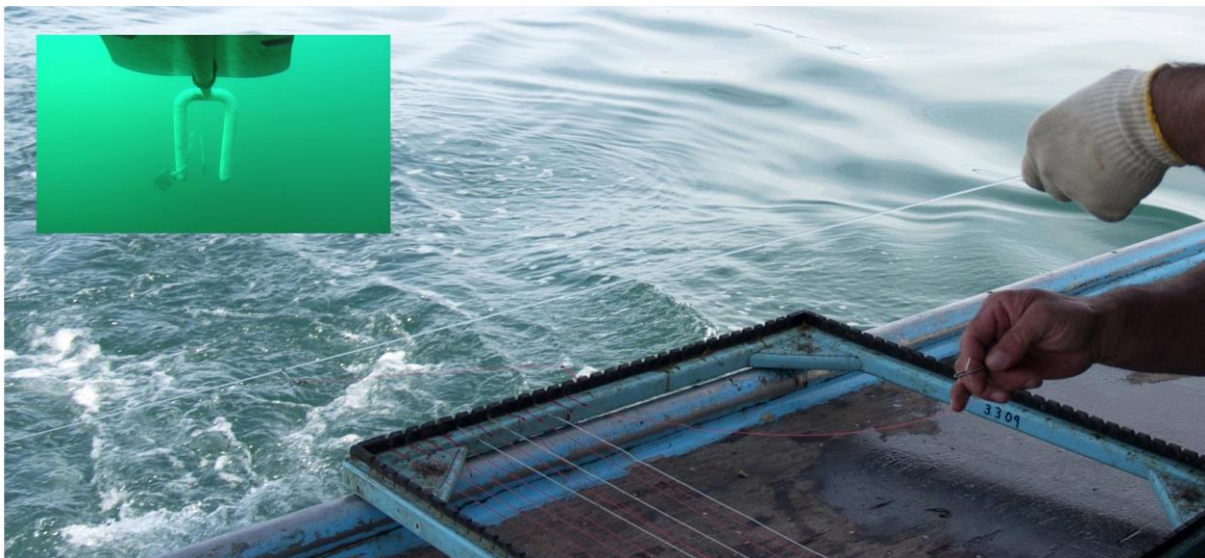


Kellian Line Setter Sea Trials Refinement of design and subsequent developments



**Final Report prepared for
Department of Conservation**

Contract 4529

G. Barry Baker, Dave Goad, Brian Kiddie and Rowan Frost

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1. Introduction

In 2011 quantitative seabird risk assessment work (Richard et al 2011) highlighted the high degree of potential risk that small vessel (inshore) bottom longline fisheries in New Zealand posed to a number of protected species, including the black petrel *Procellaria parkinsoni* and flesh-footed shearwater *Puffinus carneipes*. Although a suite of mitigation measures was mandatory in these fisheries, including the use of streamer lines, line weighting, night setting of longlines and restrictions on offal discharge during setting and hauling, their use is still not universal and bycatch of protected seabirds still remained a concern (Richard et al 2011). In ongoing experimental work to find solutions Goad et al (2011) and Pierre et al (2013) investigated the efficacy of operational practices in use in these fisheries for reducing seabird bycatch risk, reported on the influence of weighting regimes and float placement on sink rates of hooks, as well as describing some initial sea trials to test and develop a novel mitigation device, the Kellian line setter.

The Kellian Line Setter is an underwater setting device intended for demersal longline fisheries and developed by Dave Kellian, a fisherman from Leigh, New Zealand. The initial concept involved running the mainline under a nylon roller towed behind the vessel at depth. The line then ran over second roller, behind and below the first one, to stop weights pulling the backbone off the bottom of the first roller. Snoods, floats and weights pass beside the rollers, rather than over them (Goad 2011; Figure 1). A lead ball on a wire cable held the device at depth and allowed for deployment and recovery with a small winch. Attached to the lead ball a steel tube held the rollers behind the cable and a paravane on the steel tube assisted in maintaining stability during towing. Once deployed, setting depth could be adjusted by increasing or decreasing the cable length.

The initial prototype had been developed through a series of at-sea trials which were conducted during 2011. While these trials had been encouraging, the issue of fouling on the rollers was identified as needing resolution before further testing should be considered (Goad 2011). In 2012 we refined the initial prototype at the Australian Maritime College (AMC), using the engineering expertise of staff at the Circulating Water Channel (flume tank) facility of the College. This permitted critical examination of the hydrodynamic characteristics of the device, and re-design to eliminate operational impediments (line fouling) that were inhibiting proof of concept and the potential for uptake of the device by industry.

The new prototype (KLS 2 – Figure 1) consisted of a stainless steel cowling and funnel arrangement that incorporated two rollers, and which was towed behind a vessel at depth. The mainline was fed through the cowling, under the first roller and over second roller to stop weights pulling the backbone off the bottom of the first roller. Snoods, floats and weights passed beside the rollers, rather than over them (Baker and Frost, 2013). The hydrodynamic attributes and functionality of the modified prototype were assessed in the controlled environment of a flume tank but further testing and evaluation at sea was required under normal fishing conditions.

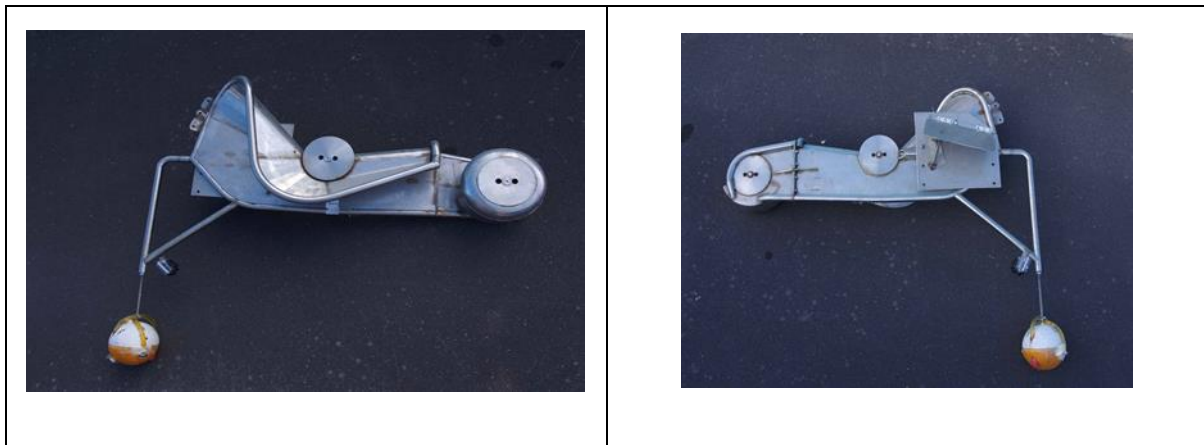


Figure 1: Kellian Line Setter Prototype 2.

In December 2013 Latitude 42 Environmental Consultants was awarded Contract 4529 to conduct sea trials of the Kellian Line Setter 2. The overall objective of this project was to test the at-sea feasibility, and to the extent possible, the effectiveness, of reducing the availability of hooks to seabirds by using the improved Kellian line setter, in inshore bottom longline fisheries.

In early 2014 we conducted initial performance testing of the KLS 2, near Tauranga, New Zealand (Baker et al. 2014). These trials showed that the line setter sat reasonably straight at low speeds (< 2 knots), pulling slightly to starboard, but with a longer tow rope and at higher speeds it ran progressively further off to starboard and at a shallower angle, before breaking the surface at about 4 knots. The KLS 2 also appeared to roll over at speed, such that the ball was further out to starboard than the top. The line setter was systematically modified in an iterative way over a series of sea trips to improve performance (Figure 2). Changes included adding an adjustable paravane beside the funnel, increasing the weight of the ball, increasing the length of the stud above the ball, moving the towing point, and adding a second paravane above the ball to improve stability (Figure 3; Baker et al. 2014). While performance was improved and some gear was set through the line setter, we recommended further development work and additional modifications to the device that would be best achieved through performance assessment under controlled conditions in the flume tank in Australia (Baker et al. 2014). Proposed modifications for consideration included:

- Potentially combining or simplifying the design of the two paravanes used in the iterative approach in the initial testing at sea trials to improve stability of the device. The paravanes were added during the initial performance testing to provide the necessary forces to hold the setter at depth at setting speeds.
- Slight refinement of the funnel shape to prevent the mainline rubbing on the funnel's leading edge and to guide the traces around the outside of the funnel.
- Development of a guide to send weights around the side of the rear roller so that weights on 'dropper' ropes can be deployed. Modifying the rear roller cheek could also help the passage of weights through the setter.



