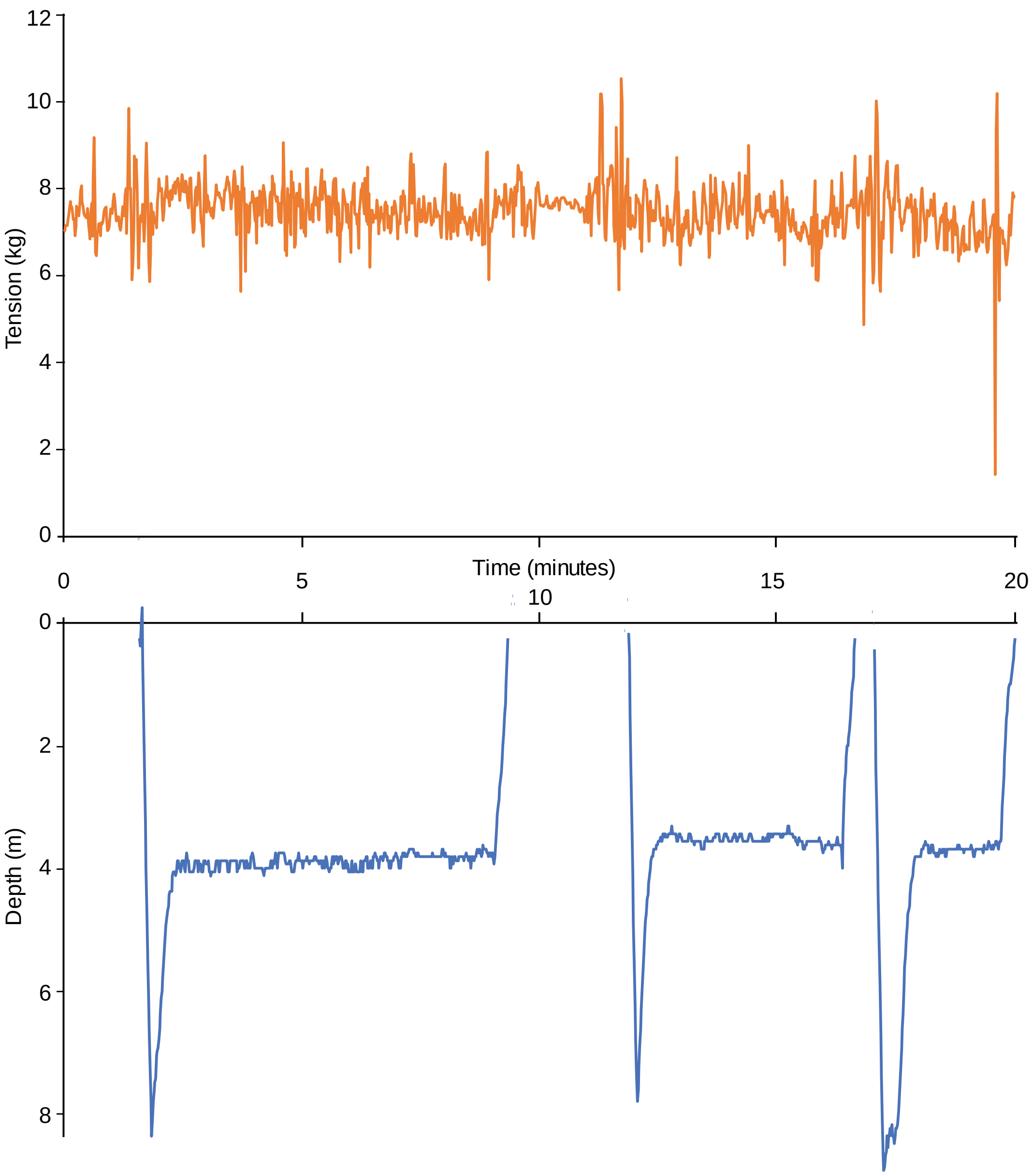

Figure 4u. Line tension and setter depth over time

Table 6u. Setter performance metrics. † measured from the longitudinal axis of the setter, * starboard side down, ^ front down.

