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Report on preliminary analyses of FAD acoustic data

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Executive Summary

The deployment of satellite and echo-sounder buoys on drifting Fish Aggregating Devices (FADs) has dramatically increased their use by the purse seine fishery, with more than 30,000 FADs estimated to be deployed annually in the Western and Central Pacific Ocean (WCPO). This large volume of echo-sounder readings transmitted every day by buoys on FADs has the potential to be a useful source of information for scientific analysis that could help inform mitigation measures, enhance our understanding of fishery dynamics, and potentially provide independent data on tuna biomass for regional stock assessments. To this end, the current study investigates the type of data available, 'ground truths' acoustic estimates, and identifies further avenues of research.

The available data comprise acoustic data from over 5000 buoys deployed on FADs from US-based private sector firms Tri Marine and South Pacific Tuna Corporation in the WCPO in 2016–2018. This included data from two different satellite echo-sounder buoys: Satlink and Zunibal, which present different operational characteristics, such as biomass estimates, depth bins, transmission frequency.

The biomass estimates from echo-sounder buoys were found to be influenced by i) the time of the day, with maximum biomass estimated before sunrise, and ii) the lunar phase, with a slight increase in biomass detected during and just after the full moon.

FAD colonization processes were investigated using the maximum daily biomass estimates after deployment. Biomass estimates showed a significant increase up to around 30 days drifting. To investigate the biomass colonization before a fishing set, catch per set from logsheet operational data were matched with the acoustic dataset using position (≤ 2km) and date/time (same date). In general, high variability was detected and no clear pattern could be identified between catch and echo-sounder biomass estimates. Many factors may influence both the echo-sounder estimated biomass and the catch per set. For instance, it would be relevant to assess the catch/biomass relationships by large areas of the WCPO, as they would present different environmental characteristics. In general, an increasing trend in estimated biomass was detected over the two to five days before a fishing set. Relatively high biomass was noted >15 days before a set for many FADs.

The annual spatial distribution of biomass estimated from buoys was investigated. Although this was influenced by the fishing grounds of the two fishing companies and by the difference in estimated biomass between both echo-sounder buoy brands, it showed higher biomass in the eastern WCPO from 2°S to 10°S and 2°N to 5–10°N. Visual comparison with maps of total CPUE from associated sets showed some similarities in areas with high estimated biomass and high CPUE.

We invite WCPFC-SC15 to:

- Note results from this preliminary analysis of acoustic data from echo-sounder buoys deployed on FADs.
- Note the potential, over the longer-term, to derive an index of abundance that could be used in stock assessments.
- Note that given the high variability in the acoustic data, and the various parameters to be accounted for, there is a need for accessing a larger dataset covering the whole WCPO.
- Endorse the continued cooperative relationship with the fishing community to obtain business confidential data for analysis by regional scientists, particularly with regard to FADs, and the fishing strategies involved in their use.

1. Introduction

The deployment of satellite and echo-sounder buoys on drifting Fish Aggregating Devices (FADs) by the purse seine fishery has dramatically increased over the last two decades. In the Western and Central Pacific Ocean (WCPO), although the number of FAD sets has been relatively stable over recent years, FADs are now deployed in the tens of thousands each year and this fishing mode corresponds to more than 40% of the reported purse seine tuna catch (Williams and Reid, 2018). Satellite and echo-sounder buoys are new technological developments to track FADs and indicate the amount of tuna beneath them, which increases fishing efficiency dramatically (Lopez et al., 2014). They also have the potential to be a useful source of information for scientific investigations (Moreno et al., 2016). It has been estimated that more than 30,000 FADs with satellite buoys are deployed annually in the WCPO (Escalle et al., 2018; Gershman et al., 2015) with the majority being deployed with an echo-sounder (Escalle et al., 2019). This represents an extremely large data source that has the potential to help inform simple mitigation approaches to addressing juvenile bigeye and yellowfin tuna catches, increase our understanding of fleet dynamics, and potentially provide a new source of fishery-independent data on tuna abundance for regional stock assessments. This source of information would be particularly important for skipjack assessments, given the long-term reduction in pole and line fishing effort, the main source of informative CPUE trends for the models.

This report presents results from a scoping project in collaboration with two US-based private sector firms Tri Marine and South Pacific Tuna Corporation to investigate the available data, identify potential influences on the pattern of estimated biomass, and assess the relationships between estimated biomass under FADs and catch. Both firms have multiple large purse seine vessels that operate in the WCPO and represent a large expanse of the fishing grounds, along with operational characteristics that are representative of a large segment of the fishery. Results from evaluations performed within this project were used to identify whether the following objectives might ultimately be addressed using fisheries echo-sounder data from satellite buoys deployed on FADs:

1) Whether acoustic buoys on drifting FADs could provide new fishery-independent data for stock assessments (e.g. indices of abundance);
2) Whether limiting sets to only those FADs that have a large estimated biomass beneath them could reduce the proportion of bigeye and yellowfin caught.

2. General description of the data

2.1 Structure of the datasets

Biomass estimates were independently provided to Tri Marine and South Pacific Tuna Corporation by the two satellite echo-sounder buoy providers (Satlink and Zunibal), each with unique characteristics (Table 1). The data available for analysis comprised acoustic data from 4546 Satlink and 583 Zunibal buoys deployed on FADs in the WCPO in 2016–2018. This tranche of data corresponded to over 3.5 million transmissions.