Port side

Starboard side

Figure 2: Kellian Line Setter Prototype 2 with modifications used to improve performance during initial performance testing at sea (Baker et al. 2014).

It was our intention to confirm in the flume tank that effective performance of the KLS 2 could be achieved at sea behind a vessel at speeds of 5 - 6 knots, before returning the device for further testing at sea in New Zealand. In this report we describe our work to address this aim, as well as reporting on the development and trialling of further prototypes that may allow bottom longline gear to be efficiently deployed underwater.

2. Progress

Kellian Line Setter 2

The KLS 2 was shipped to Australia and was trialled in the flume tank in December, 2014, following modifications made during the sea trials. Despite adjusting both paravanes through a wide range of settings and experimenting with the cable attachment position, we were unable to produce the necessary forces to replicate the extreme results (i.e. strong movement to starboard and surfacing) seen in the trials at sea. Although the device tracked slightly to starboard it did not do so strongly, and it maintained towing depth. We concluded that this was because we were unable to replicate the conditions encountered at sea in the flume tank (notably speed of water flow, the forces exerted by the longline, and the flow characteristics behind boat) to cause the KLS 2 to misbehave. It was therefore impossible to tune the device as expected and no further modifications were made. Construction of a scaled model may have permitted this but would have exceeded budget and time restrictions.

We reviewed the KLS 2 design and discussed ways of making improvements. We considered the asymmetrical design of the device, originally considered necessary to minimise gear-fouling issues during setting, was likely to continue to generate stability issues under differing sea conditions. We

therefore took the opportunity to test simple and more symmetrical designs while we had the flume tank available. We constructed a simple device using a bent rod and weight (Figure 3), and noted that a more symmetrical device could provide a suitable guide for fishing gear and was likely to permit gear setting at depth while tracking truly behind a vessel. Preliminary trials of this simple prototype provided promising results, and led to two new designs, which we have called the KLS 3 and KLS 4 (as modified).

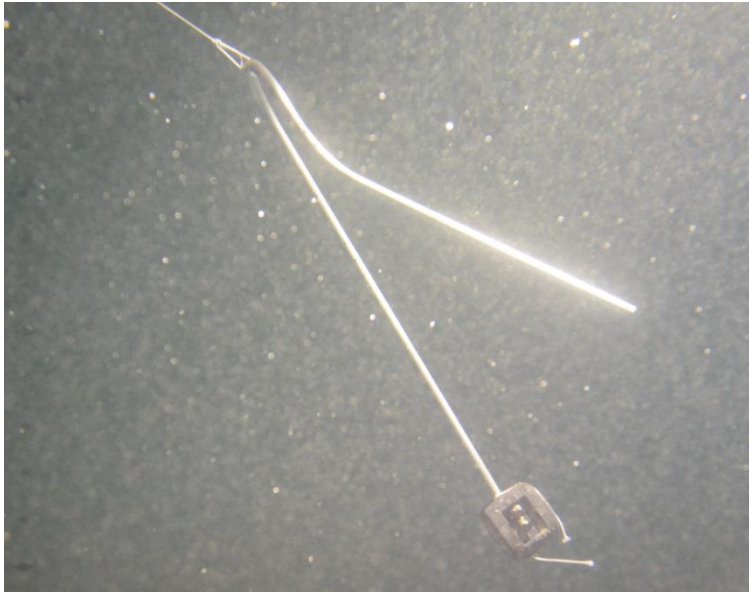


Figure 3. Bent rod and weight trialed in flume tank. This simple device formed the basis for the design of the KLS 4.

Kellian Line Setter 3 (KLS 3)

The KLS 3 is a refined version of the KLS 2, symmetrical in design with a single roller and simple cowling to guide weights, hooks and floats under the roller (Figure 4). There are two paravanes shown on the unit, with the potential for positioning a dorsal fin to improve tracking if required.

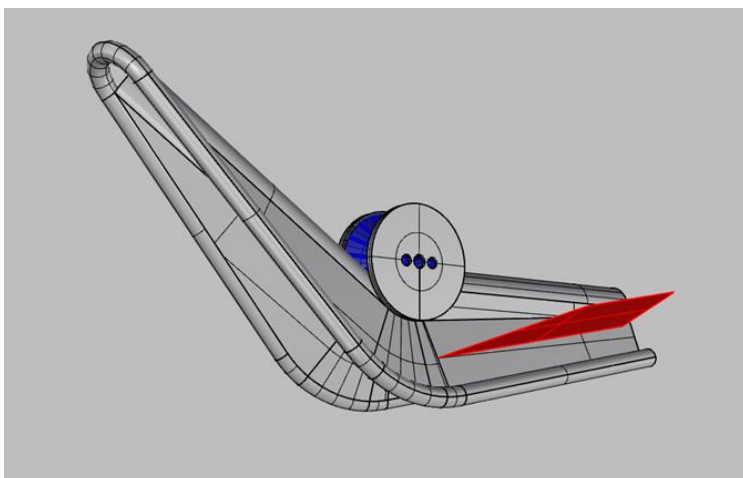


Figure 4: KLS 3 concept drawing.

Key features of the design are:

1. **Tow point.** The device would be towed from the fore most point on the setter, although we gave consideration to the tow point at the roller. This was rejected as the setter would have potentially been unstable in pitch and roll. By moving the attachment point as far forward the unit should track straighter and be more stable. Another advantage of a forward tow point is that the hydrodynamic forces on the funnel will act to raise the tail of the setter, which will increase the angle of attack of the paravanes, and hence increase the force keeping the setter level in pitch.
2. **Paravanes.** The paravanes will have around 15 degrees of adjustment up and down in their current configuration.
3. **Weight.** By using stainless steel tube of 31.8mm dia. in the lower half of the setter, 14kg of lead can be located internally in the stainless tube. This has the advantage of providing both lower drag (the lead ball contributed around 10-20% of the drag on the KLS 2), be less susceptible to snagging issues, and easier to handle. However, it may reduce the vertical stability, and the design assumes we can get extra stability out of the paravanes. This assumption would need to be tested through model construction and flume-tank testing.
4. **Construction.** This has been vastly simplified when compared with the KLS 2. There are only 2 pieces of stainless steel that need multiple bends, with the remainder constructed from flat plate combined with standard tube sizes. This should ensure the device is considerably cheaper and quicker to construct than for the KLS 2. Plate thickness of 1.6mm will make bending and fabrication easier on lighter equipment.

This device was not constructed but remains an option for future work. We would initially recommend the use of 3D printing to construct a model for testing in the flume tank, prior to proceeding further with this option.

Kellian Line Setter 4 (KLS 4)

This design removed the pulleys, and attempted to minimise drag and simplify the design to the greatest extent possible. It aims to set the longline under a weighted U shaped guide, with swept-back legs to smooth the passage of snoods and weights and to help with tracking. The design was driven from the simple design trialled in the flume tank (Figure 3). A preliminary KLS 4 design is shown in Figure 4. This device was constructed in New Zealand from stainless steel tube of 50 mm diameter, and filled with lead shot to give a total weight of 20kg. It has been field tested and subsequently modified, as necessary, following 12 days of sea-time. Reports on these trips and subsequent results are provided below.

