Agreement on the Conservation of Albatrosses and Petrels

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Development of a Bird-scaring Line Compliance Monitoring Device

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SUMMARY

The project was successful in advancing the development of a pilot Bird-scaring Line (BSL) compliance monitoring device. The device which attaches directly to a BSL, records if and when it is deployed during fishing operations. At-sea trials were carried out to improve technical and performance aspects of the device on vessels using different gear configurations and BSL types. A total of 10 trips (9 observed and 1 un-observed) were conducted onboard 10 different vessels using trawl, pelagic and demersal longline gear. Five different device prototypes were tested. Improvements were made to the data collection software, sensitivity to fluctuations in tension and increased robustness to fleet related operational conditions, as well as to the use of two different types of BSLs. The device is now able to connect wirelessly and transmit data. We found significant difference between fleet's 'Tension Profiles' which can be used in identifying discrepancies as well as validating actual deployments. Significant differences were also found between environmental data recorded in Beauford Scales (BS) within one of the fleets, showing how relatively small variations in BS measurements can have significant impact on the tensions generated by the pull of the BSL. We were able to assess compliance with the use of BSLs, however more deployments are required to validate future versions of the prototype to ensure continuous data collection during each fishing set is improved. The date and time stamp collected by the device can be used to confirm mandatory night setting in the longline fleet by using the vessel's own geolocation entries to logbooks.

1. INTRODUCTON

1.1. Rationale

Fisheries bycatch is one of the principal threats to seabirds and other marine megafauna, such as turtles, sharks and marine mammals (Clay et al., 2019; Lewison et al., 2014). Bycatch impacts 28% (100 species) of all seabird species including 50 globally threatened species(Diaz et al., 2019). While seabird bycatch mitigation measures, such as bird-scaring lines (BSLs) have been in use since the early 1990s and proven to successfully reduce seabird deaths and bait loss in fisheries (Brothers 1991), compliance with their use, however, remains a challenge (Phillips et al., 2016). The use of electronic monitoring devices may therefore be essential tools to ensure implementation and compliance with mitigation measures while vessels are out at sea (Diaz et al., 2019; van Helmond et al., 2020).

Bird-scaring lines are the primary mitigation measure used to mitigate seabird interactions and bycatch in trawl and longline fisheries. The use of BSLs in South Africa is required by national fisheries permit conditions in the offshore hake trawl, horse mackerel mid-water trawl and all longline fisheries fleets (DEFF 2017, 2020a,b). Permit conditions in the pelagic longline and mid-water trawl fleets, further require the presence of on-board fisheries observers to cover 20% and 100% of total fishing effort respectively (DEFF 2020a,b). In other fisheries, such as demersal hake longline, on-board observer programmes are initiated and financed by industry on an ad hoc basis, often related to market-based incentive mechanisms such as Marine Stewardship Certification, fisheries improvement programmes and other green listing initiatives. For instance, the demersal offshore hake trawl sector has funded a fisheries observer programme since 2005 which covers approximately 10% of its annual fishing effort (Andrews et al., 2016). Given the various observer schemes and relatively low levels of at-sea observer coverage in South Africa, assessing compliance with the use of seabird bycatch mitigation measures is difficult, and the use of electronic monitoring devices is seen as a way to increase compliance monitoring and to improve the dissemination of compliance monitoring data.

In 2020 a grant from the Agreement for the Conservation of Albatrosses and Petrels was awarded to Birdlife South Africa (BLSA), in partnership with Imvelo Blue Environment Consultancy (Imvelo) for a project to further the development of a pilot-BSL compliance monitoring device. The device uses mechatronic engineering, i.e. the integration of mechanical, electronic and electrical signals to convert the mechanical tension, measured in kilogram units (kg), of a deployed BSL into an electronic output in the form of tension data points, each associated to a specific date and time.

1.1. Device description

The device works by continuously measuring the tension (kg) exerted by a BSL when it is dragged through the water. The BSL is attached to the tension sensing element of the device which records the tensile force being exerted onto it by the BSL. The tensile force is thus detected by the computing unit within the device and at set recording intervals. This information is converted into data points associated with the date and time the tensile force was exerted onto the BSL. Each prototype of the device consists of: a securing mechanism that attaches directly to a BSL; an internal storage component that communicates with the computing unit, configured to record tension data; an independently rechargeable battery system; and a waterproof casing manufactured from rigid material (Figure 1).