Treatment	Speed (knots)	Setter depth (m)	Tension (kg)	Line angle (degrees)†	Pitch angle (degrees)^	Roll angle (degrees)*	leg rake angle (degrees)
Control	5.2	-		-	-	-	-
Setter	5-5.4	3.8 - 4	5.5 - 6.5	45	2.5 - 3.5	13 - 17	124
Setter	5.2	3.8 - 4	8.5 - 9.5	45	2.0 - 3.0	14 - 16	132

Table 7u. Catches, fate of baits, and lost clips per 100 hooks for different treatments *This section of line was lost from the setter and 45 hooks were set normally.

Treatment	Speed (knots)	Hooks	Per 100 hooks								
			SNA	KAH	GUR	baits returned	bait ok	bait damaged	bait lost at setter	bait lost prior	snoods unclipped
Control	5.2	120	13.3	1.7	0.8	0.0	-	-	-	-	-
Control	5.2	120	15.0	0.8	0.0	2.5	-	-	-	-	-
Setter	5	120	6.7	1.7	0.8	2.5	70.0	1.7	10.0	16.7	0.8
Setter	5.4	120	5.8	0.0	0.8	0.0	53.3	0.8	18.3	25.0	2.5
Setter	5.2	120	6.7	0.8	0.0	0.0	61.3	0.0	21.8	16.8	0.0
Setter*	5.2	75	10.8	0.8	0.0	0.0	61.3	0.0	22.7	16.0	0.0

Appendix 2. Trip reports for work on the line depressor.

Trip 1d

Aims

To trial latest modifications to the line depressor, and

To deploy time depth recorders (TDRs) to assess sink profiles with and without the setter.

Methods

The line depressor was attached to the top of the vessel's shelter deck and the roller unit was mounted at the end of an aluminium pole. The pole was braced using rope stays to either side of the vessel, at the stern.

The roller head (Figure 1d) had been modified to increase the depth of the guide below the roller.

Figure 1d. Close up of roller from astern (left), and side view of roller unit (right).

Due to reasonably large swells trials were conducted in Tauranga Harbour, in water depths of eight to fifteen metres. Three lines were set with the tide, which reduced in strength during the trials. Line setup comprised a 3-4 kg steel weight with a 100- or 150-mm diameter float on a three-metre rope at 75 m spacing, with triple egg floats trialled briefly midway between droppers during one line.

The depressor was deployed on the surface during the start of line a and then adjusted downwards with the roller at approximately 0.3 m depth during the second part of line one, and during lines two and three. Video footage was taken from on deck and from a pole held underwater in front of the depressor. Trials focussed on examining the passage of weights and floats past the depressor, and during lines two and three 50 hooks, baited with cardboard, were deployed through the depressor.

Time depth recorders were deployed on all three lines in groups with and without the depressor, to compare sink profiles.

Results

Operating close to the surface it was easy to observe the performance of the depressor from the vessel, and using Go Pro cameras mounted onboard. Despite poor visibility a Go Pro camera mounted on a handheld pole gave some indication of the path of floats and snoods below the surface (Figures 2d and 3d).

Figure 2d. Still taken from Go Pro camera mounted on the vessel showing depressor attachment and longline.

Figure 3d. Stills taken from underwater Go Pro footage showing three egg floats catching on the depressor (left) and a dropper float entering the depressor (right).

When deployed on the surface all dropper floats passed smoothly under the depressor. With the depressor at 0.5 m depth floats occasionally caught on the leading edge of the depressor (Figure 3d), which was close to vertical. These catch ups would build up tension on the line and either the float would pull through the depressor, or beside the depressor, sometimes pulling the line out of the depressor (Table 1d). Smaller dropper floats (100 mm vs 150 mm diameter) passed through the depressor more easily, and modifying the float attachment by adding a short rope strop to the float allowed the dropper floats to pass beside the depressor without pulling the line out. Egg floats arranged in a group of three on a short strop consistently caught up.

From underwater video footage hooks appear to have been pulled between the cheeks, with snoods almost in line with the longline.