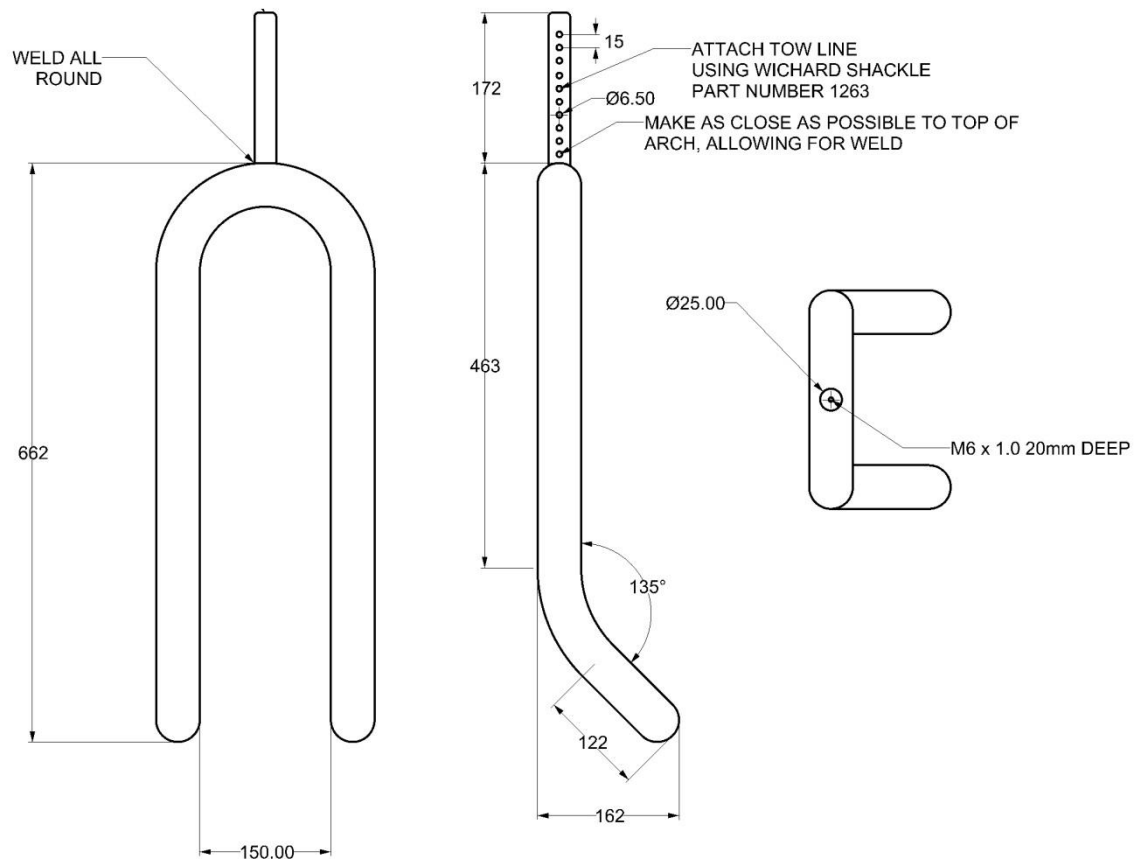


Figure 5: Schematic drawing of the KLS 4 preliminary design.

Trips 1 - 4

The KLS 4 was lowered into the water and as it went under the surface it flipped with 180 degrees of yaw. This was repeated several times with a similar result. When lowered with 5m of cable below the surface the setter sat back behind the vessel at a comfortable angle, indicating that the weight was sufficient to overcome the drag forces and sink it close to the boat.

To solve the flipping problem the bend was cut off the legs (Version KLS 4.1) resulting in a reduction in weight to 15kg (Figure 6).

When lowered into the water the device remained straight behind the boat and seemed stable in the water without the longline deployed. However with the longline in the starboard side of the setter the force exerted by the line caused the setter to twist, and wander in the water, with a yaw angle of 45 to 90 degrees clockwise, and the legs of the U swept back with a pitch of around 30 degrees.

Several hooks were put through the setter indicating that the 50 mm diameter tube was sufficient to guide the longline and gear, providing its position in the water could be controlled. The longline was entering the setter very close to the towline attachment point and this resulted in several foul-ups.

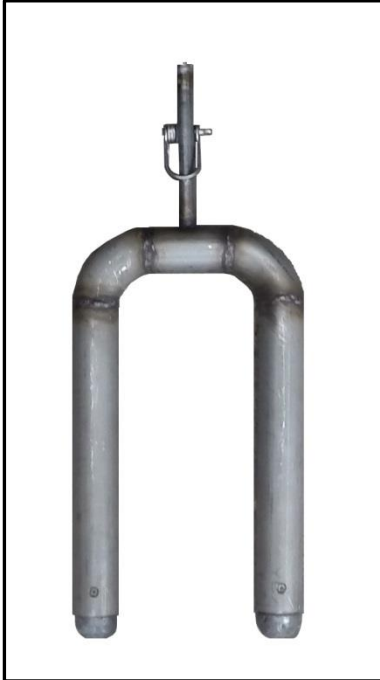


Figure 6. Photograph of version KLS 4.1

In an attempt to counter the force exerted by the longline the tow point was moved off centre, in line with one of the legs (version KLS 4.2). This however was not stable and caused similar results to the previous trip but with the longline entering opposite side of the 'U' to the tow cable, with a yaw angle of around 60 to 90 degrees (Figure7).

In order to tow the setter without yawing a version KLS 4.3 was conceived (Figure 8), using similar principles to version 1. This was trialed during a further three trips.

Trips 5-7

This configuration successfully held the setter stable in the water such that there was no significant roll pitch or yaw with the longline setting through the U. The setter was stable at 5m depth with 10m of cable between the sea surface and the setter. This equated to a measured tow cable downward angle of 29 degrees from horizontal at the back of the boat, at 5 knots. Increasing the cable length to 15 m lowered the setter to 7.5m depth. The setter didn't tow exactly straight behind the boat and was roughly 2 degrees to starboard.

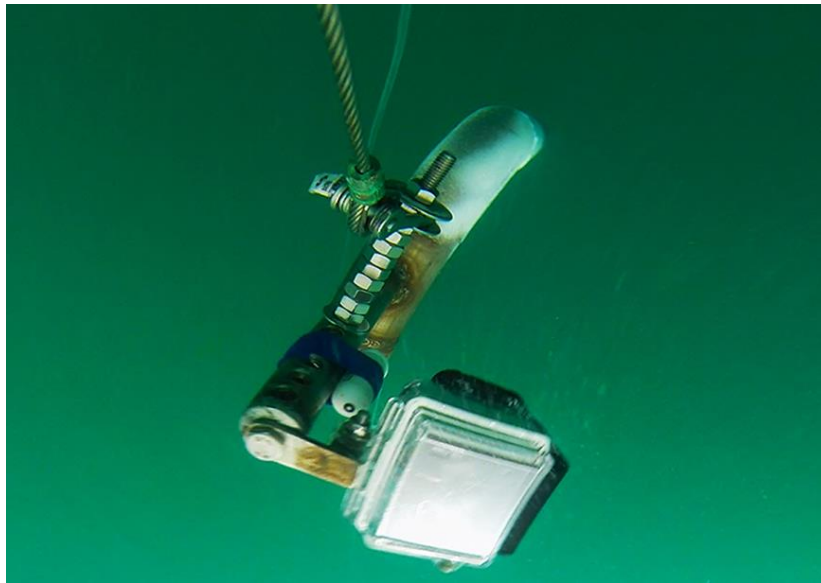


Figure 7. Version KLS 4.2. Photograph from tow cable mounted camera showing offset tow point and longline passing through setter.