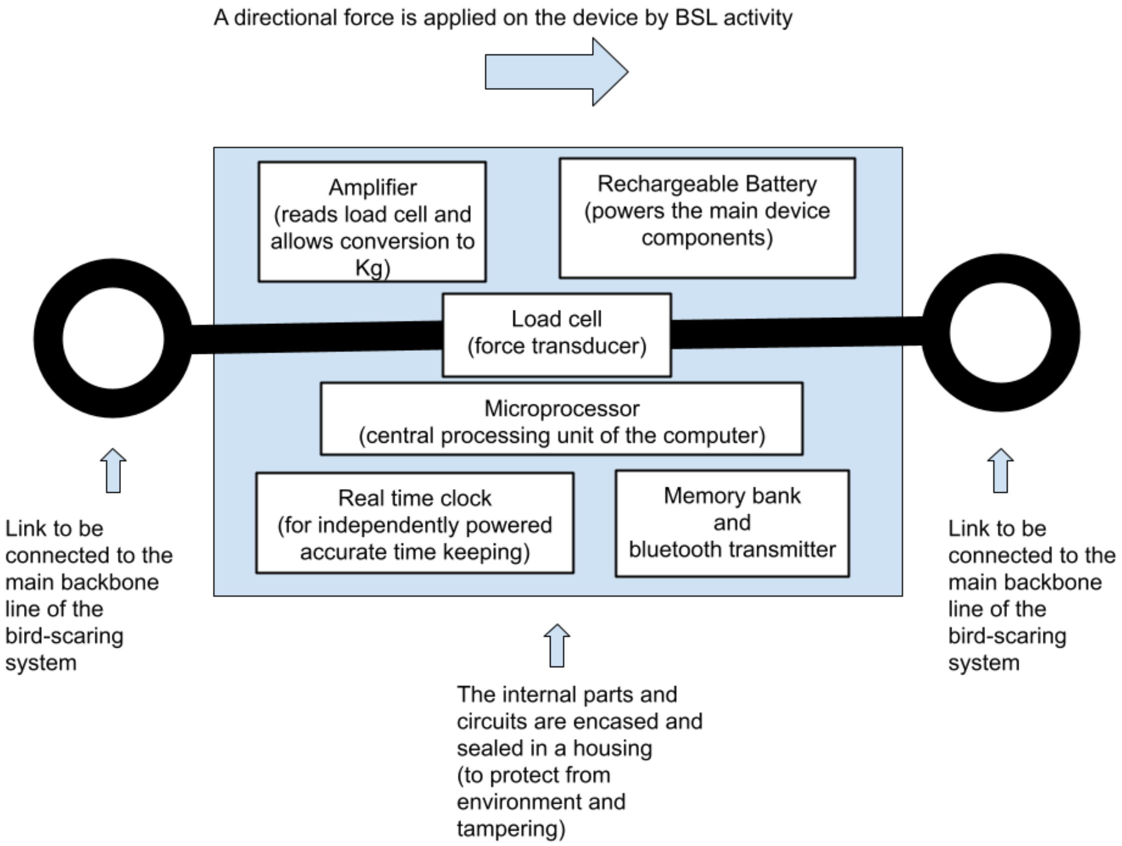


Figure 1. Diagram showing the components of device prototype (T3).

2. OBJECTIVES

The project aims to further the technical development of the BLS compliance device and test its performance ability to withstand various deployment circumstances, including operational and environmental influences, through at-sea deployments.

The following specific objectives were addressed through sea trials:

a) Refine the data collection software and adjust its sensitivity to various deployment conditions at sea, such as weather and fluctuations in tension, as well as potential tampering with the BSL or deployment methods.
b) Capture the data electronically, eliminating the need to remove the device from its attachment point.
c) Tamper proofing of the device and the recorded data.
d) Adapt the device for ease of use on various fleets and for different types of BSLs.
e) Develop 'Tension profiles' that can be used to analyse and validate the data in the absence of on-board Observers.

3. METHODS

3.1. Device deployment and data collection

Before each deployment of a device, the real time clock was set, and a weight calibration was conducted by attaching the device to a fixed point and attaching standard known weights to the tension sensing end of the device. Battery status was checked, and each device was then activated, sealed, and brought to harbour for deployment on a vessel departing on a fishing trip. Before departure each device was attached to a BSL. Upon the return of the vessel the device was retrieved unless an entanglement of the BSL or other damage to the device had detached it, and no further deployment of the device was possible.

Each prototype of the device collected real-time continuous tension data in kg units of tensile strength. The data were sampled and stored by the device's internal mechanisms at set intervals and converted to data points associated with the date and time of capture. Each device was set to trigger the collection of data when a tension equal to or exceeding 4 kg was exerted by the BSL for more than 4 minutes (min), defined as the start of a 'Measured Event'. A 'Measured Event' could last for several hours and ended when the tension dropped below 4 kg for more than 4 min (Figure 2).

Each 'Measured Event' can be expressed as 'Tension Profiles' as the product of the tension in kg produces by the pull of the BSL over time (Figure 2).

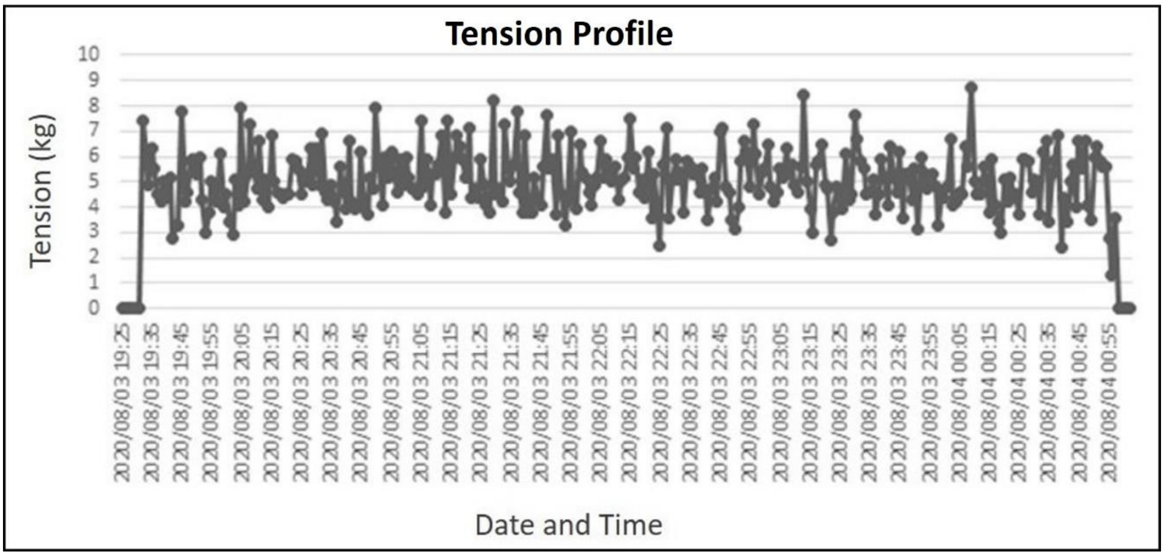


Figure 2. Graph of a 'Measured Event' of more than five hours of data outputs, expressed as a 'Tension Profile', showing the fluctuations in tension, produced by the pull of a BSL while deployed.