Table 1d. Fate of line following deployment of floats through line depressor

set	depth	dropper floats			egg floats		
		ok	catch up	lost line	ok	catch up	lost line
1	0	6	0	0	-	-	-
1	0.5	5	2	2	-	-	-
2	0.5	9	1	2	-	-	-
3	0.5	13	2	3	0	3	1

Line sink profiles from TDRs were inconclusive as sink times to depth appeared to be driven by water depth rather than whether the depressor was in use, with shallower depths consistently producing slower sink times to depth (Figure 4d).

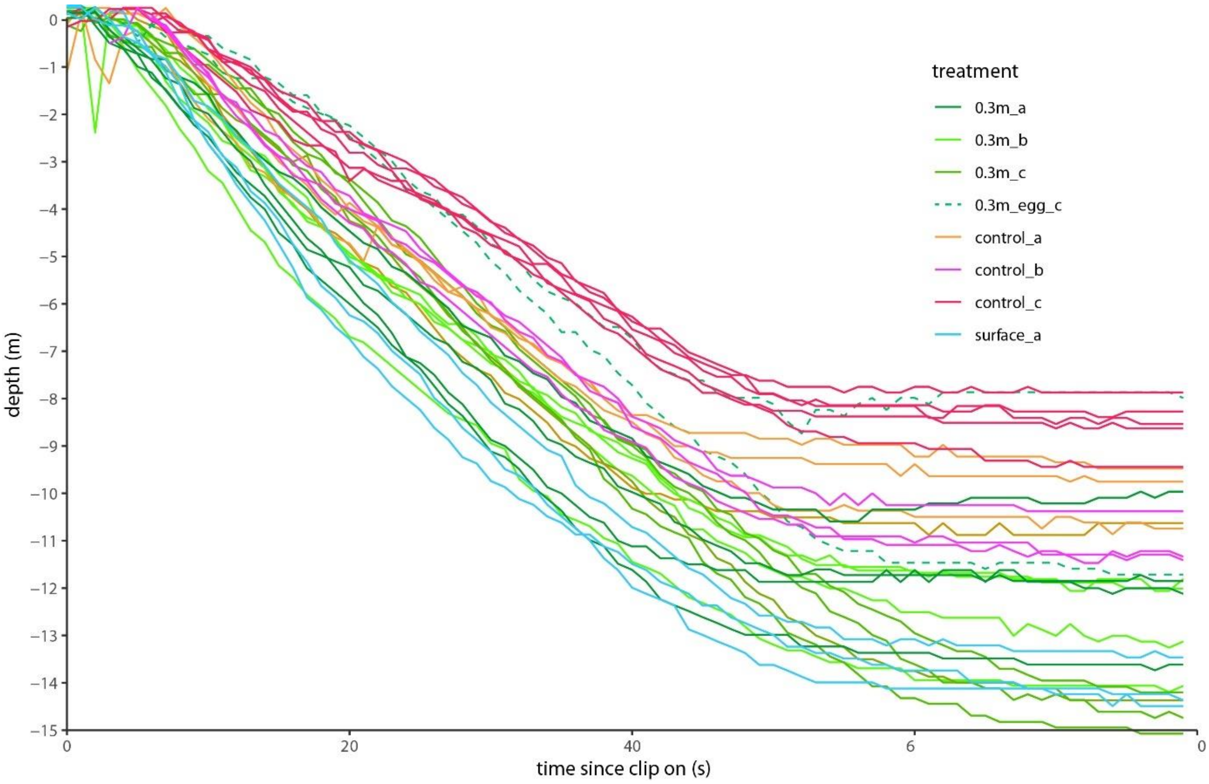

Figure 4d. Line sink profiles by treatment and line. Control deployments were without the depressor, 0.3 m deployments were through the depressor at 0.5 m depth, and surface deployments were through the depressor at the surface. Speed was reasonably consistent at 5.5 knots.