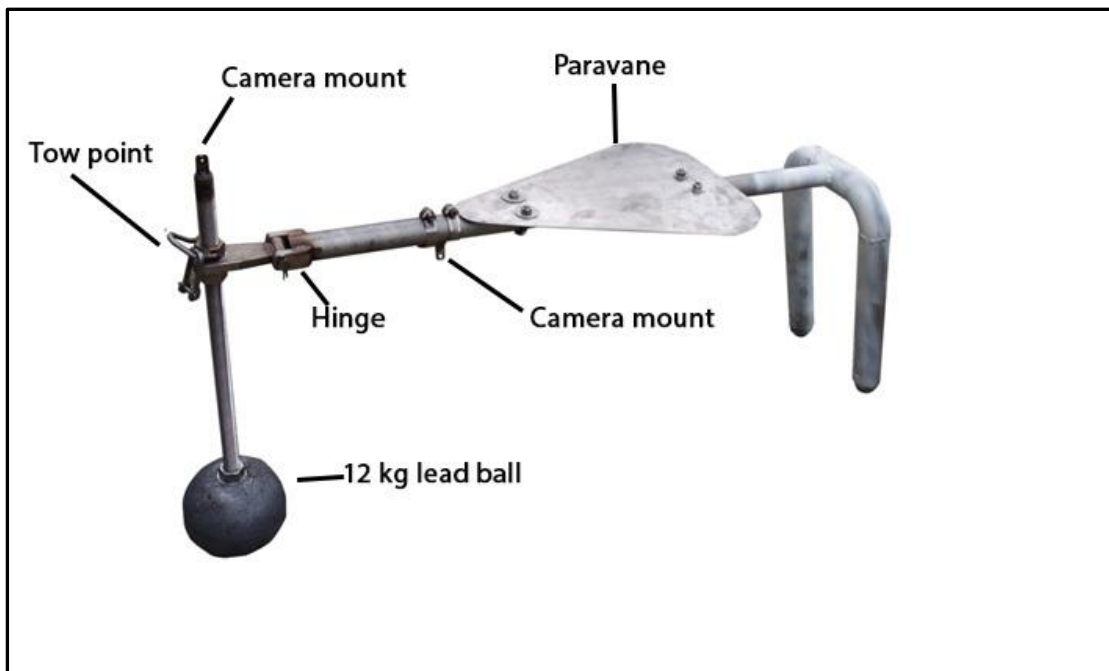


Figure 8. Version KLS 4.3

During Trip 6 180 hooks were set at depth with one snood lost. Several weights and floats passed through the U, although these did catch momentarily until enough tension built up in the line to pull them through.

In order to compare the sink rate profile of gear set through the line setter to that of normal gear Starr-Oddi DST centi time depth recorders (TDRs) were clipped onto the longline, in the manufacturer-supplied housing. To estimate the variability in sink rates of gear set normally, TDRs were attached beside weights and midway between weights equally across all normal gear configurations employed. On the line set using the underwater setter TDRs were attached in two groups, one when operating at 5m depth and the second at 7.5m depth, both on an unweighted sections of the line.

The time TDRs left the vessel was labelled as time zero (in Figure 9). TDR data were corrected for pressure offsets (as TDRs did not all read 0 m at the sea surface) and also for surface water temperature (as TDRs took some time to acclimatise to surface water temperature, and use temperature to correct pressure readings).

Sink profiles recorded by TDRs clearly show the longline sinking much closer to the vessel and indicate that there is a huge reduction in the widow of availability of hooks to birds behind the boat when setting gear through the setter (Figure 9).

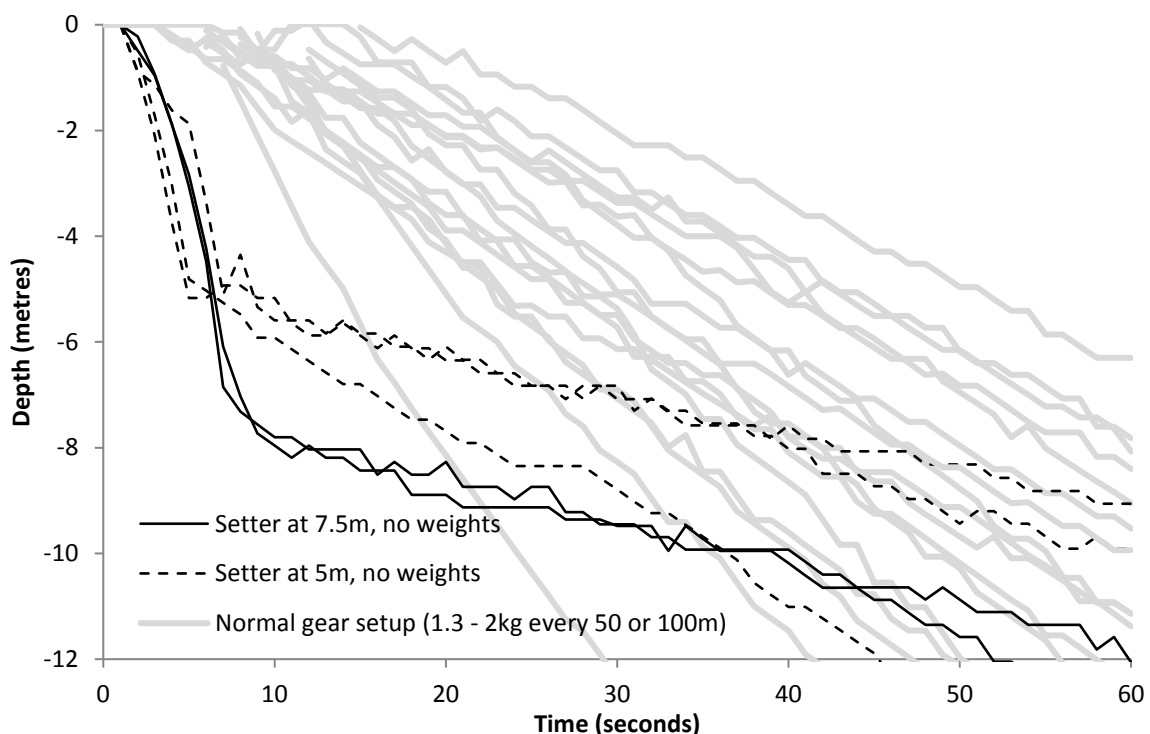


Figure 9: TDR data from 2 sets with normal gear setup (grey line) and a set using the setter with no weights (solid and dashed black lines).

The longline entered the setter almost vertically with a catenary in the line between the stern and the setter (Figure 10). Despite a reasonably high line-tension the water flow consistently pushed the longline into a curve before it entered the setter (Figure 10). This resulted in snoods, floats, and

weights entering from above or behind the U. It is thought this is due to the setter pulling the line down much closer to the boat than with previous versions.

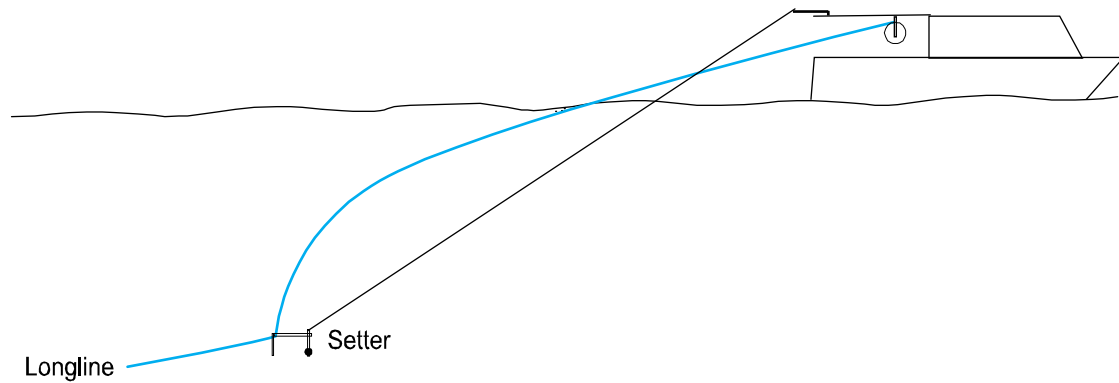


Figure 10. Diagram showing setter, longline and tow cable relative to the vessel.

Prior to Trip 7 a small rudder was attached above the lead ball as shown in figure 11.

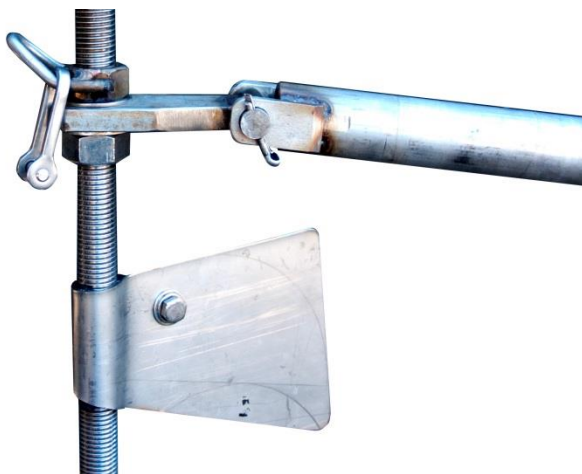


Figure 11. Rudder attached to setter just above lead ball.

