Paper submitted to the Thirteenth Meeting of the CCSBT Compliance Committee, 11-13th October 2018.

A new method using AIS data to obtain independent compliance data to determine mitigation use at sea

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Abstract

Seabird mitigation measures use is a requirement for all pelagic longline vessels south of 25°S in the Atlantic and Indian Ocean, and south of 30°S in the Pacific. Monitoring the implementation of these measures is difficult due to low levels of observer coverage and the remote environment operations are conducted. Recent advances in technology provide opportunities for improved compliance monitoring at minimal cost. Here we describe a novel method for monitoring night setting compliance using Global Fishing Watch's AIS data. We assessed more than ~61,000 sets by over 300 vessels for compliance with night setting regulations using a convolutional neural network. Results indicate that in areas where seabird mitigation measures are required a maximum of ~15% of sets have less than two hours overlap with daylight, and the percentage of sets fully compliant with night setting could be much lower (<5%). In future, technology could be used for monitoring night-setting compliance at a broad scale by Member States, RFMOs and the wider public.

Introduction

Within the five tuna Regional Fisheries Management Organisations (tuna RFMOs), ICCAT, IOTC and WCPFC require pelagic longline fishers to use two seabird mitigation measures from a choice of night-setting, bird scaring line or branch line weights, whilst fishing south of 25°S, or south of 30°S in the case of WCPFC (ICCAT Recommendation 11-09, IOTC Resolution 12/06; WCPFC CMM 17-06). Further, in accordance with CCSBT's Recommendation to Mitigate the Impact on Ecologically Related Species of Fishing for Southern Bluefin Tuna, CCSBT Members are required to comply with these measures. In addition, IATTC requires its vessels fishing south of 30°S to use at least two seabird bycatch mitigation measures, selected from a longer list of options (IATTC Resolution C-11-02).

At-sea monitoring of vessel- and set-level compliance with Conservation Management Measures is difficult. However, technology is increasing the range of options available for effective monitoring. System such as electronic monitoring, Vessel Monitoring Systems (VMS) and Automatic Identification Systems (AIS) have become available to the fishing industry, governments and to some extent the general public, facilitating higher levels of scrutiny and monitoring of fleets.

In 2016 – 2018, the Royal Society for the Protection of Birds (RSPB), the UK BirdLife partner, received funding to further investigate the sources of bycatch mortality of declining South Georgia albatross populations. This identified Japan and the Fishing Entity of Taiwan as the pelagic longline fleets with the highest overlap (spatially and by fishing effort) with South Georgia albatrosses and petrels (Clay et al. 2017), which also corresponds with Japan and Fishing Entity of Taiwan having high pelagic longline fishing effort in areas overlapping with albatrosses. In addition, the project supported investigation of remote tools to monitor compliance with seabird bycatch mitigation measures.

Global Fishing Watch (GFW) is an independent, international non-profit organisation that aims to advance ocean sustainability and stewardship through increasing transparency. They do this by offering data and near real-time tracking of global commercial fishing activity.

Here we describe a new method to monitor compliance with night setting using GFW's AIS data, which presents an opportunity for compliance monitoring by RFMOs, Member States, the fishing industry and the wider community.

Methods

An analysis was conducted on Global Fishing Watch data corresponding to pelagic longline vessels that conducted sets south of 25°S in the Atlantic and/or Indian Oceans, and/or south of 30°S in the WCPFC convention area during 2017, to determine the timing of setting behaviour using AIS position data. 2017 data were used as there are substantially more AIS data available during 2017 than previous years due to more satellites in operation. For 2017, Global Fishing Watch used satellite data from satellite providers Orbcomm and Spire, thus drawing on AIS received from more than 60 satellites. The analysis focused on Japanese and Fishing Entity of Taiwan vessels for this phase of method development for the two-fold reason that these were the principal fleets identified as overlapping with South Georgia albatrosses (Clay et al. 2017), and that they are the fleets with the high pelagic longline fishing effort in areas overlapping with albatrosses. However, the approach has been designed such that it can be applied to any AIS data, regardless of flag.