Satlink buoys transmitted acoustic (echo-sounder readings) and position information separately, with generally two transmissions of position data and three acoustic readings (mostly around sunrise) per day. In order to access the position related to each acoustic transmission, we linearly interpolated the position dataset at those times. Hence, for each echo-sounder reading, we had access to estimated position, date/time, total biomass estimates (t) and biomass estimates at 11.2m depth intervals or bins from 3 to 115m.

Zunibal buoys transmit every hour with data for both the position of the buoy and echo-sounder readings. Transmissions included position, date/time and total estimated biomass (t). In addition, for some of the data, transmission included raw echo-sounder data at 1.6m depth bins from 1.6 to 120m. Finally, Zunibal buoys present a sensor archiving in/out water position, allowing access to buoy deployment position, which was available for a subset of the Zunibal data.

Generally, the different characteristics of each echo-sounder buoy brand will affect the analyses performed on acoustic data. Most of the analyses were therefore performed separately. In addition, given the higher number of Satlink buoys, with larger spatial distribution and access to data per depth bins, most of the preliminary analyses presented in this paper were performed on Satlink data only.

Table 1. Summary of received data per echo-sounder buoy brand.

Brand	**Satlink**	**Zunibal**
Year	2016–2018	2016–2018
Number of buoys	4546	583
Frequency of echo-sounder readings	Generally 3 per day (range 0-4)	Generally 1 per hour with associated position
Frequency of position transmission	Generally 2 per day	Generally 1 per hour with associated acoustic data
Number of echo-sounder transmissions	2,620,434	884,271
Biomass estimates	Total estimates in tons	Total estimates in tons
Biomass estimates per depth bin	Yes 11.2m; from 3 to 115m	No
Echo-sounder raw data	No	Occasionally 1.6m; from 1.6 to 120m
Buoy deployment position	No	Occasionally

2.2 Data processing

Similar to the analysis of the Parties to the Nauru Agreement (PNA) FAD tracking dataset (Escalle et al., 2019), the raw position and acoustic dataset included transmissions from active buoys drifting at-sea but also included data from some that were still on-board a vessel (before deployment, or following recovery). Therefore, data were processed by identifying at-sea and on-board positions following the approach of Maufroy et al. (2015). Random Forest models were calibrated using a learning dataset, then used to predict the class (at-sea or on-board) of positions in the echo-sounder dataset. Additional correction procedures were also performed to eliminate isolated or short at-sea or on-board sections surrounded by long on-board or at-sea positions (Escalle et al., 2019). Each buoy trajectory with acoustic data then consisted of one (85% of the FADs) or several drifting ("at-sea") segments (2–7 segments per FAD), separated by "on-board" positions. Deployment positions were identified as the first at-sea position.

Note that this data processing procedure was not needed for some of the Zunibal data, for which deployment positions and transmissions from being on-board a vessel were already known.

For some analyses the data were separated into main areas of the WCPO : i) equator, between 5°S and 5°N; ii) southwest, south of 5° S and west of 175°E; iii) southeast, south of 5° S and east of 175°E; and iv) north, north of 5°N (Figure 1).

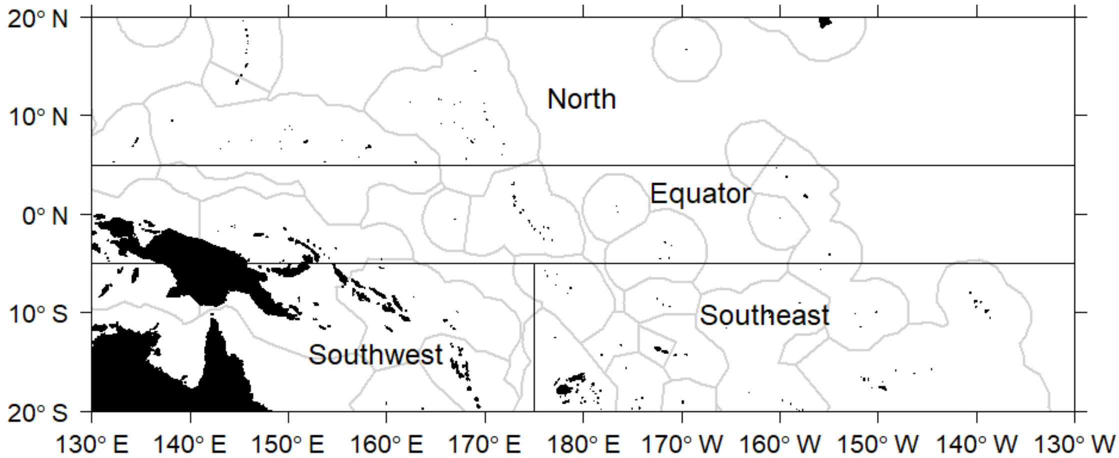

Figure 1. Map of the areas of the WCPO used in the study.

3. Maximum estimated biomass and influence of the time of the day

The biomass estimated by echo-sounder buoys ranges from 0 to 350 t (Figure 2). However, the profile of the distribution of maximum daily biomass estimates was different between Satlink and Zunibal buoys. For the majority of days, the maximum estimated value from Satlink buoys was between 1 and 5t. Note that when the echo-sounder estimated a biomass of less than 1t, no acoustic signal was sent, only a transmission of the position was received. The distribution of maximum daily biomass estimates decreases gradually from 5 to 100t. Zunibal buoys presented maximum daily estimated biomass mostly between 0 and 25t, then a gradual decrease in the distribution of maximum daily biomass from 30 to 100t was seen (Figure 2).