The rudder allowed the setter to be 'steered' behind the boat, with the horizontal deflection angle approximately equal to the angle of the rudder. The addition of the rudder resulted in more drag, reducing the depth of the setter and the downward angle of the setter by 7 degrees. Similarly, halving the weight of the lead ball further reduced this angle by 3 degrees. This indicates that by adjusting the weight of the setter and the angle of the rudder, the position of the setter behind the stern can be controlled both vertically and horizontally.

Trip 8

Weighted plugs from the legs were removed and the half - ball weight was used, so the setter was slightly lighter than trip 7.

One hundred and fifty baited hooks were deployed through the setter at the end of a normal longline set. Cameras were attached above and below the paravane, and two time-depth recorders (TDRs) were attached to the setter (Figure 1). The 'U' of the setter was painted to record the path of the longline based on wear on the paint.

The weather was good and the vessel was taken out of gear and slowed down almost to a stop allowing the setter to be deployed on the line. The speed was gradually increased to normal setting speed (5.5 knots) and then clipping hooks on continued as per normal.

The setter ran at about 2.5 m depth approximately 15 m behind the boat and following the deployment of more cable it ran for most of the time at 4.5 m depth approximately 20 m behind the boat.

Three float weight combinations and 150 hooks were deployed through the setter with no catch-ups, although one snood was lost.

Review of camera footage showed that several baits came off and some were squashed / damaged as they were pulled around the tube. Wear on the paint showed that the line spent most of the time running in the corner between the top of the 'U' and the horizontal bar. Baits that followed the path of the backbone were prone to being squashed in this corner.

It appeared that the combination of speed, weight size, and the position of the setter behind the boat is crucial. The above worked well with 3 kg weight / 100 mm hard float combinations.

Smaller weights, at times, sank behind the setter and were pulled forward and over and around the top of the 'U', increasing tension in the line and the likelihood of catch-ups.

To improve the passage of baits through the setter the following changes were made to produce a revised setter (KLS 4.4 – see Figures 12, 13, 21):

1. The diameter of the tube at the top of the 'U' was increased so that the gear travels around a larger radius. This aimed to reduce damage to baits and smooth the passage for gear.
2. The diameter of the legs was reduced to compensate for the increased drag of the larger tube.
3. The top of the U was angle backwards at the outer ends, aiming to keep the backbone in the outside corner of the 'U' and away from the central tube, to smooth the passage for gear
4. The rudder angle was increased to push the setter away from the longline, so the backbone entered the setter from one side. This aimed to improve the chances of baits passing around the legs rather than the top of the 'U'.

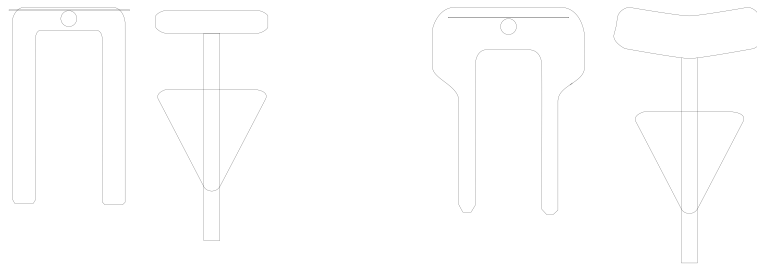


Figure 12: Schematic drawing showing modifications to the back end of the setter (KLS 4.4). From left to right is a view looking aft as trialled, a plan view as it was trialled, post modification view looking aft and post modification plan view.

Trip 9

After making the modifications the setter was deployed to determine how the changes in drag profile and weight altered its towing attitude. Due to the available cast stainless steel tube reducers, the setter legs were tapered in two stages (Figure 13).

The slight increase in weight with the extra material compensated for the increase in drag caused by increasing the tube diameter from 50 to 89 mm. It was therefore not deemed necessary to alter the weight of the lead half-ball, which contributed 6 kg to the overall weight.



Figure 13: KLS version 4.4, post modification showing the weight and configuration used for trips 9 - 12.

Trip 10

The setter was deployed, in a similar manner to previous trips, for the last 250 hooks of a set.

Normal practice when snapper longlining is to deploy a series of ‘intermediate’ surface floats at intervals along the line. These allow the line to be recovered if bitten through by sharks. These floats present a unique challenge to the setter as they are deployed with a heavier weight and have a rope wound around the float, which unwinds as the line sinks. To deploy these through the setter the arrangement shown in Figure 14 was employed. By casting the floats to one side of the setter the rope connected to the surface float passes underneath the ‘legs’ of the setter.

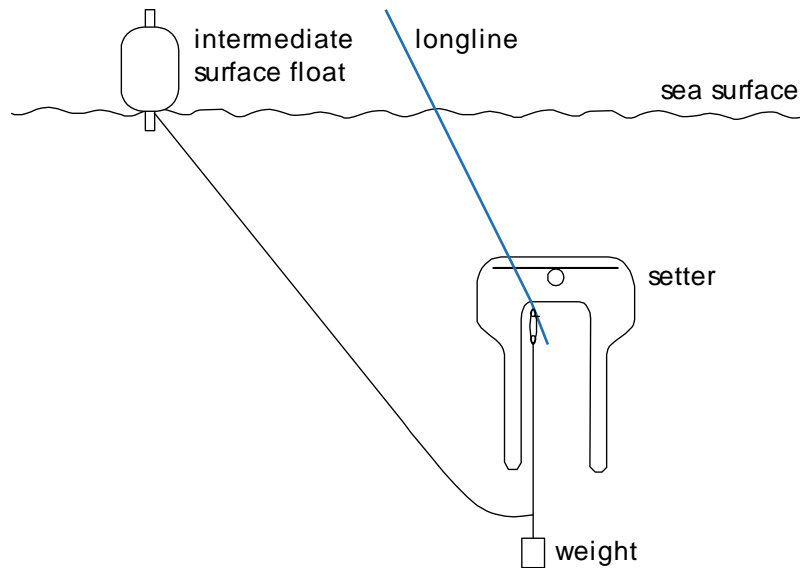


Figure 14: Schematic drawing showing configuration of intermediate floats deployed through the setter.

Due to low light levels underwater the passage of gear was not visible on the camera footage, however no catch-ups occurred and fish catch was consistent between the line set through the setter and that set normally. The setter was running at 4 m depth.

A stop was manufactured to restrict the movement of the hinge at the front of the setter and therefore allow more control when deploying the setter onto the line (Figure 15).



Figure 15: Photograph showing adjustable stop to control the amount of movement in the hinge at the forward end of the setter.

Trip 11

With dive torches strapped to the setter to illuminate the passage of the line and gear 1050 hooks, half of a typical set, was deployed through the setter. All hooks were baited with sanmar (*Cololabis saira*) chopped into approximately 12 mm wide steaks (Figure 16), tails and heads were not used. In addition to the vessel's normal 'hockey stick' clips a card of 50 'Waiheke' clips, more commonly used in the snapper fleet, was deployed through the setter.

Initially the setter was deployed with 10 m of cable from the sea surface to the setter, at a speed of around 4 knots. One intermediate float was accidentally deployed on the wrong side of the setter

causing a tangle, so the set was suspended, the float untangled and then the set recommenced with 20 m of cable on the setter. Cable was payed out to 25 m and speed increased to a maximum of 6.3 knots.



Figure 16: baited hooks

Video footage from the camera beneath the setter was reviewed between a quarter and full-speed and the fate of snoods deployed through the setter was recorded in the following categories (Figure 19):

- Bait OK, deployed through the setter with no observable damage
- Bait lost from hook as it passed through the setter
- Bait damaged as it passed through the setter. Usually the guts were squeezed out of a piece of bait, but in some cases passage through the setter resulted in a ripped bait with only some remaining on the hook.
- Bait lost before entering the setter (lost before entering the field of view of the lower camera).
- Snood tangled around backbone
- Snood lost or unclipped by setter
- Fate undetermined

The stop worked well, allowing the setter to be positioned over the line and deployed more easily.