A 'Matched Event' was defined as a 'Measured Event' which coincides with the Observer's and/or ships log's records of a BSL having been deployed at the same time that the attached device records the event. Furthermore, the number of 'Matched Events' may or may not correspond to the number fishing sets and this will depend on whether a BSL was or not deployed during the set or, if the device is no longer able to continue to capture BSL tension data, for example if it is not connected to a BSL or the device runs out of battery.

A device was either ‘Active’ or ‘Inactive’, the latter noting a misfunctioning device not able to record data. Each deployment of an ‘Active’ device provided two types of information: a) Compliance data, in the form of tension data as ‘Matched Events’ indicating a BSL was deployed during fishing operations; b) Technical data regarding the electronic function and hardware performance of a device was provided by an ‘Active’ device, whether deployed or not. Both types of data were used to further improve on each of the device prototype’s internal software and electronic components, as well as external casing and attachment points.

Once retrieved each device was inspected for external damage and potential tampering. The casing was opened, security seals were checked, and each of the internal components was inspected and tested to determine their working status. The date and time of the internal clock were accessed, and a weight calibration was conducted and checked against previous deployment records of the device. The memory bank containing all the data were also downloaded for further analyses during this process. The data are accessible via FTDI (Future Technology Devices International Limited) cable and require calibration standards to be decoded. Wireless software access is protected by code and wirelessly accessible data is read-only.

If there were no signs of tampering, no breaches, all components were in working order and no significant calibration deviations occurred between device deployment and retrieval, then the technical aspects of the device were considered to be working as expected.

3.2. At-sea trials

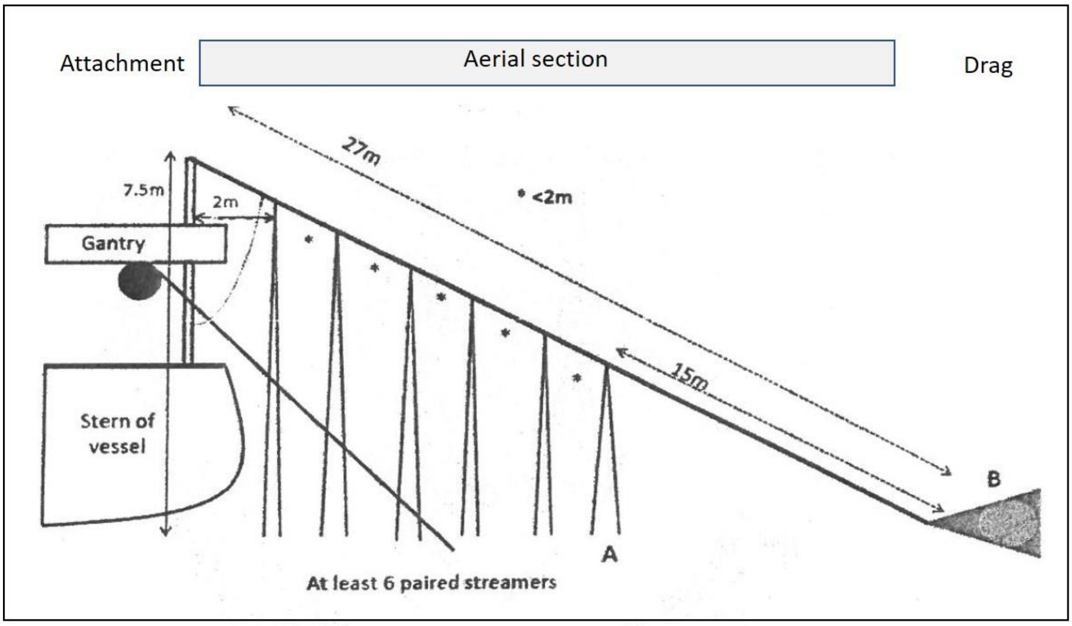
3.2.1. Vessel and trip information

At-sea trials were carried out between June 2020 and March 2021 on board selected vessels based on gear type and vessel owner’s willingness to participate in the trials. We recorded start and end dates of fishing trip and number of fishing sets when access to fishing logs was possible. Some of the deployments were conducted as part of regular Observer deployments required by fishing permits or as part of industry Observer Programmes. The Observers were all trained fisheries observers, familiar with seabird mitigation measures, as well as with the vessel’s fishing gear and operations. On trips deploying Observers they were tasked with ensuring the device was attached to the BSL, and available to troubleshoot in case of entanglements or attachments issues. Observers are not tasked with enforcing compliance with mitigation measures. Environmental data was collected for 2 trips and included wind and swell parameters.

3.2.2. Bird-scaring line use and fleet operations

All BSLs used during the trials were provided by a BLSA approved manufacturer using standard materials and constructed according to permit condition specifications. This ensured all tension profiles generated by the device reflect only ambient and fleet operational conditions. The trawl and longline BSLs differ in length, overall weight (14.5kg and 3.5kg respectively) and materials used (Figure 3).

3a.



3b.