Discussion

Several areas for improvement were identified:

- Modifying dropper float attachment and deploying egg floats in strings rather than bunches could reduce the frequency of catchups and loss of the line from the setter.
- Adding depth to the cheeks of the depressor has likely improved line retention, but tapering these such that the leading-edge slopes downwards would smooth the passage of floats and reduce catchups.
- Running the setter further below the water would increase the load on the pole and supporting ropes such that these may have to be strengthened.
- Widening the cheeks of the depressor may allow for smoother passage of floats.
- Pivoting the depressor would facilitate turns during line setting.
- A paravane mounted behind the roller unit could be used to hold it at depth, with a trip release for recovery. This would reduce load on the pole and bracing ropes.
- The attachment point and pole construction is still in its first iteration. Mounting the depressor on a hydraulically powered articulating arm would be stronger, allowing greater depth and stability in the water.

Deploying TDRs in deeper water, with consistent depth, is necessary to identify whether the depressor improves sink profiles. TDR deployments should also be conducted at higher line tension.

Next steps

- Feedback results to engineer
- Consider and implement further modifications
- Trial revised version in deeper water and at varying line tensions

Trip 2d

Aims

To trial revised shape, and

To deploy time depth recorders (TDRs) to assess sink profiles with and without the setter, at high and low line tension.

Methods

The shape of the roller unit was modified to provide a smoother lead-in for floats (Figure 5d).

Figure 5d. Modified roller unit shape

A single line was set from 20 – 40 m depth, initially deploying control gear beside the depressor. Line setup comprised 100 mm floats with 3.5 kg steel weights on three metre ropes. The line was then set through the depressor, with the same dropper configuration but with the inclusion of a 150mm extension strop between the float and the longline to allow it to pass beside the roller unit without pulling the line out. During both control and dropper treatments TDRs were placed midway between weights. Weight spacings of 75 and 150 m at low and high line tension were tested for both treatments. The line depressor was run at approximately 0.25 m below the surface.

Results

Three out of 24 droppers caused the longline to drop out of the depressor, however deploying weights in line with the depressor after the first two appeared to reduce reoccurrence. When the line was lost it was relatively easy to slow the vessel down and push the longline back under the depressor with a gaff. No droppers caught up on the depressor. Inspection of the roller unit post deployment showed no signs of wear, indicating that the roller was turning and the line was exiting cleanly.

Three TDR records were discarded due to a misplaced weight and, on two occasions, when the line came out of the depressor post TDR deployment. Consequently, the control 75 m spacing treatment at low tension and the two 150 m spacing depressor treatments each had two valid TDR records, as opposed to three repeats for all other treatments.

Times to six metres TDR depth indicated that the depressor holds the potential to decrease sink times, particularly for the 150 m spacing at high tension (Table 2d).

Plots of mean TDR depth by treatment show that the increase in sink time is most apparent close to the vessel (Figure 6d).

Table 2d. Weight spacing, line tension and mean time to six metres for different treatments.

Weight spacing (m)	Tension (kg)		Mean time to 6 m (s)	
	Control	Depressor	Control	Depressor
150	3.7	2.7	38	39
150	5.3	5.3	40	32
75	3.6	2.9	26	24
75	4.5	4.4	26	23