The model used to classify vessel locations as setting/not setting is a 1D, convolutional neural network, generally similar in structure to the classic LeNet-5 architecture (LeCun et al. 1998) although implemented in 1D rather than 2D[1].

The model was trained using thirteen 15-day periods of hand-annotated vessel tracks, each labelled by up to three annotators for a total of 37 labelled tracks. The ability of the annotators to accurately label tracks was in turn evaluated by comparing their performance to BirdLife data for three of the tracks for which we have high quality logs from BirdLife observer fishing trips. The latitude, longitude, speed, course and setting status of the vessel was interpolated onto one-hour intervals before being passed to the model. Set timings predicted by the model were then compared to the timing of nautical dawn and dusk at the setting location to determine compliance with night setting.

The performance of the model was evaluated using four measures of cross validation:

- Accuracy: proportion of locations at which hand-annotators and the model agree on setting/not-setting
- Recall: the ratio of the number of times that the model predicts that a vessel is setting compared to the number of times that the annotators say the vessel is setting.
- Precision: the ratio of the number of times that the model predicts that a vessel is setting compared to the number of times the vessel is actually setting (according to the annotators).
- F1-score (1 / (1/ recall + 1/precision)), where recall and precision together give a balanced picture of the success of the model at finding all the time points when the vessel is setting (recall) and how likely a given time point assigned as setting is actually setting (precision).

Both Accuracy and F1-score give an overall measure of how the model is doing, with F1-score less affected than Accuracy by biased data sets.

The analysis examined two datasets, the first being the whole data set of ~61,000 sets by over 300 vessels, which included sets in the Atlantic Ocean, Indian Ocean and the Pacific Ocean. However, these data include a number of vessel tracks with large gaps in time between vessel positions, largely because some vessels broadcast weaker class B AIS messages, which are often not received by satellites. Visual inspection of these tracks suggests that it is possible to identify the presence/absence of setting behaviour, but the large gaps make it harder be confident of the precise location and time of the start and end of the set.

As a result, a second dataset was created, filtered to sets with a daily AIS coverage gap of 2 hours or less. As sets are interpolated to whole hours, the result is that any errors in set length due to a coverage gap will at most be one hour. Additionally, the vessel list was filtered to include only vessels that had at least 30 sets with a data gap of <2 hours south of 25°S (south of 30°S in the WCPFC area), such that we could calculate a robust estimation of median setting time per vessel. The dataset was also filtered to remove sets that occurred on a day when two vessels may have shared the same AIS identity (spoofing), and was filtered to exclude data from the IATTC Convention Area, as this is not included in the CCSBT ERS Recommendation. This filtering resulted in a refined dataset of 15,049 sets from 201 vessels, on which the majority of results presented below are based.

For each set we calculated the number of hours that setting occurred outside of the hours between nautical dusk and nautical dawn ("daylight"). For sets that occur entirely between nautical dusk and nautical dawn (from here on known as "night setting") this number is 0. For sets that occur entirely in daylight this number is the entire set

[1]For detailed information on the model see: https://github.com/GlobalFishingWatch/gfw-longline-sets-model

duration. For sets that overlap with nautical dawn or dusk, the number represents the amount of time that a set either continued into daylight or was initiated before night.

Given that the model is based on hour-interpolations, and we don't expect the neural network to always accurately predict the exact start and end of each set, we also created an additional category of "Mostly Night Sets" for those sets in which the model predicts setting to either occur at night or overlap with daylight by less than 2 hours. However, this will overestimate the number of compliant night sets, by including as night sets those that did not actually occur completely during the night due to the uncertainty around exact start times of sets.

We use median daylight overlap for each vessel rather than distribution of daylight overlap for all sets, as sets by the same vessel are unlikely to be independent, as vessels tend to have particular setting routines, and this could lead to pseudo replication.

Results

In total we analysed ~61,000 sets by 300 vessels in our full data set, and 15,049 sets by 201 vessels in the refined data set. Of the 201 vessels in the refined data set 148 fished south of 25ºS (30ºS in WCPFC), representing 52 Japanese and 96 Fishing Entity of Taiwan vessels.