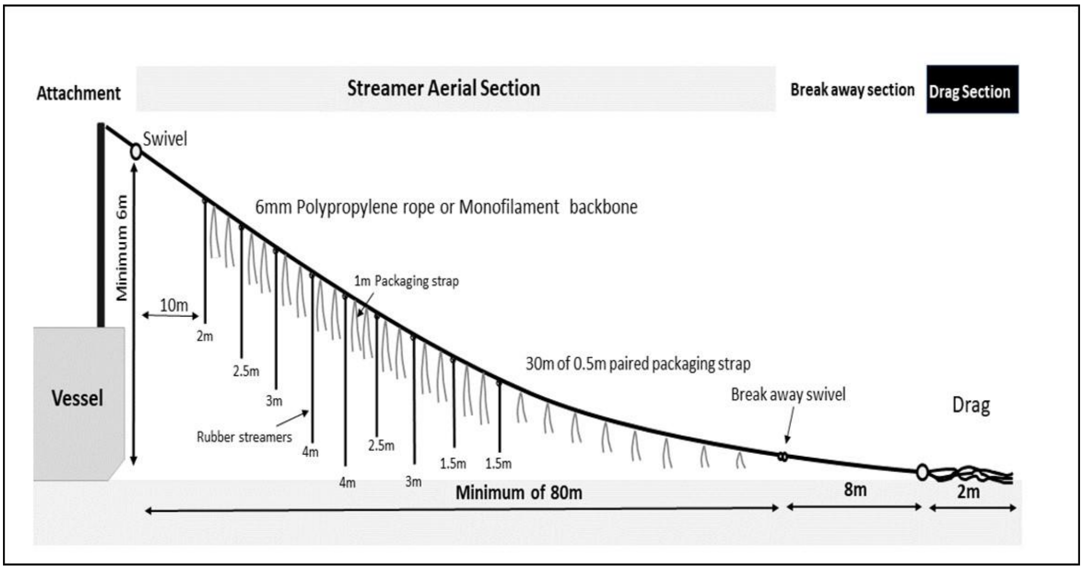


Figure 3. Schematics and specifications of Bird-scaring Line mandatory in South Africa: a) Demersal trawl; b) Demersal and Pelagic Longline fleets.

Fleets differ in the way they set their gear and operate. Trawl nets are set between 3 and 4 times per day, with the 4th set often set at night. Each trawl lasts for approximately 4 hours depending on the catch and a BSLs should be deployed from the moment the trawl doors enter the water and until just before they are brought back out, during hauling. Longline vessels set their lines once per day after nautical dusk, and BSLs must be deployed before the first hook(s) enter the water. Setting normally last between 3 to 6 hours depending on the fleet, number of hooks and if more than one line is set. Bird-scaring Lines must be deployed for the entire setting period, they are not required during hauling.

3.3. Statistical methods and variables

To assess the influence of fleet types and weather conditions on 'Tension Profiles' produced by the device, we applied non-parametric Kruskall-Wallis Rank Sum tests. For between fleet comparisons, we used the full available dataset of all 'Matched Events' (see above for definition of 'Matched Events'), and for comparisons of 'Tension profiles' under different weather conditions we included only 'Matched Events' when a Beaufort Scale score was recorded by Observers. For the latter analysis we only used data collected from the Pelagic Longline (PLL) trips where the highest range of Beaufort Scale scores were recorded.

4. RESULTS

4.1. Device deployments, function and improvements

A total of 10 sea trips, with 10 participating vessels representing 3 different fleets; Trawl, Pelagic Longline (PLL) and Demersal Longline (DLL), took part in the trials (Table 1). Each trip carried an 'Active' device attached to a BSL when leaving harbour.

Table 1. Total number of trips and participating vessels by gear type and device prototypes used, in ascending order of development from T3A to T3E.

Gear Type	Vessels/trips	Device prototype used
Pelagic longline	4	[1]Series T3 A, B, D
Demersal longline	3	Series T3 A, C, E
Demersal trawl	3	Series T3 B, C, D

[1] Two T3B prototypes were used on different vessels.

A total of 5 different device prototypes were tested and improved upon in ascending order from T3A to T3E (Table 2). Because of the nature of the deployments and varying lengths of trips, older and newer versions of the prototypes overlapped in time. Deployment of the same prototype across different fleets yielded different results; from working as expected to malfunctioning due to fleet specific operational aspects, such as high-tension events, or internal technical issues (Table 2). On two occasions an Observer was able to re-attach a device to the BSL at sea, if it has detached due to a high-tension event or entanglements and data collection could continue. However, no BSL tension data could be collected if there was internal damage to components, device malfunctioned, or the Observer was unable to re-attach the device to the BSL. Each deployment provided valuable technical and hardware diagnostics which helped improve subsequent prototypes.

Table 2. Device prototype performance.

Fleet	Prototype	Date activated	Status on retrieval	Diagnostic on retrieval
PLL	T3A	25-Aug-20	Active	Worked as expected. Security seal intact. Wear and tear on attachment points.
DLL	T3A	18-Sep-20	Inactive	Loadcell malfunction. High tension damage, outer casing breached and attachment point missing. No internal corrosion.
PLL	T3B	29-Jul-20	Active	Battery charger malfunction. Security seal intact.
Trawl	T3B	29-Jul-20	Active	Worked as expected. Security seal intact. Attachment points replaced at sea.
PLL	T3B	23-Jun-20	Active	Worked as expected. Security seal intact.
Trawl	T3C	15-Jul-20	Inactive	Battery malfunction. High tension damage. Security seal intact. Attachment points replaced with alternative lines and wire during trip.
DLL	T3C	18-Sep-20	Active	LED indicator malfunction. Security seal intact.
Trawl	T3D	07-Aug-20	Active	Worked as expected. Security seal intact. Attachment point missing.
PLL	T3D	18-Sep-20	Active	Worked as expected. Security seal intact.
DLL	T3E	09-Dec-20	Inactive	Loadcell and electronics malfunction. High tension damage, outer casing breached and corrosion damage. Wear and tear on attachment points

PLL = Pelagic Longline, DLL = Demersal Longline. LED = Light Emitting Diode.

Improvements to each device included better water-proof outer casing design including a Light Emitting Diode (LED) light that indicated device activity. Better electronic chipsets including (i) the addition of a Bluetooth low energy (BLE) transmitter which communicates wirelessly with smartphones and allows for IoT (internet of Things) integration and (ii) troubleshooting of poor battery performance issues. Improvements to the tension calibration protocol, to allow for a greater tension sensitivity so that the device is able to detect changes of 50-100 g.