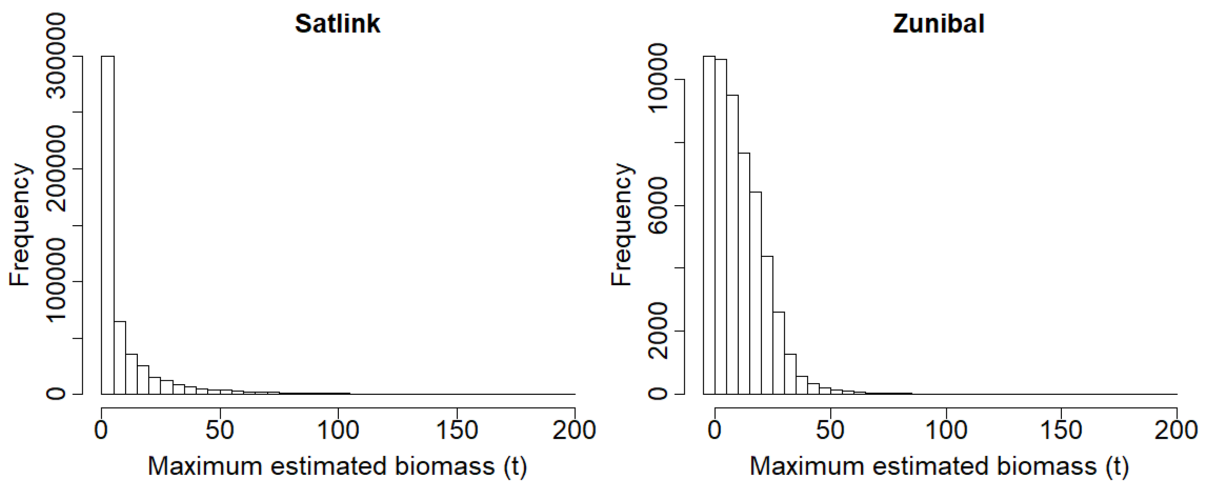

Figure 2. Maximum estimated biomass per day for the Satlink and Zunibal echo-sounder buoys. Values above 200 t (0.4% of all values) were removed from the histogram to increase interpretability.

Satlink buoys usually transmit three echo-sounder readings daily (models DSL+), mostly before sunrise, or an echo-sounder reading per hour (model ISL+) (Figure 3). Zunibal buoys usually transmit echo-sounder data every hour or two (Figure 4). The maximum daily biomass was found before sunrise for Satlink buoys, mostly from the three hours before sunrise (Figure 3). Zunibal buoys showed a different pattern, with a maximum daily biomass being found from 1h to 9h before sunrise (Figure 4).

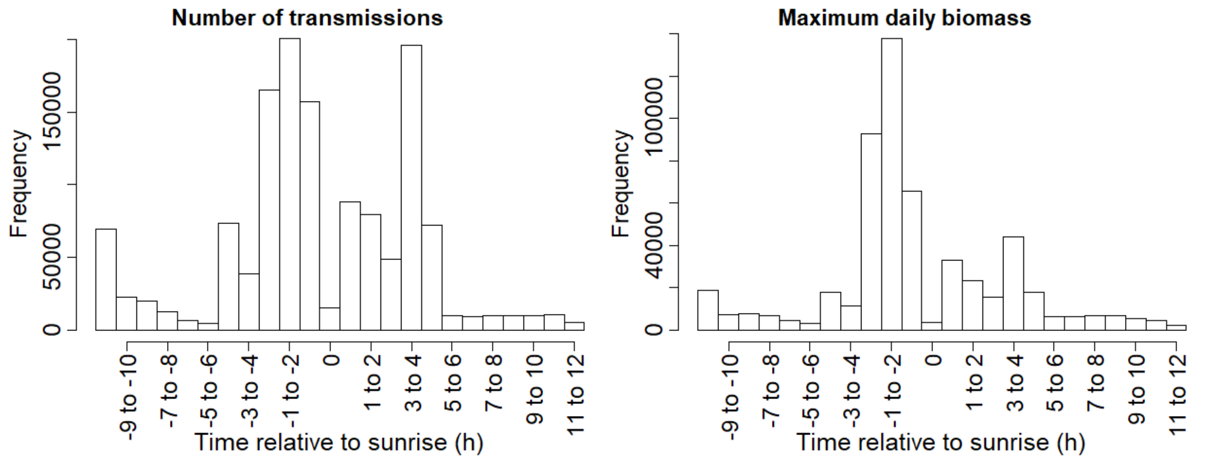

Figure 3. Time relative to sunrise of acoustic data transmission (left) and of the maximum biomass estimated per day (right) for Satlink buoys.