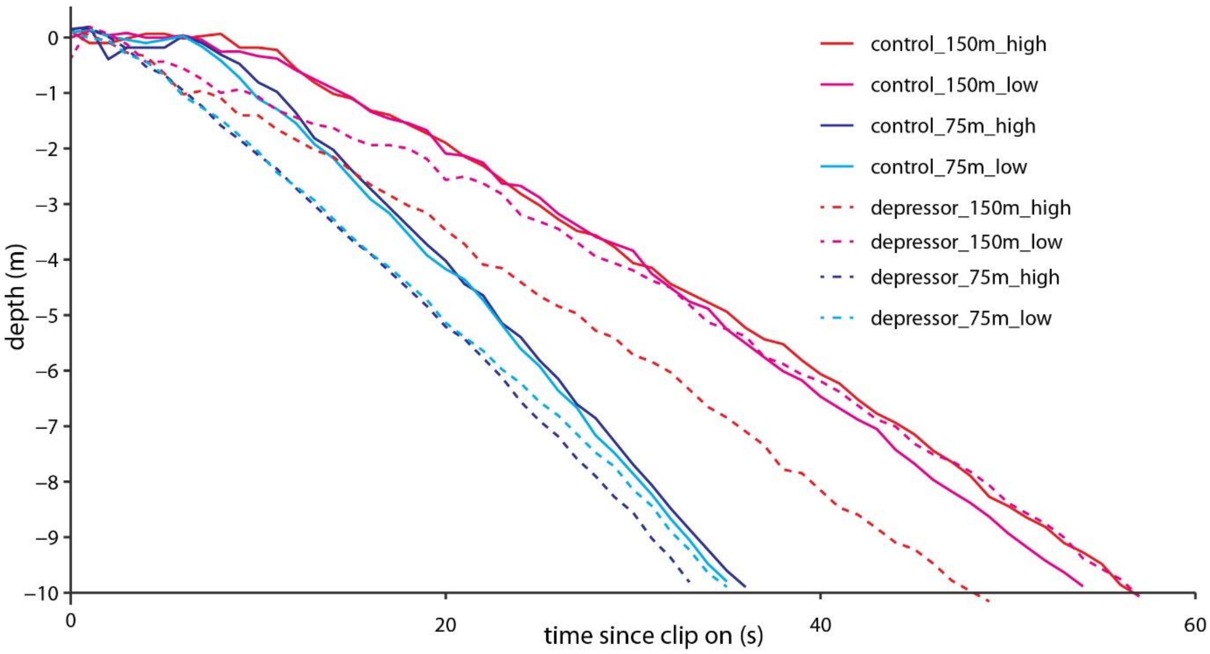

Figure 6d. Plot of time after deployment vs mean TDR depth, by treatment.

Discussion

The plots show the line sinking sooner through the depressor, especially close to the vessel. This increase is less apparent at greater distances astern but still translates to a three second advantage at 75 m spacing with high tension and an eight second advantage with 150 m spacing at high tension. Differences at low tension were less, and not noticeable at 150 m spacing. These results should be interpreted with caution as the gear through the depressor was set in deeper water. However, based on the shape of the sink profiles, times seem to be reasonably reliable.

In terms of the mitigation standards this results in a reduction of the required tori line length from 95 to 76 m for the 150 m weight spacing, and 62 to 54 m for the 75 m spacing. These figures are based on the setting speed of 4.6 knots but do indicate that, providing the skipper is happy to set at high line tension and reasonably slowly, then setting gear through the line depressor may allow for setups with one dropper a card (150 m spacing) to meet the mitigation standards.

Next steps

Assess bait loss / damage through the depressor

Trip 3d

Aims

To trial the depressor deeper

To examine bait loss through the depressor

To deploy time depth recorders (TDRs) to assess sink profiles of different depressor configurations

Methods

The pole was lengthened and a solid attachment for the stays was fabricated.

A single line was set, initially with the depressor 1.0 m below the surface, with droppers at 75 m and 150 m spacing, with a similar gear setup to the previous trip. The depressor was then raised to 0.3 m depth and 100 hooks baited with pilchard were deployed with 75 m weight spacing. A further 100 baited hooks were set in a control section, without the depressor and with 75 m weight spacing. The line was hauled immediately from the last end set and soak times ranged from 20 minutes for the first of the control hooks hauled to fifty minutes for the last of the hooks set through the depressor.

TDRs were attached midway between weights with four repeats at each treatment. All setting was conducted at four knots and with 4.4 kg line tension.

Results

The depressor performed well at 1.0 m depth, though load on the pole and stays increased relative to 0.3 m depth, and the pole did bend slightly. Droppers all passed through the depressor with no catchups, at both depths.

Several knots caught on the line tension meter, building up tension on the line and at times the vessel speed was reduced to release these catchups.

Mean TDR depth by treatment over time was calculated, dropping two TDR records close to catchups. Sink profiles and times to 6.0 m TDR depth indicate that the depressor is decreasing sink time to depth (Figure 7d, Table 3d).