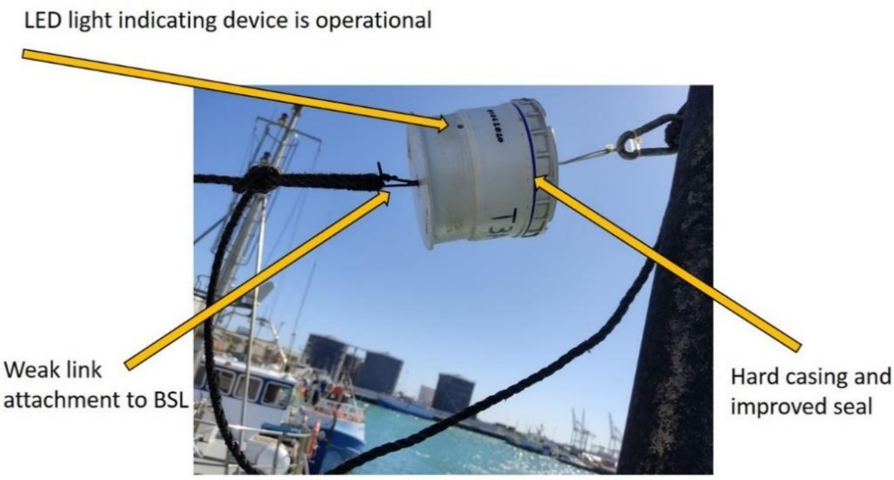


Figure 4. Image showing improvements made to the casing and device to withstand the harsher conditions on Trawl vessels.

The trials aboard trawl vessels during this project revealed the need to make the prototypes more robust in order to withstand the tough conditions and heavier BSLs used by these vessels. This involved improving the hardware seals to protect electronics, improving the device attachment points, including a mechanical weak link which protects the device in case of line entanglement, and using materials that minimize rusting and wear and tear. Figure 4 shows one of the improved versions of the T3 prototype attached to a BSL.

4.2. Sea trials

Of the 10 trips carried out during this project, nine carried Observers. They recorded no instances of deliberate tampering or removal of devices. Of the 10 trips, seven deployed a BSL with an attached device. Of the remaining three trips, two did not deploy a BSL, as confirmed by the Observer and the absence of 'Matched Events' records collected by the device. The third trip did not carry an Observer, however the device remained 'Active' and showed no signs of having been tampered with, upon retrieval. The device recorded a 'Measured Event', but, without access to the fishing logs, it was not possible to assess if this was a 'Matched Event', which would indicate that the BSL had been deployed during a fishing set, hence non-compliance with the BSL can be inferred (Table 3)

A total of 283 fishing sets were observed of which 52 yielded 'Matched Events', recorded by the device and verified using the ships vessel logs, which confirmed that a BSL was deployed during a fishing set (Table 3). Five (Trip ID#: 3,4,5,8,10) of the 10 trips, recorded 'Matched Events', with one trip (Trip ID# 5) recording the same number of 'Matched Events' (n=5) as the number of Fishing sets (n=5) (Table 3).

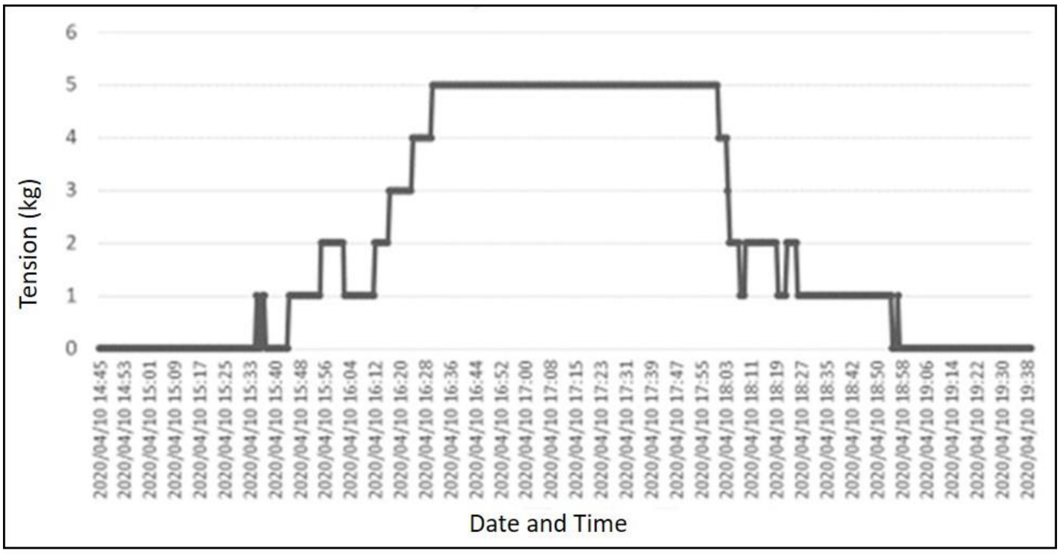
Table 3. Trip information and Device function data, see Results for discussion.

Trip information						Device compliance and function		
Trip ID #	**Fleet**	**Observer**	**Fishing start date**	**Fishing end date**	**# Fishing sets**	**BSL + Device deployed**	**# Matched events**	**Device Status**
1	DLL	Yes	14/12/20	23/01/21	65	Yes	0	Inactive
2	DLL	Yes	29/08/20	14/09/20	NA	No	0	Active
3	DLL	Yes	29/12/20	29/03/21	150	Yes	3	Inactive
4	PLL	Yes	27/08/20	08/09/20	11	Yes	1	Active
5	PLL	Yes	01/08/20	05/08/20	5	Yes	5	Active
6	PLL	No	23/06/20	10/07/20	NA	No	0	Active
7	PLL	Yes	22/09/20	30/09/20	NA	No	0	Active
8	Trawl	Yes	26/08/20	28/08/20	9	Yes	7	Active
9	Trawl	Yes	16/07/20	09/09/20	NA	Yes	0	Inactive
10	Trawl	Yes	22/08/20	06/09/20	43	Yes	36	Active
				Total	**283**		**52**	

NA = Not Available. PLL = Pelagic Longline, DLL = Demersal Longline.

Data collected from each of the devices produced a series of ‘Tension Profiles’ which were useful to detect inconsistencies indicative of discrepancies caused by device malfunction (Figure 5a) as well as unusual events such as BSL entanglements (Figure 5b) which could place prototypes under extreme tensions and cause damage to the internal mechanisms as well as damage the casing of the device (Table 2).