Cross validation between model results and the results from the hand-annotation were as follows and indicate 90% confidence in the model:

	Score
Accuracy	0.94
Recall	0.91
Precision	0.90
F1-score	0.90

As an additional check, 30 tracks that were not part of the training set were labelled by the model and then reviewed by hand to verify that it was correctly labelling the setting locations. These showed the model labelling a large majority of the sets correctly, consistent with the above metrics.

The results of the analysis based on the refined data set are presented in Table 1. Across all oceans, the model identified 3.4% of sets south of 25ºS (30ºS in WCPFC) as being fully night set, and 13.1% of sets as mostly night sets (overlapped with daylight by <2 hours). The majority of sets (86.9%) south of 25ºS (30ºS in WCPFC) overlapped with daylight by >2 hours.

For the sets that occurred outside of the areas of the seabird bycatch CMMs (north of 25ºS, or north of 30ºS in WCPFC) we determined that 13.4% of sets were mostly night set (overlap with daylight by <2 hours) and 86.6% of the sets overlapped with daylight by >2 hours. As such, there is no evidence that vessels are changing their setting timing in relation to their location, with the vast majority of vessels overlapping with daylight by >2 hours in all areas (Figure 1).

The results are very similar when calculated using the full dataset (84.1% of the sets south of 25ºS overlap with daylight by >2 hours and 84.5% of the sets north of 25ºS overlap with daylight by >2 hours) (Figure 1).

Most vessels that overlap with day light are overlapping with nautical dawn rather than nautical dusk (Figure 2).

[1]For detailed information on the model see: https://github.com/GlobalFishingWatch/gfw-longline-sets-model