Initially the setter ran at around 4 m depth, and increased to 6 m depth with 20 m of cable deployed, then settling down at 5.75 m. 25 m of cable resulted in a depth of 7.5 m, which then reduced to 6m as the speed was increased to 6.3 knots (figure 17).

Review of the video footage and examining wear on the paint showed that the modification to the setter caused the backbone to consistently run in the corner of the 'U', away from the horizontal tube and the paravane.

Most baits passed through the setter without damage, 10% sustained some damage, and less than one percent were lost (Table 1). More damage to baits was recorded towards the end of the set with higher speeds and the line setter running deeper. A single 'Waiheke' clip and 10 hockey stick clips were lost during the set.

Examining footage from the camera above the setter indicated that baits lost prior to entering the setter were jerked off the hooks as they rapidly changed direction to pass down and forwards through the setter. Bait loss or damage generally occurred as the baits were pulled around the tubing. (Figure 18).

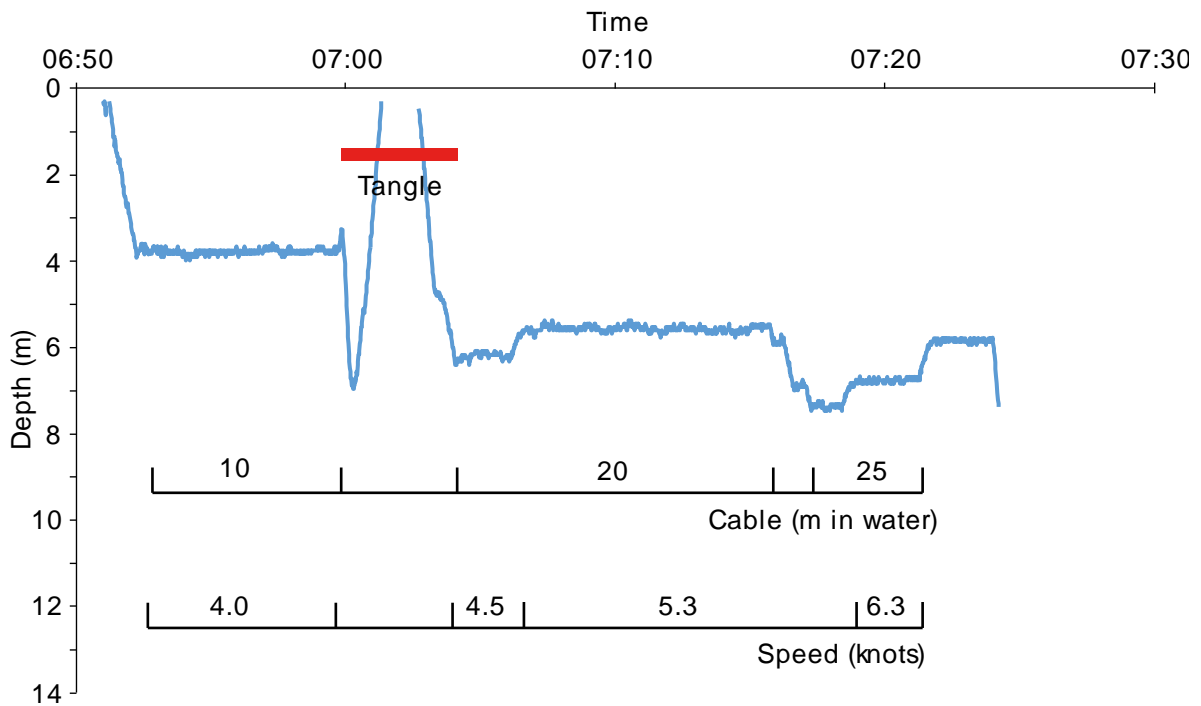


Figure 17: Time depth recorder records showing depth of the setter over time, during trip 11, annotated with the length of cable deployed and the setting speed. Tangle with an intermediate float is shown in red, with the setter recovered and re-deployed.

Table 1: Set characteristics and the fate of baits and snoods derived from review of the lower camera footage.

Bait type	sanmar
Depth (m)	4 - 6.75
Speed (knots)	4.5 - 5.5
Number of hooks set	1 050
Bait OK (%)	87.6
Bait lost at setter (%)	0.7
Bait damaged (%)	9.8
Bait lost before setter (%)	1.8
Tangled snood (%)	0.1
Lost snood (%)	0.1
Fate unobserved (%)	0.0

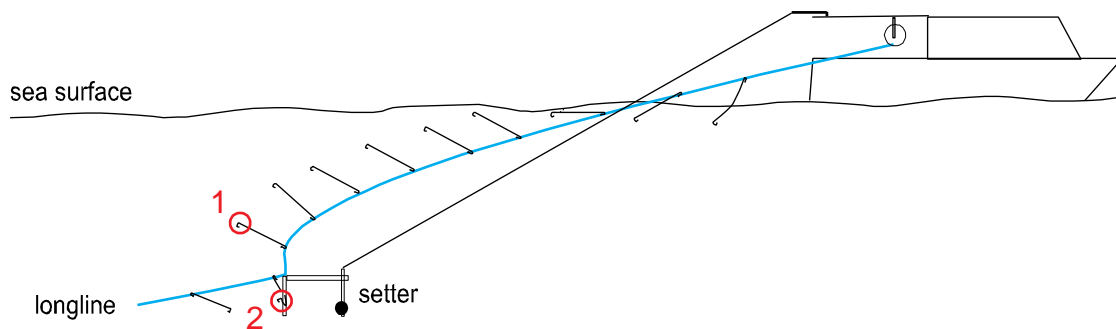


Figure 18: Schematic drawing showing path of snoods through the setter and the two points at which baits are vulnerable to loss or damage: 1 = bait lost before setter due to rapid change in direction of hook, 2 = bait lost at setter when hook passes around tube.

Trip 12

A shorter than normal line was set, with the setter deployed after approximately 100 hooks had been set.

Half the hooks were baited with pilchards (*Sardinops neopilchardus*) and half with sanmar, to examine the influence of different bait types on bait loss. Pilchard was thought to be the most fragile bait used by the snapper fleet. Pilchards were cut into approximately 12 mm wide steaks and baited in the same way as sanmar, through the flesh above the backbone.

The setter was deployed deeper than previous trials to investigate how deep hooks could be set without a loss in performance. Progressively more cable was deployed, and setting speed increased through the trial, with a maximum of 40 m of cable and 5.2 knots at the end of the test period.

Gear was set after daybreak, with a tori line and sufficient weight to meet regulations. A single camera was used in the lower position on the setter and the second camera was set up on the wheelhouse to record bird activity.

Initially gear was deployed as normal and then the setter was lowered over the line and hooks deployed at depth.

Bird abundance was low, with several red-billed gulls (*Larus novaehollandiae*) in attendance. At times, the gulls would show interest in the line under normal setting conditions. This interest and the amount of time they spent directly over the line appeared to drop off once the setter was deployed. The tori line appeared to deter gulls from landing on the water over the line. No baits were observed to be taken by the gulls and no attempts to feed were observed. A single flesh-footed shearwater was seen during the haul but showed little interest in the fishing operation.

750 hooks were deployed through the setter. The plan was to deploy an entire set of 1000 hooks of approximately half sanmar and half pilchard baits, however a float catch-up caused the setter to drop the backbone, and the remainder of the set was completed as normal, without the setter.