5a.



5b.

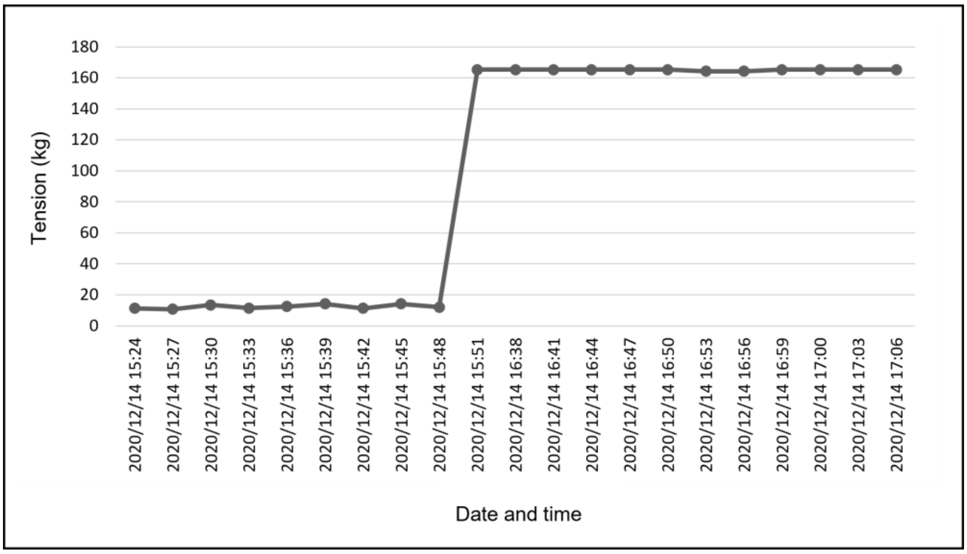


Figure 5. Tension profile data graphs showing examples of a) poor sensitivity to the tension exserted by a BSL and b) BLS entanglement event resulting in a sudden extreme rise in tension.

4.3. Tension profile differences between fleets

In this analysis we included all available data, recorded at 60 second intervals for 'Matched Events' from 2 trawl vessels (Trip ID#: 6 & 7), 2 pelagic longline vessels (Trip ID#: 1 & 2) and 1 demersal longline vessel (Trip ID#: 5). There was a significant difference in the tensions of the BSL device across the three different fleets, with the highest tension profiles recorded for demersal longline vessels (median ± IQR: 13 ± 4.6 kg) and the lowest tension profiles recorded for pelagic longline vessels (4.8 ± 1.2 kg. (Figure 6).

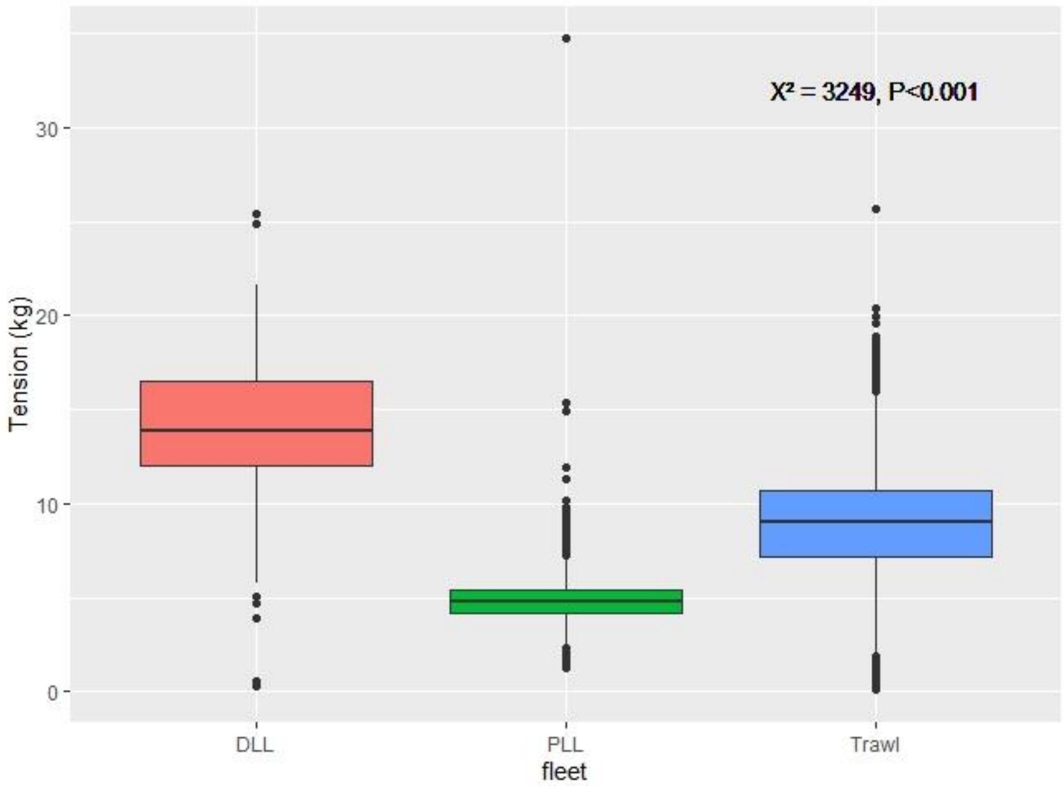


Figure 6. Fleet specific tension profiles recorded by the Bird-scaring Line compliance device for the Demersal Longline (DLL), Pelagic Longline (PLL) and Trawl fleets. Kruskall-Wallis test statistics are given in top right.

4.4 Tension profile differences between different weather conditions

In this analysis we included data from one PLL vessel (Trip ID#1). There was a significant difference in the tensions of the BSL device between the different Beaufort Scale (BS) scores, with the highest tension profiles recorded for BS 6 (median ± IQR: 5 ± 1.5 kg) and the lowest average tensions recorded for BS 5 (4.4 ± 1.1 kg) although these tensions varied considerably in comparison to BS 3 (4.8 ± 0.6 kg) and BS 4(4.6± 0.8 kg) (Figure 7).