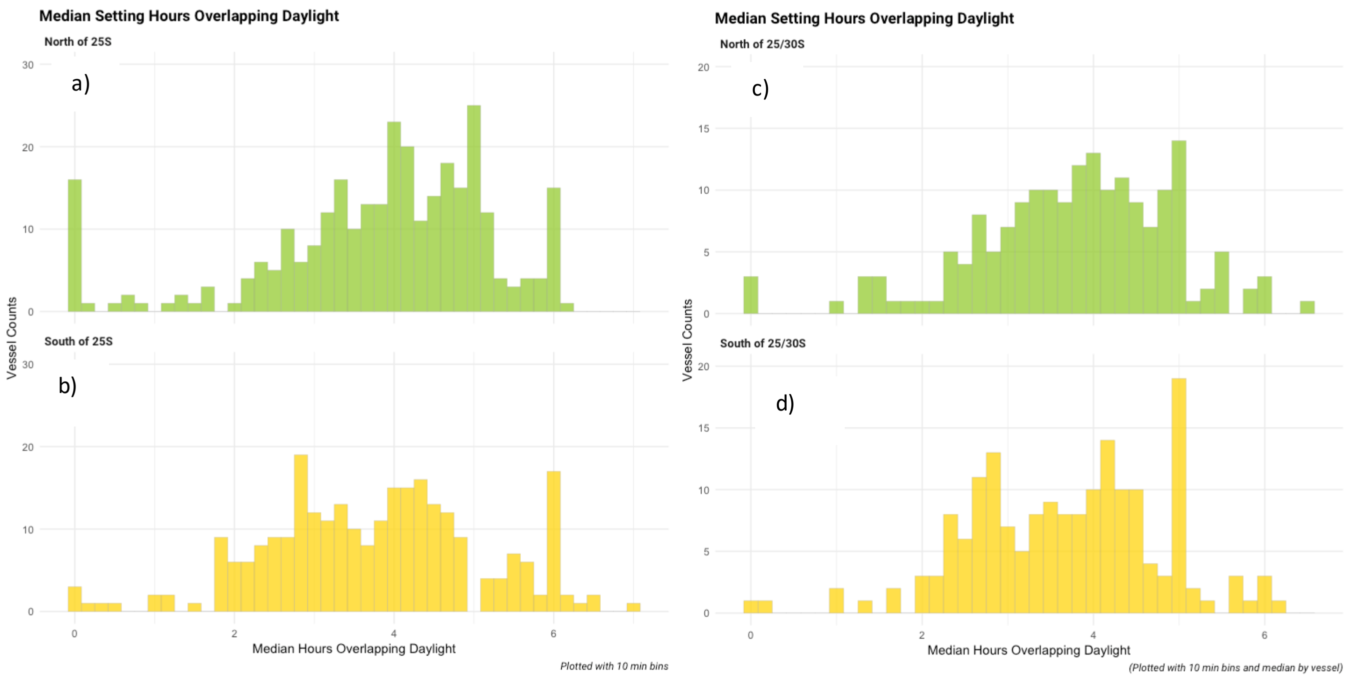

Figure 1: Median number of hours vessels overlap setting with daylight for a) full data set north of 25°S; b) full data set and south of 25°S; c) filtered data set north of 25°S (30°S for WCPFC); d) filtered data set south of 25°S (30°S for WCPFC)

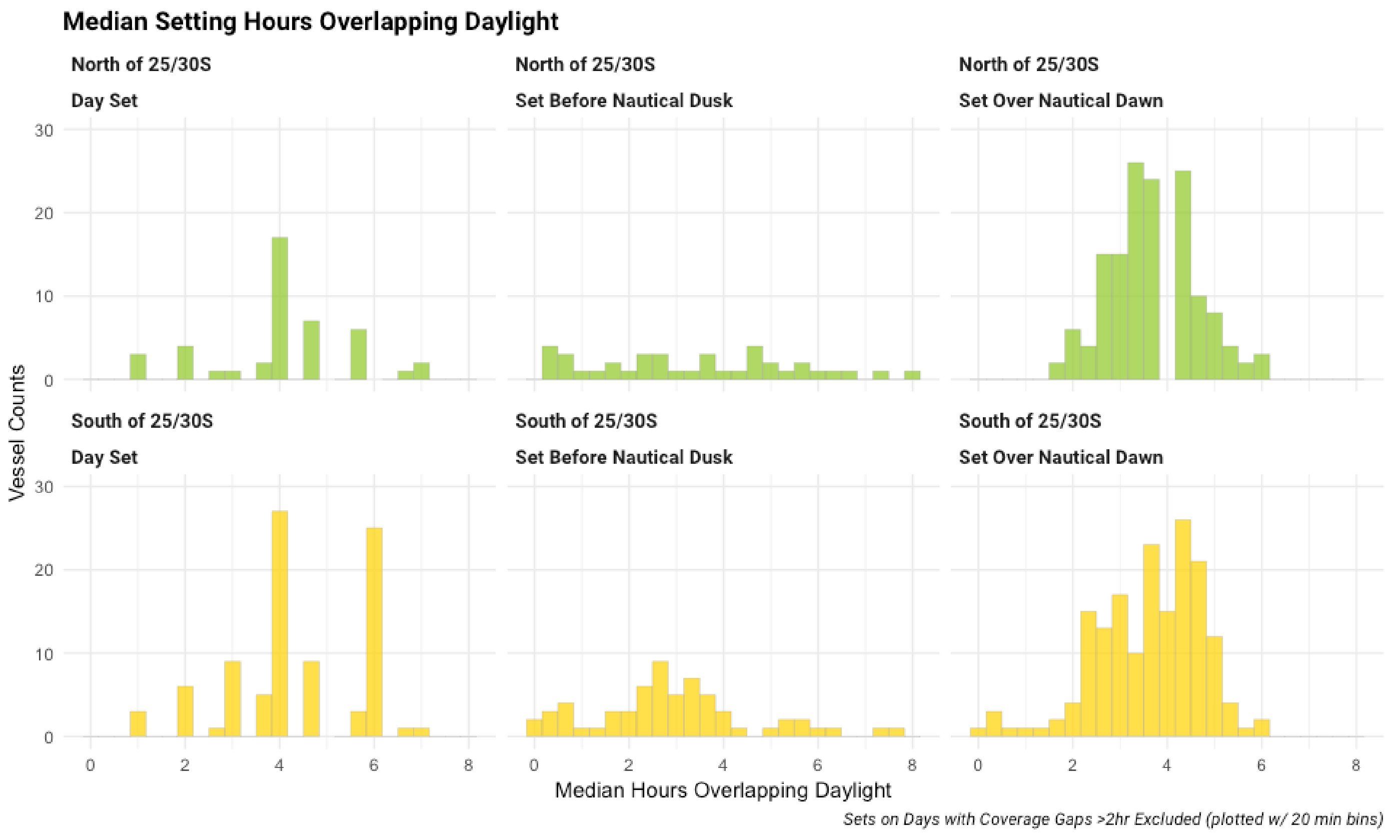

Figure 2: Median setting hours overlapping daylight for vessels setting during the day, over nautical dusk or dawn north and south of areas requiring seabird mitigation