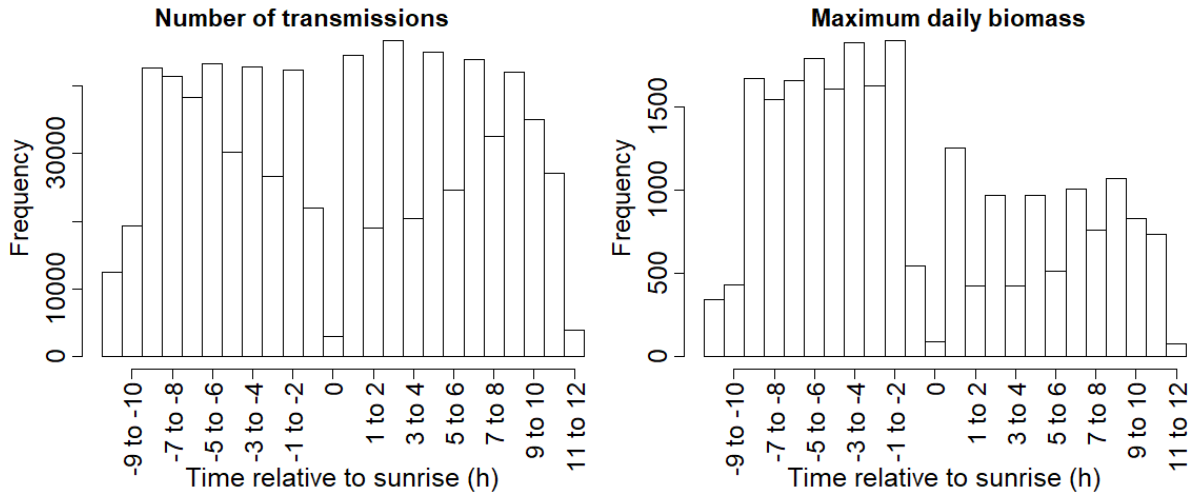

Figure 4. Time relative to sunrise of acoustic data transmission (left) and of the maximum biomass estimated per day (right) for Zunibal buoys.

4. Colonization of biomass after FAD deployment

FAD colonization processes after deployment were investigated using the maximum biomass estimated per day or per 5-day periods per buoy (Figure 5). Note that the deployments considered here are the buoy deployments, which may not correspond to the FADs' actual deployment, as buoys may be deployed on FADs of floating objects found at-sea. This will therefore add bias to analyses of colonization processes. In addition, although for this project we had access to the full acoustic trajectories from buoys of the two participating fishing companies in the WCPO, some FADs/buoys may have been deployed in the EPO, and drifting time would in reality be longer.

Our analysis suggests that across the WCPO the estimated biomass generally increases up to around 30 days post deployment (Figure 5), biomass then remains relatively constant over the next few months. Some reduction of biomass is seen after about 60 days. Similar trends were found for buoys transmitting in the equator area only (Figure 6). In the southeast and southwest areas, no clear trend through time could be identified, with the range of biomass being at relatively high levels from the beginning in the southeast. This could be due to the fact that many FADs were deployed in the EPO but only appeared in our dataset when entering the WCPO convention area. Therefore drifting times considered here would have in reality already being longer. However, the difference in the colonisation patterns detected in the equatorial region could also potentially be linked to stronger currents in this area, causing the steadier detection levels compared to other areas (Figure 5). Finally, in the southwest region, few buoys transmitted data, leading to very high variability in the data. This could also be caused by some FAD still transmitting while beached, causing some of the variability and high marks detected.

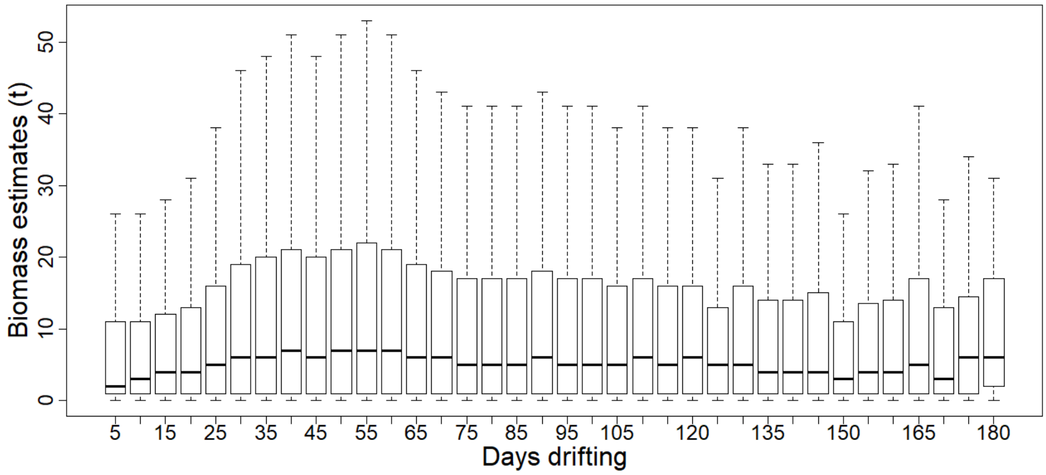

Figure 5. Evolution of the maximum biomass estimates from Satlink echo-sounder buoys in 5-day bins post deployment.