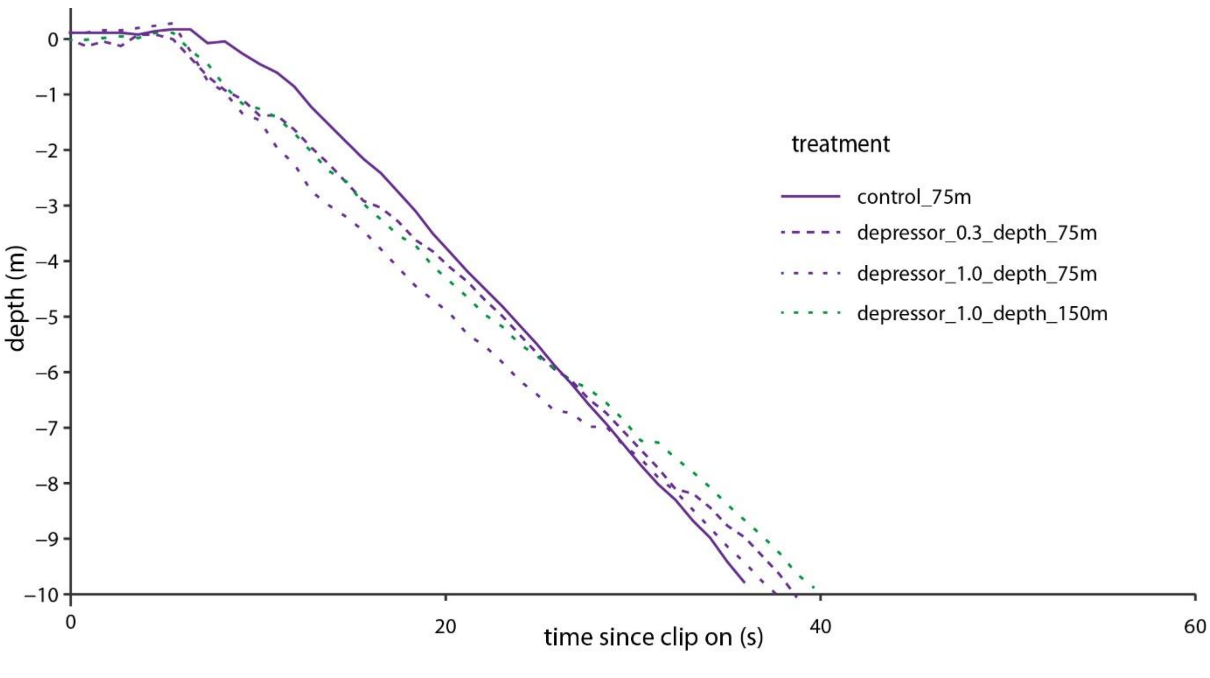

Figure 7d. Plot of time after deployment vs mean TDR depth, by treatment.

Table 3d. Time to 6m depth for different treatments. All gear was set at 4.5 knots and a line tension of 4.4 – 4.8 kg.

Treatment	Mean time to 6 m depth (s)
Control 75 m weight spacing	22
Depressor 0.3 m depth 75 m weight spacing	21
Depressor 1.0 m depth 75 m weight spacing	21
Depressor 1.0 m depth 150 m weight spacing	25

Setting hooks through the depressor was successful, though bait retention and catch was less on the depressor section (Table 4d). Two hooks were embedded in the guide, through a relatively thin glass fibre layup, and the snood snapped, allowing the set to continue.

Table 4d. Bait returns and fish catch for gear deployed through the depressor at 0.3 m depth and without using the depressor (control). Gear was deployed at 4.5 knots, a line tension of 4.4 – 4.8 kg and with 75 m dropper spacing.

Treatment	Bait returned	Empty hook	Fish caught	Snapped snood
Control	37	34	26	2
Depressor	37	41	16	4

Discussion

Sink profiles are promising, indicating that at 1.0 m depth and with higher-than-normal line tension the depressor is reducing hook depth close to the vessel and is capable of sinking gear with 150 m weight spacing in similar times to control gear set at 75 m spacing.

Higher bait loss would be expected for the depressor gear, as it had a longer soak time, however fish catch was also less than the control gear indicating that some loss may be occurring.