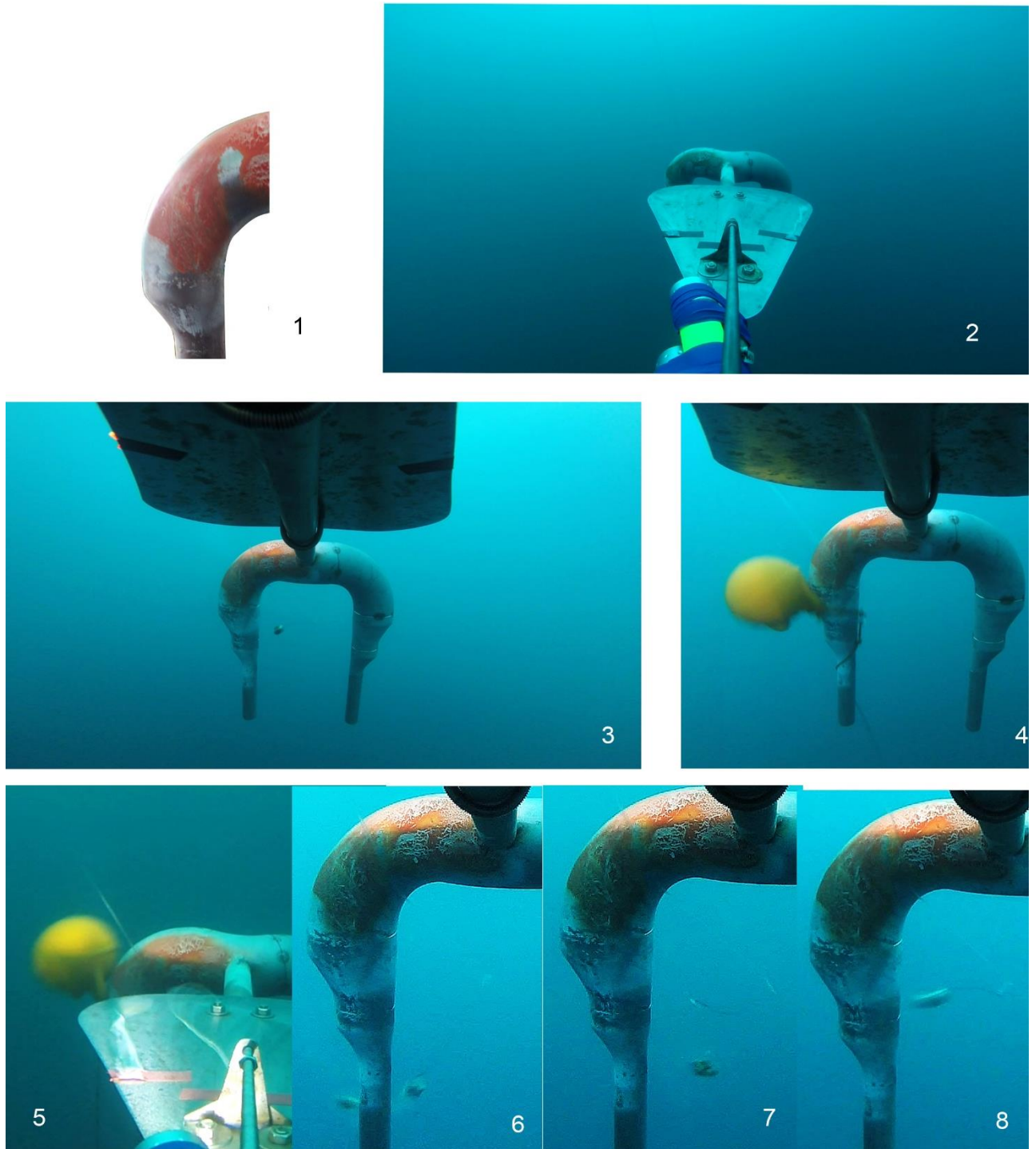


Figure 19: Still images and frames extracted from video footage showing the passage of fishing gear through the setter: 1: wear on painted portion of U, 2: Upper camera field of view, 3 lower camera field of view, 4 and 5: passage of float - weight combination, 6: severely damaged bait, 7: lost bait 8: intact bait, Note that image quality appears higher when viewing the images as video footage.

The setter deployed hooks at 7.75 m - 12 m depth depending of the speed and length of cable deployed (Figure 20). As the cable was deployed the drop in tension allowed the setter to sink deeper, before it settled out at a reasonably constant depth. Increases in speed, with the associated increase in drag, resulted in shallower depths.

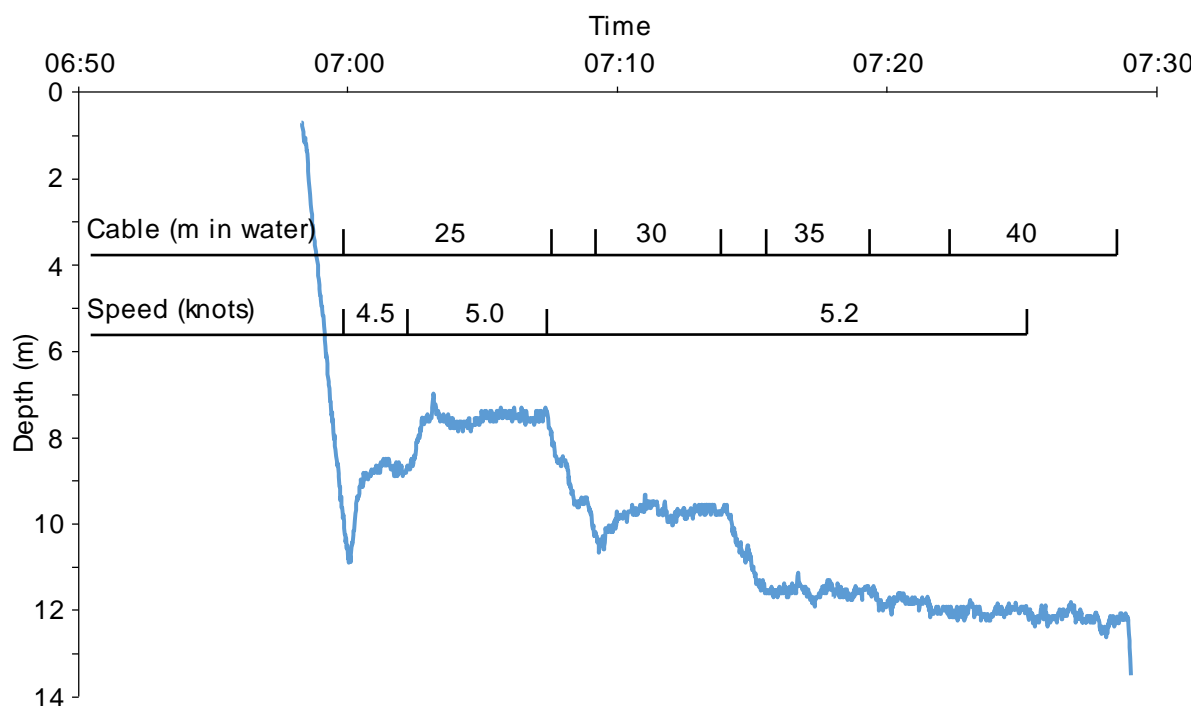


Figure 20: Time depth recorder records showing depth of the setter over time, during trip 12, annotated with the length of cable deployed and the setting speed.

Bait loss was unacceptably high, particularly for the larger and more fragile pilchard baits. Despite being set at higher speeds and deeper depths sanmar baits were less vulnerable to damage and loss (Table 2).

One weight, 5 (out of 50) 'Waiheke' clips and 10 'hockeystick' clips (out of 700) were lost. Not all of these were identified when reviewing the video so some may have been lost prior to the field of view of the camera.

Table 2: Set characteristics and the fate of baits and snoods derived from review of the lower camera.

Bait type	pilchard	sanmar
Depth (m)	7 - 9.75	12
Speed	4.5 - 5.5	5.5
Number of hooks set	453	298
Bait OK (%)	25.2	62.8
Bait lost at setter (%)	43.7	13.8
Bait damaged (%)	6.2	18.8
Bait lost before setter (%)	22.3	1.0
Tangled snood (%)	0.0	1.7
Lost snood (%)	0.2	1.3
Fate unobserved (%)	2.4	0.7

Higher speeds and deeper setter depths resulted in more catenary in the line prior to it entering the setter. This required a greater change in direction for snoods passing around the setter, more wrap around the 'U', and more force on the hooks as they change direction, all of which increased the potential for bait loss.