Table 1. Evaluation of night setting by Ocean/RFMO area where seabird mitigation measures are required (data based on refined data set)

Ocean/RFMO	% compliant night sets	% mostly night sets (<2 hrs overlap with daylight)	% daylight sets (>2 hrs overlap with daylight)	Vessels	Sets
Atlantic	5.2	24.2	75.8	40	1898
Indian	3.5	11.1	88.9	115	11156
WCPFC	1.3	24.8	75.2	37	1995
Total	3.4	13.1	86.89	201	15049

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We compared vessel median setting hour overlaps with daylight by flag state (Figure 3). The results found that Japan and Fishing Entity of Taiwan have similar setting hours both north of 25ºS and south of 25ºS (or 30ºS in the WCPFC area), and very few, if any, vessels are consistently night setting.

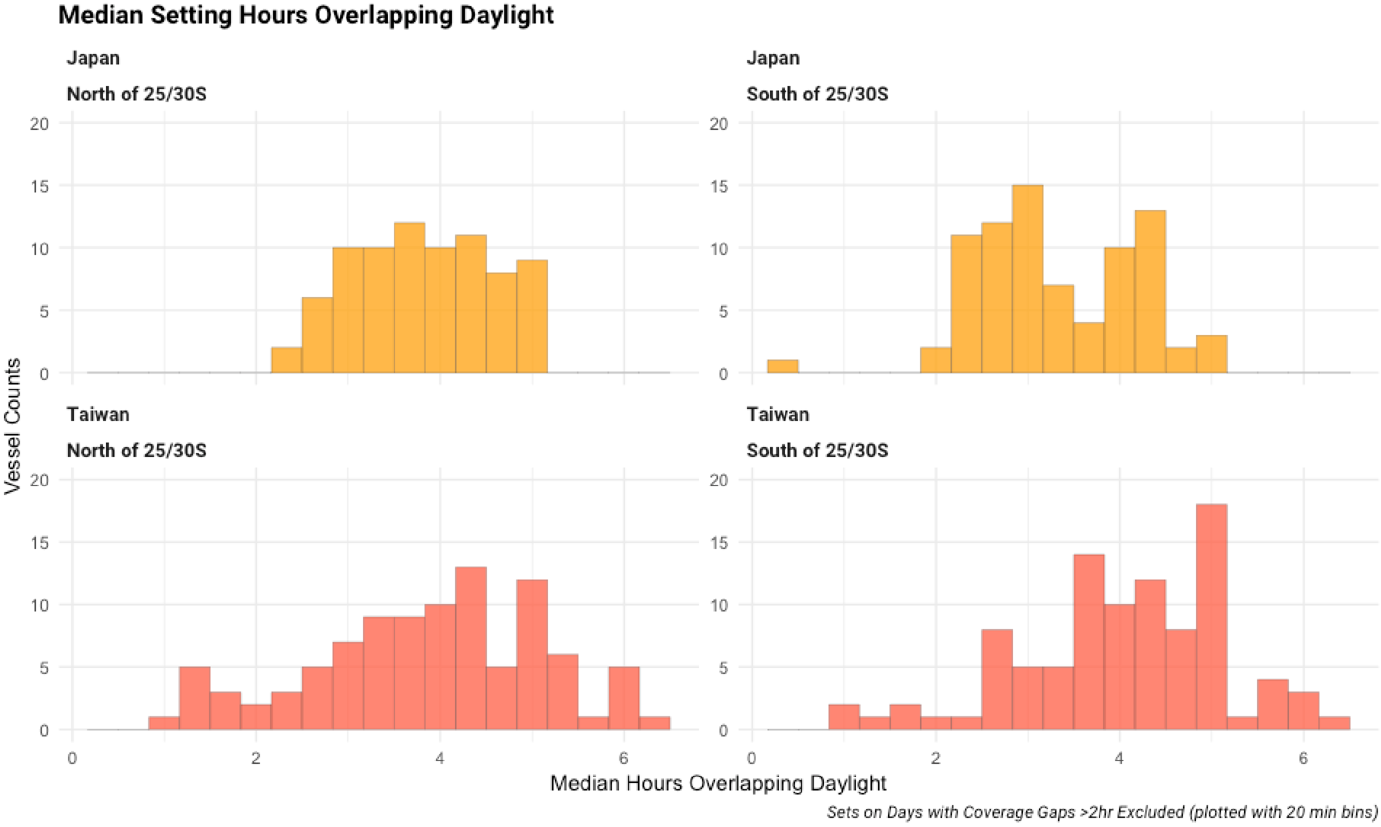

Figure 3: Median setting hours overlapping with daylight by Member State

Discussion

Night setting is one of the three bycatch mitigation measures options established under existing tuna RFMO seabird conservation measures, alongside bird-scaring lines and line weighting. The reason for its effectiveness is that seabirds, in general, are less active at night and are therefore less likely to be foraging and interact with fishing operations. For night setting to be effective the entire set must start after nautical dusk and end before nautical dawn. Indeed, the Agreement on the Conservation of Albatrosses and Petrels (ACAP) state in their Best Practice advice that line setting should not be commenced until at least one hour after nautical dusk and should complete setting at least one hour before nautical dawn (ACAP 2014). Research by Japan has shown that seabird bycatch rates are dramatically higher during the day, and specifically that bycatch rates suddenly increase one hour before sunrise, at nautical dawn, indicating that night setting is very effective for seabird mitigation (Inoue et al. 2017). This research is reflected in other bycatch studies (Baker and Wise 2005, Belda and Sanchez 2001).

However, the current study, using independence compliance data, finds that uptake of night setting as a mitigation measure by the two study fleets is very low across the oceans (less than ~15% and more likely <5%), with 85% of sets conducted with more than a two hour overlap with daylight. These levels are significantly lower than have been reported recently (Fisheries Agency of Taiwan 2017, Fisheries Agency, Council of Agriculture and Overseas Fisheries Development Council 2018, and Oshima 2017). Reasons for discrepancies in