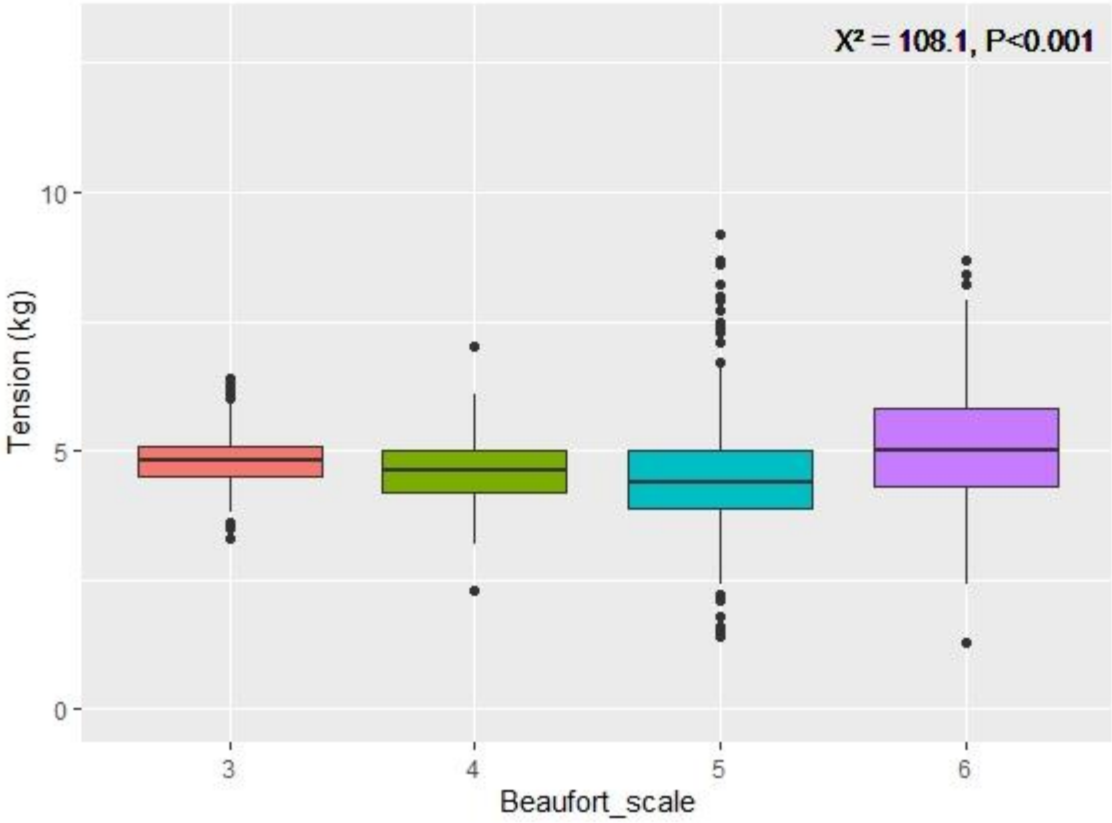
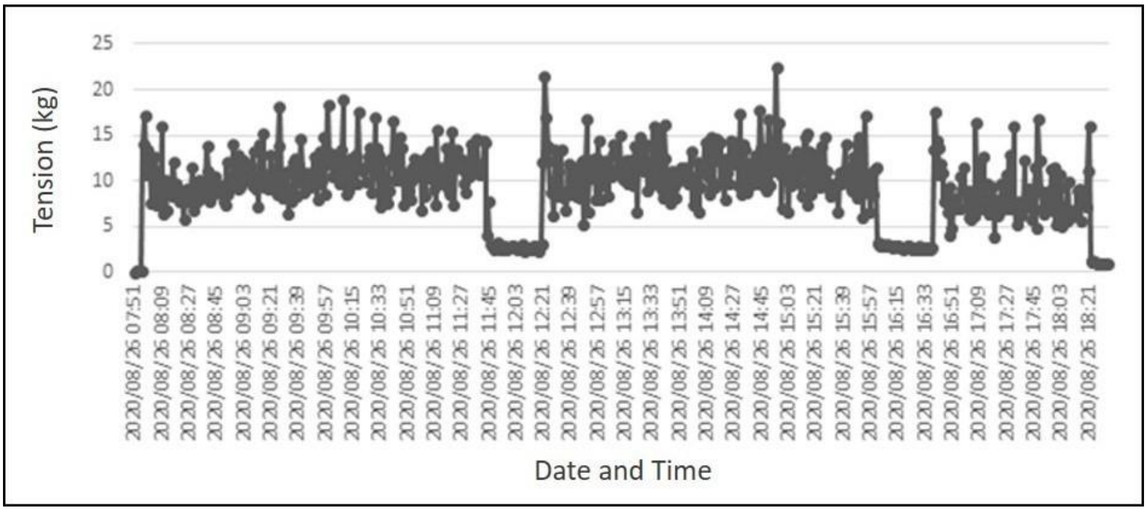


Figure 7. Tension profiles recorded by the Bird-scaring Line compliance device for different weather conditions using Beaufort Scale scores for the pelagic longline fleet. Kruskall-Wallis test statistics are given in top right.