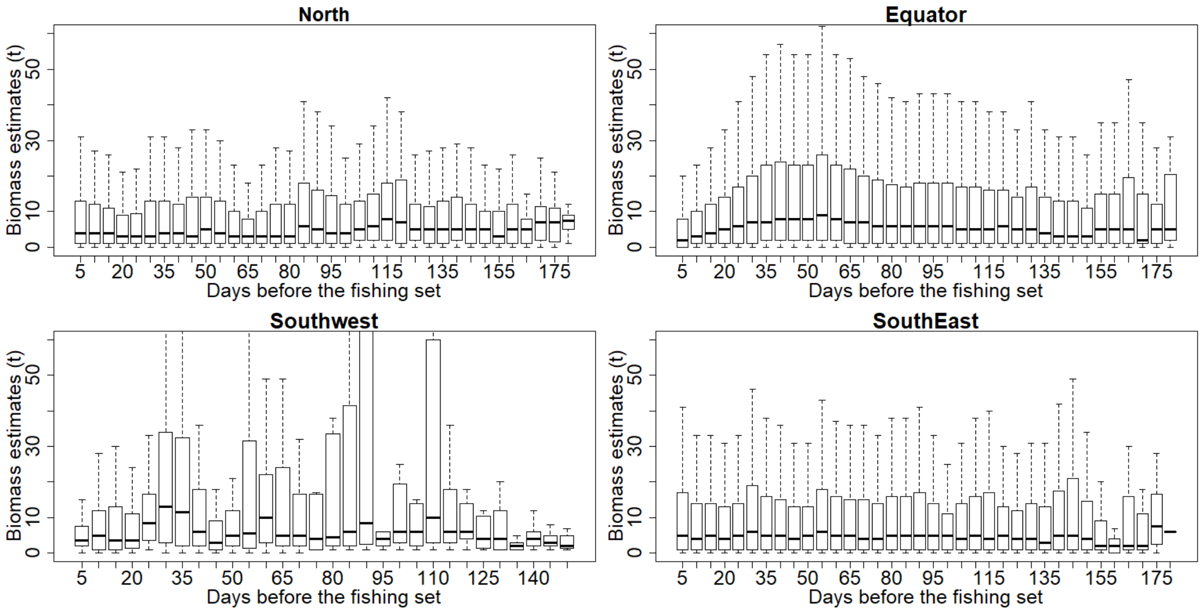

Figure 6. Evolution of the maximum biomass estimates (t) from Satlink echo-sounder buoys over 5-day periods with time after buoy deployment, per areas of the WCPO.

5. Influence of the lunar phase

The influence of the lunar phase on the biomass has been suggested as a factor affecting catch rates of tuna and was investigated here (Figure 7). Although additional analyses are needed to test if the patterns are significant, an increase in the range and median estimated biomass is detected at, and just after, the full moon, in all areas except the southwest.

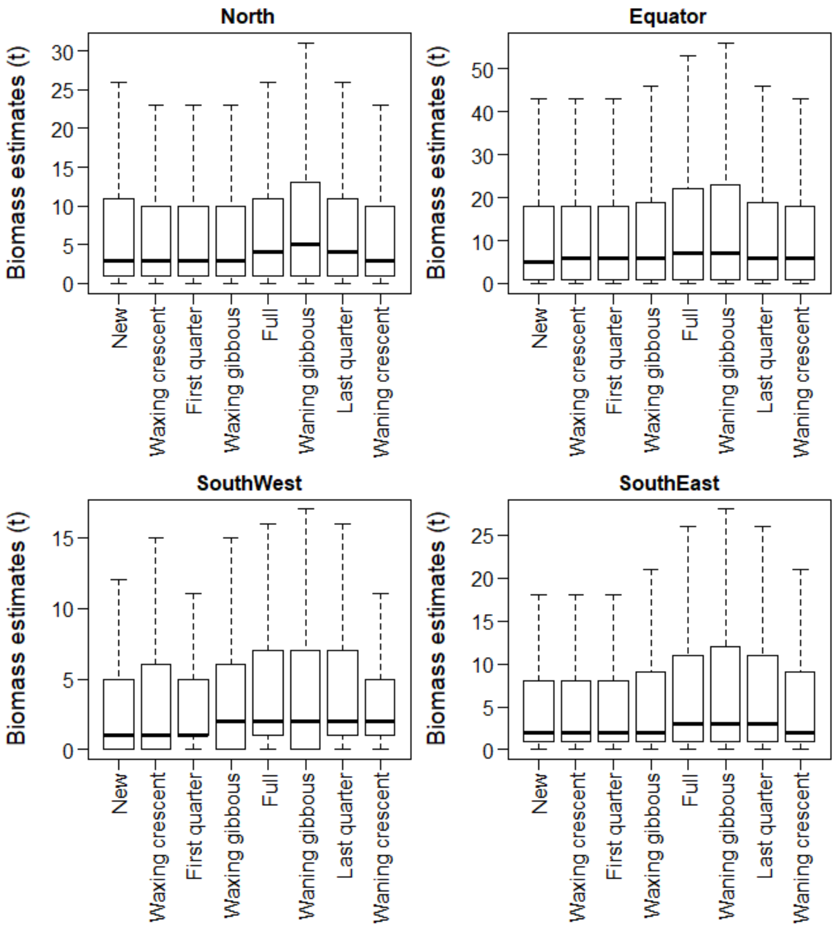

Figure 7. Boxplot of the maximum daily biomass estimates from Satlink echo-sounder buoys and moon phase by area within the WCPO.

6. Relation between achieved catch and estimated biomass

Although independent estimates of biomass are not available to ground-truth the estimates derived from the echo-sounder buoys, the relationship between estimated biomass and resulting catch can be used to provide some useful information.