3. Discussion

Overall the development of the setter has been a continual learning exercise and we have been fortunate to have a team with different backgrounds, experience and skills. While flume tank work and mathematical modelling were useful in calculating expected forces and suitable dimensions, it proved hard to factor in all the variables using life-size designs. In future we would recommend the use of scale models, which would permit simulation of greater setting speeds and other fishing parameters in the flume tank. For novel projects such as the Kellian Line Setter, there is little specific theory to underpin development, unlike that which exists for other structures used in the marine environment. During the course of this project we concluded that to further refine of the Kellian Line Setter it would be easier and cheaper to progressively build prototypes to evaluate and learn from each stage. A combination of TDRs, video camera footage, and measurements of tow-cable load and angle has allowed us to critically review each trip and prioritise alterations for further trialling in a systematic manner.

Moving to a simpler design with less drag and no inherent instability led to promising results in terms of setting gear and made manufacturing and alterations easier and cheaper. It also had the advantage of being able to run gear through the setter from the port or starboard side.

Progress on the setter has been incremental, with each trip providing a basis for iterative change. Work has been limited by the availability of personnel, suitable weather, low abundance of birds, and fishing conditions. However, the trips described above resulted in a prototype which warrants further testing under normal fishing conditions, to refine the setting parameters detailed below and determine an effective operational window:

- At a setting depth of 4 to 7 m the setter seems to be functioning reliably. Operating the setter below 8 m is likely to result in an unacceptable degree of bait loss for pilchard baits hooked through the muscle.
- Increased speed results in a shallower cable angle, and the need for more cable to be deployed to reach specified depths. At present 6 m depth is achieved with 20 - 30 m of cable at 4 - 6 knots.
- Weight float combination of 3 kg of lead and 100 mm round hard floats, and straight 3 kg lead weights pass through the setter consistently at the speeds and depths described above.
- The setter can be deployed from the start of the set or part way through.
- Pilchard bait, used by some vessels, is more prone to bait loss than sanmar. Hooking pilchard bait into the backbone, as is common practice, is likely to reduce bait loss. Squid bait is tougher than sanmar and, although it has not been trialled, is expected to stay on hooks well.

Given the scope and nature of the project we are unable to guarantee the ultimate feasibility and functionality of the Kellian Line Setter, but can see potential solutions to the current problems that we feel will lead to a device that will permit the setting demersal longline gear at depth without impinging fishing efficiency.

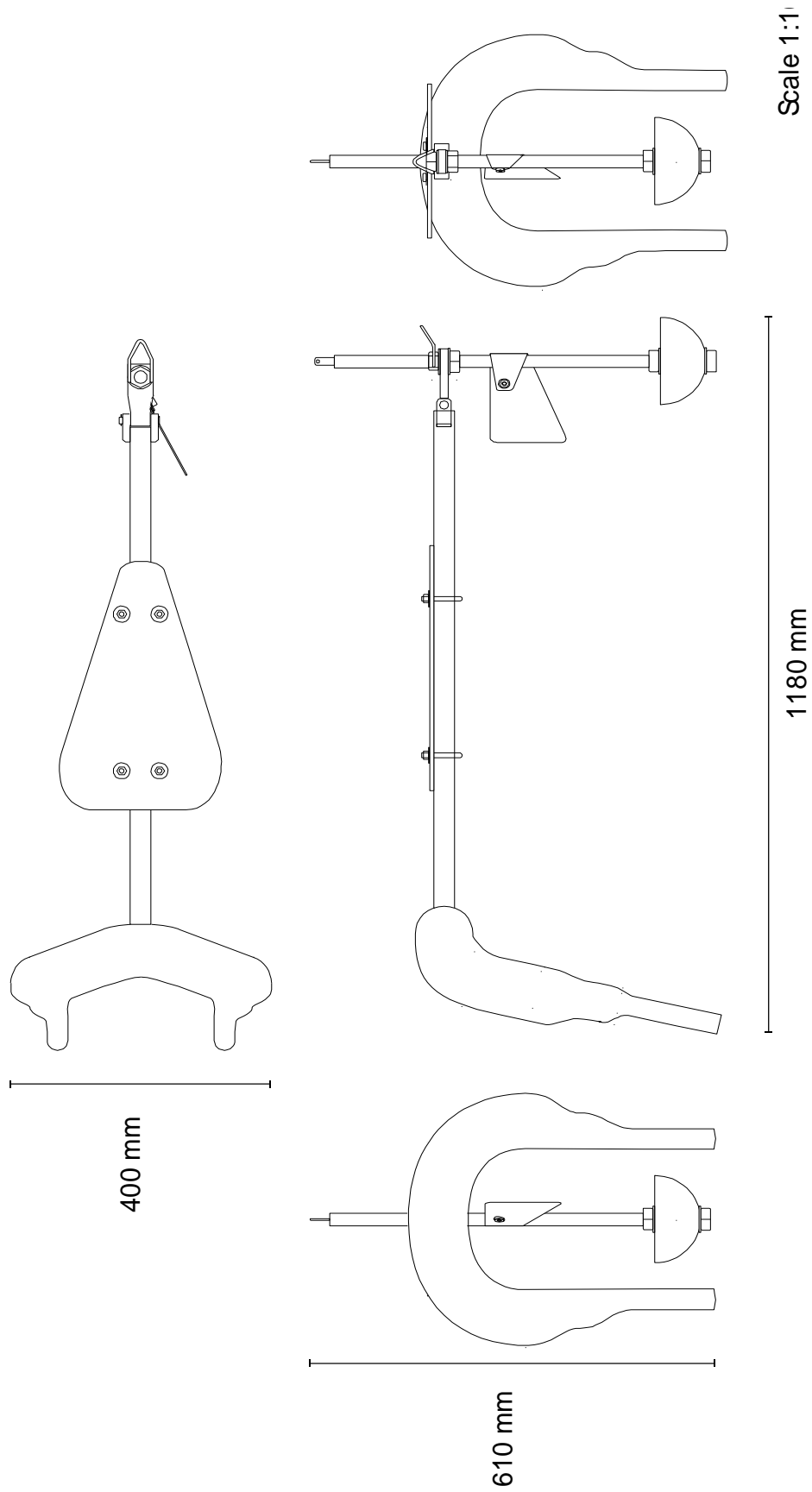


Figure 21: Schematic drawing of Kellian Line Setter version 4.4.

4. Next steps

Although the work described above fulfils the requirements of Contract 4529, it is our intention to continue development of the Kellian Line Setter. The setter will be trialled as part of the normal longlining operations aboard *FV Kotuku*, as and when the skipper feels the extra level of mitigation is warranted, most likely at times of the year when flesh-footed shearwaters are breeding on Karewa Island.

Video footage will be collected and reviewed to assess the performance of the setter and to identify further refinements. Improvements will continue to be made on an iterative and as-warranted basis.

Further modifications and trials under consideration include:

- A further increase in the diameter of the tubing used to construct the 'U', which will smooth the passage of hooks, baits and floats. This may require an increase in weight to overcome the increase in drag. Stepping up to 100 mm diameter tube with no taper on the legs is under consideration.
- An increase to the angle at which the legs are raked back, to smooth the passage of, particularly, floats.
- Testing further variations of the intermediate float and float - weight combinations deployed through the setter.
- Construction of a purpose built cradle and davit arm to facilitate the deployment and recovery of the setter is underway, and this will allow easy deployment in poor weather conditions.
- Performing a daytime set with tied on baits and a short tori line, using the setter to deploy baits at increasing depths to record bird behavioural response.
- Casting and fitting a new torpedo - shaped weight to reduce drag, once the optimum weight is established.
- Limiting the movement of the hinge and removing the stop.

We believe that the Kellian Line Setter will be capable of significantly reducing interactions with seabirds in New Zealand's bottom long line fishery once the existing design has been extensively trialled under full fishing conditions. At that stage, it would be appropriate to consider commercial fabrication of a few units that could be provided to fishers with a willingness to work with a person familiar with the use of the line setter. It is important when rolling out any new bycatch mitigation technology to ensure that skippers and crew are fully supported so that full effectiveness can be achieved. There are a number of examples of good ideas that have been abandoned or never fully taken up because initial operational problems led to widespread loss of confidence in the technology being evaluated.

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