4.5 Development of fleet specific tension profiles as diagnostic features

A dataset of different tension profiles or models can be built over time against which individual tension profiles can be compared to determine if the measurements are consistent with previous trends. For example, Figure 8 shows a typical tension profile for a trawl and pelagic longline set. A detailed look at the trawl tension profile graph (Figure 8a) shows the tension increasing from zero as the BSL is deployed at the start of the trawl set and fluctuating between 5 to 20 kgs around a mode of 10 kg during trawling. Occasional spikes above 20 kg in the tension can be attributed to a vessel changing direction during the trawl or increases in drag due to currents. The end and start of each trawl are clearly visible as the tension decreases to below 5 kg when the BSL is brought back on-board and tied off awaiting the next trawl set, lasting on average 3 hrs. The longline tension profile graph (Figure 8b) shows tensions of between 3 to 7 kg around a mode of 4.5 kg during the 5.5 hrs of setting, common to this fleet. Occasional seemingly periodic spikes above 8 kg and just below 3 kg could be attributed to the zig-zag setting pattern followed by pelagic longline vessels.

8a.



8b.

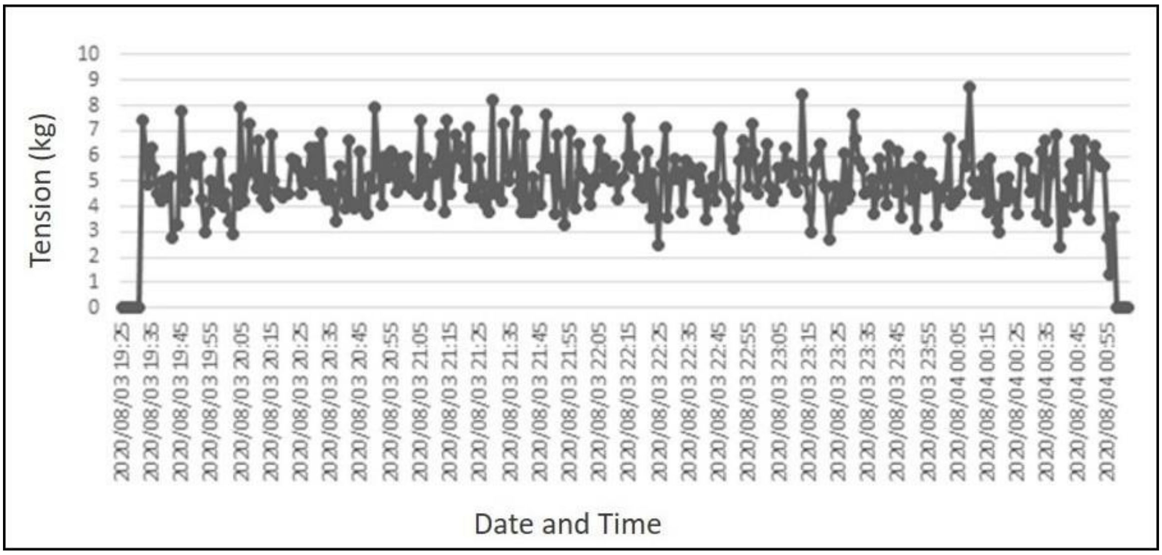


Figure 8. Tension profiles created by a) trawl and b) longline vessels using mandatory BSLs (see Figure 3).

These examples of tension profiles are a measure of some of the range of tensions the device can handle. The device can be fine-tuned by adjusting the sensitivity and frequency with which the tension is captured and used across a range of fleets and with different types of BSLs.

5. DISCUSSION

During the course of this project, we were able to trial five different prototypes of the device on three different fishing fleets using different gear and operational methods. This allowed for the improvement of the data collection software and refinement of the prototype's sensitivity to various deployment conditions at sea, such and weather, fluctuations in tension and different types of BSLs. By adding a tamper security seal to the outer casing, any potential tampering of the device could be detected. Improved chipsets allowed for the addition of a BLE transmitter which allows for wireless transmission of data and integration to the internet.

The presence of an Observer was important during these trials to provide information regarding the use of the BSLs. They were also instrumental in providing feedback regarding possible reasons for malfunction or damage to the device. The 'Active' or 'Inactive' status of a device associated to a date and time could then be corroborated with the information provided by the Observer or Fishing logs entered by the skippers. The data collected from the device deployed without an Observer can be used to assess compliance with the BSL if the device remains 'Active' for the duration of the trip, and if any 'Measured Events' recorded on the device can be compared with the Fishing logs, indicating a 'Matched Event'. If the 'Measured Event' does not coincide with a recorded fishing set, then non-compliance with the use of a BLS during an actual fishing set can be inferred. However, there is the risk that Fishing logs can be altered to coincide with the deployment of the BSL, while setting of gear takes place at another time.

There were relatively few 'Matched Event' during these trials mainly because of the various issues encountered with the prototypes malfunctioning early on during a trip, as well 'Active' devices attached to BSLs that were not deployed by skippers. More deployments are required to validate future versions of the prototype to ensure continuous data collection during each fishing set. A series of useful 'Tension Profiles' were produced which help to illustrate where problems are occurring, be they technical or operational. They also provide the basis for the creation of fleet specific datasets which can be useful in identifying discrepancies as well as validating actual deployments. While environmental data recorded in Beauford Scales (BS) was only collected during two trips, the results from one of these data sets show that relatively small variations in BS measurements between sets have significant impact on the tensions generated by the pull of the BSL. The 'Tension Profiles' created by the pull of the BSL show increasing tension and higher fluctuations recorded by the device. Finally, the date and time stamp collected by the device can be used to confirm mandatory night setting in the longline fleet, by using the vessel's own geolocation entries to logbooks, or if fitted as a future feature of the device.

6. ACKNOWLEDGEMENTS

We would like to acknowledge the willing participation in these trials of the following vessel owners and crew of the: Pelagic Longline vessels – Santa Cruz, Seawin Emerald, Seawin Diamond and Seawin Saphire; Demersal Longline vessels - El Shaddai, Sunstar and South West Condor; Trawl vessels – Datango, Harvest Saldanha and Bluebell. We would like to acknowledge the observers that took part in these trials employed by Imvelo Blue Environment Consultancy, as well as CapMarine for assisting us with access to trawl vessels and owners. Finally, we are very grateful to the Agreement on the Conservation of Albatrosses and Petrels for awarding us this grant to further the development of this bird-scaring line compliance device.

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