6.1 Relationship between catch and estimated biomass: high inter-FAD variability

Catch per set from logsheet operational data of vessels from the company owning the considered FADs was matched with the acoustic dataset using positions (≤ 2km) and date/time (same date). The relationship between catch and the echo-sounder estimated biomass on various periods before the set was studied (Figure 8). In general, considerable variability was detected and no clear pattern could be identified between catch and maximum estimated biomass 1, 2 or 3 days prior to the set, nor the mean estimated biomass over 5, 10 or 20 days prior to the set (Figure 8). Similarly, it is also important to consider the biomass estimated by depth, but again when considering all matched sets together, high variability was detected. In general, the biomass estimated by the echo-sounder is higher than the achieved catch.

Many factors may influence both the echo-sounder estimated biomass and the catch per set. First, the whole school may either not be detected by the echo-sounder, much less caught during the set. Second, a mix of species will influence the echo-sounder readings; the algorithm is programmed to estimate biomass for schools of skipjack only. In particular, bycatch species will also be detected by the echo-sounder, but will not appear in the logsheet catches.

As previously noted, this is a preliminary analysis. In general, it would be relevant to study the catch/biomass relationships by large sub-areas of the WCPO, as they present different environmental characteristics. In particular, it is important to isolate analyses for the equatorial region in which higher current speeds are experienced that could lead to overestimates of the biomass by the echo-sounder. It is also important to account for the precise time relative to sunrise (see section 3) for both the echo-sounder data and the fishing set. For instance, if the set starts after sunrise the tuna school may have already started to leave the FAD, leading to a higher estimated biomass compared to the tuna catch. It would also be relevant to identify and separate the purely targeted FAD sets from the more opportunistic ones (set on a nearby FAD when cruising, or set on a FAD belonging to another vessel that was found at-sea). In order to more effectively account for all these parameters, access to a larger dataset covering all the different areas of the WCPO is needed.

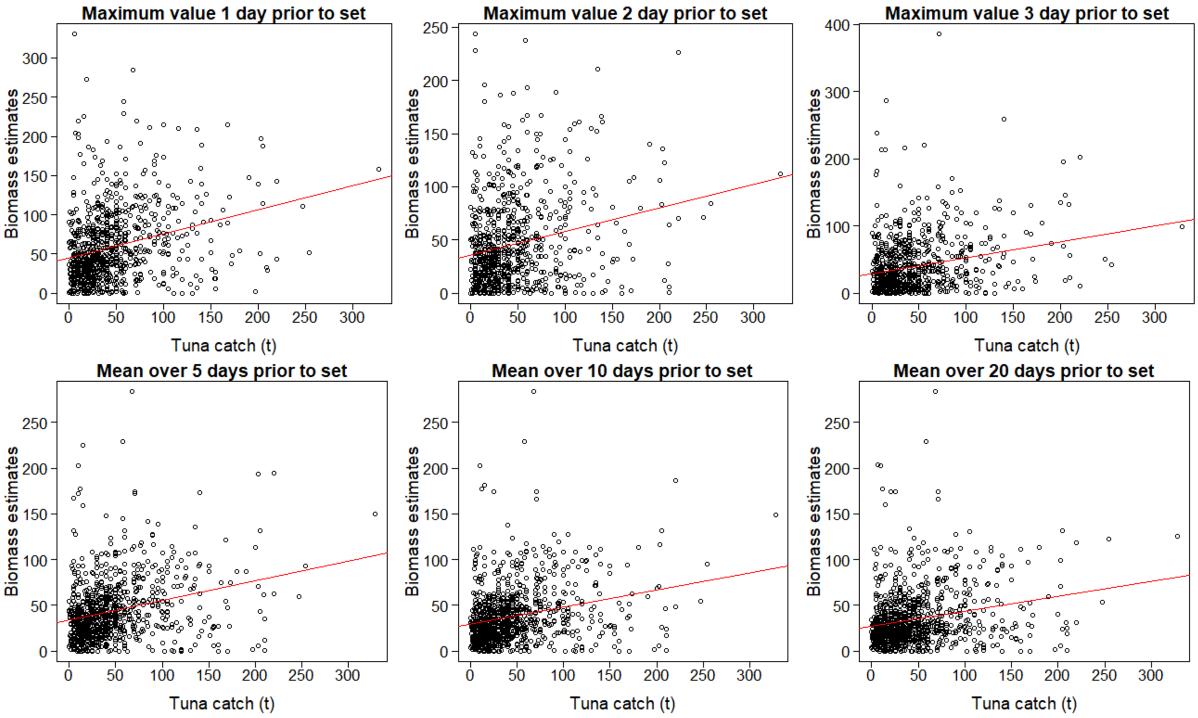

Figure 8. Relationship between catch per set (t) and the estimated biomass (t) from Satlink buoys over various periods preceding the set.

6.2 FAD-specific Patterns

Patterns of biomass estimates before and after a fishing set were investigated for some example FADs to better understand the variability between catch and biomass (Figure 9). In general, an increasing trend in biomass is detected before a fishing set. However, on a day to day basis, very high variability is detected, making any catch/biomass relationship based on a given day or period of days prior to the set highly variable (the two examples show high biomass the day prior to the set, but this is not always the case). After the fishing set, very low biomass is detected by the echo-sounder, with sometimes a biomass accumulation detected again after a few days (Figure 9).