reported night setting rates versus rates predicted by independent data could be accounted for by differences in compliance with mitigation on vessels with observers, as opposed to those without observers, where vessels with observers onboard could be more likely to use mitigation. Alternatively, there could be issues with the understanding of the definition of night setting by observers, where partial night setting is recorded as compliant night setting. Our results show that a large majority of vessels are setting over nautical dawn so this could well be a possibility. Another consideration is that not all vessels are fitted with AIS. Typically, smaller vessels are less likely to have AIS. However, the proportion of Japanese pelagic longline vessels fitted with AIS is ~80% in IOTC, ~100% in WCPFC, and ~80% in the IATTC convention areas, which is a

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relatively high proportion of all vessels. The Fishing Entity of Taiwan has slightly lower AIS coverage with AIS fitted to between ~72-81% of longlines over 100 gross tons, and ~50% of their entire distant water longline fleet (Sala et al. 2018).

For fishery managers, it has been difficult to have an accurate picture of mitigation implementation due to the low levels of observer coverage on vessels and, in some cases, difficulties in interpreting set time data from logbooks because of differences in which time zones are used. Our results show that it is possible to use independence compliance data to assess night setting to within two hours of accuracy. With further training of the model on training data sets, this accuracy could be improved further, and assistance is sought from CCSBT Member States to undertake this refinement. In future, this or similar technology will be available to Member States and RFMOs to monitor use of night setting implementation on a more automated, more independent and far larger scale than has previously been possible.

Recommendations for CCSBT

- We recommend that CCSBT and Member States recognise this novel method as a mechanism by which compliance with night setting can be determined.
- We invite CCSBT Member States to work with BirdLife and Global Fishing Watch to further develop this technique.
- We ask the CCSBT Compliance Committee to establish a work plan element to investigate how technology, such as this method, can be used to improve and automate compliance reporting in relation to seabird bycatch mitigation.

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