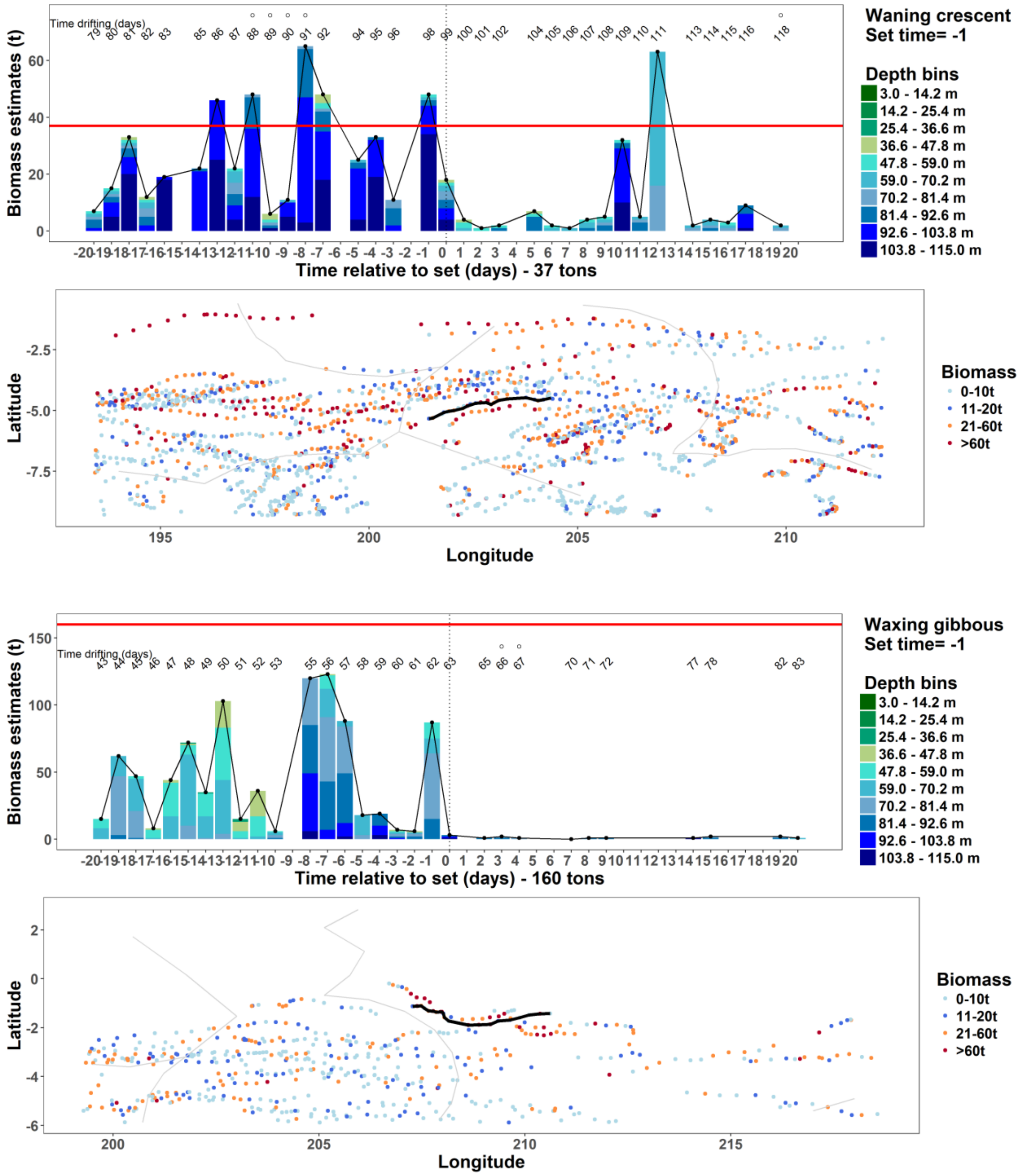

Figure 9. Two examples of biomass accumulation, from Satlink buoys, before and after a fishing set. The upper panels show the maximum biomass per day (20 days prior to and after a fishing set) and per depth bin and the red horizontal line indicates total recorded catch of the set. On the top right, above the legend, the moon phase (also indicated with circles for the full moon, above the drifting days) and the time relative to sunrise, of the beginning of the set. The lower panels indicate the drift trajectory of the FAD during the 20 days period prior to the fishing set, with the estimated biomass of nearby FADs for the same period.

Maps of the drift trajectory of each FAD, with the biomass estimated by near-by FADs, were also developed to explore if similar biomass patterns were found in near-by FADs. However, the FADs appearing on the map corresponds to only a small fraction of the FADs for which we had access to the acoustic data during this project and results are not always conclusive (Figure 9).

The evolution of the biomass estimated by echo-sounders before a fishing set was also studied for a selection of buoys matched with a fishing set (buoys with only one set identified and transmitting for more than 20 days before that set) to investigate potential patterns of biomass accumulation (Figure 10). The majority of FADs (80%) presented a maximum estimated biomass per 5-day period >30t just before a fishing set. Long-term relatively high biomass levels before a fishing set was made was also detected for many FADs. In particular, half of the sets with a total catch of more than 30t show the presence of estimated high biomass (>30t) for more than 15 days prior to the set.

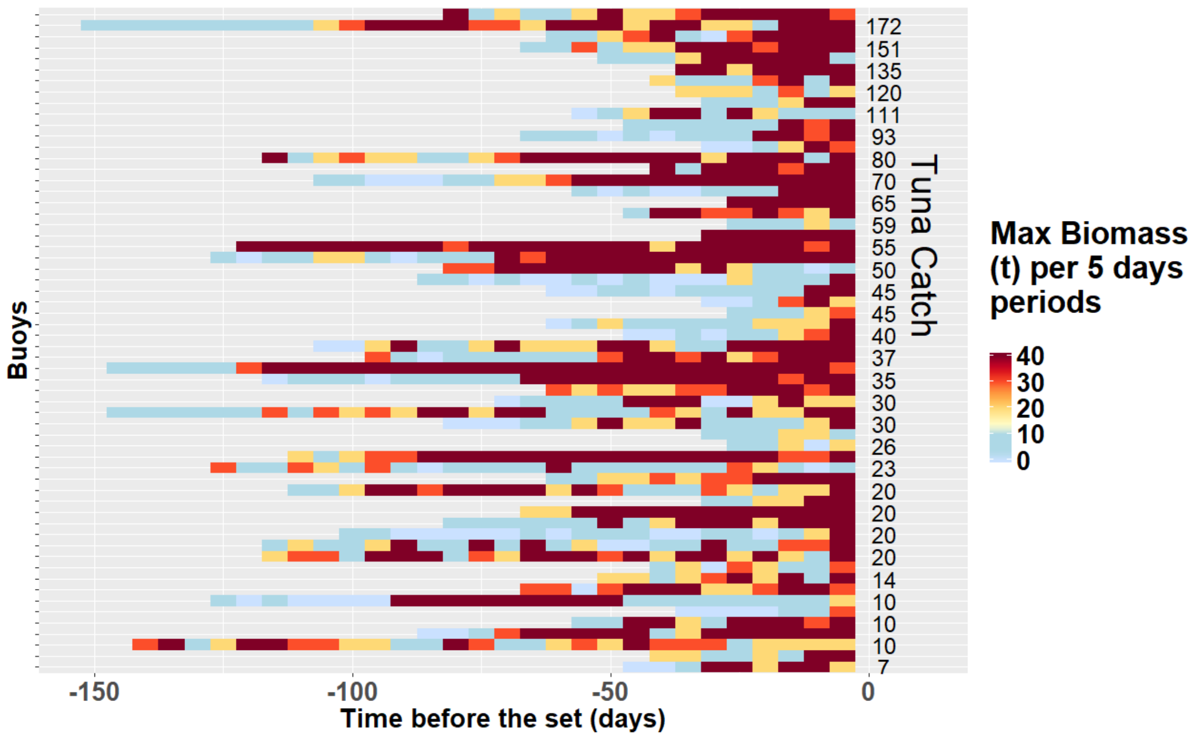

Figure 10. Maximum estimated biomass (biomass >40t rounded to 40t to increase interpretability) by Satlink buoy in 5-day bins before a fishing set on the corresponding FAD.

6.3 Biomass accumulation before a set

The pattern of the maximum daily biomass before a fishing set was examined (Figure 11). An increase in the biomass was estimated by the echo-sounder two days before the set. The range of maximum biomass the day prior to a set was 0 to 140t, with most buoys (interquartile) having an estimated biomass between 30 and 80t (Figure 11).

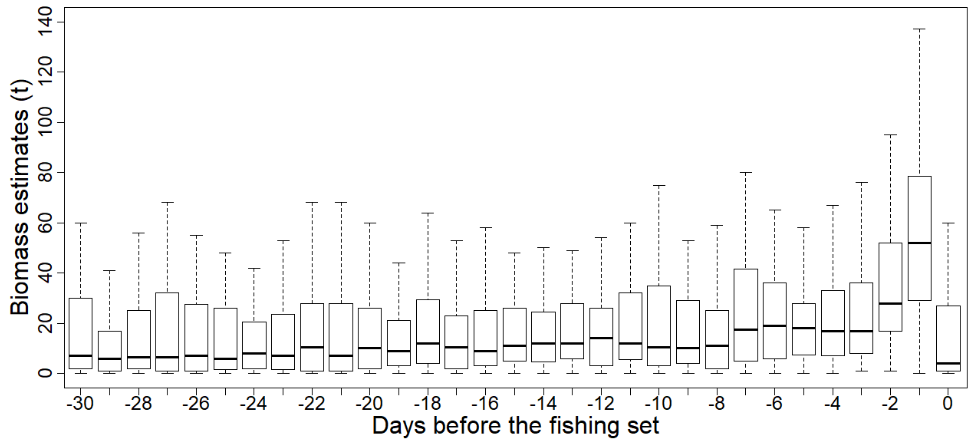

Figure 11. Evolution of the maximum daily biomass estimates from Satlink echo-sounder buoys each day before a fishing set.

When separating the dataset of buoys matched with a fishing set by large areas of the WCPO (excluding the southwest area with very few matched sets), aggregation patterns are slightly different (Figure 12). In the north and southeast areas, aggregation before the fishing set appears more gradual, with an increase over a 5-day period. However, the maximum biomass is, in general, reaching higher values in the southeast than in the north area. In the equator, the maximum daily biomass increases suddenly one to two days prior to the fishing set, but also shows more variability over the whole period studied (boxplot shows only up to 65 days prior to a set). This could highlight the more variable nature of the biomass in the equatorial area, which could potentially be affected by generally higher current speeds.

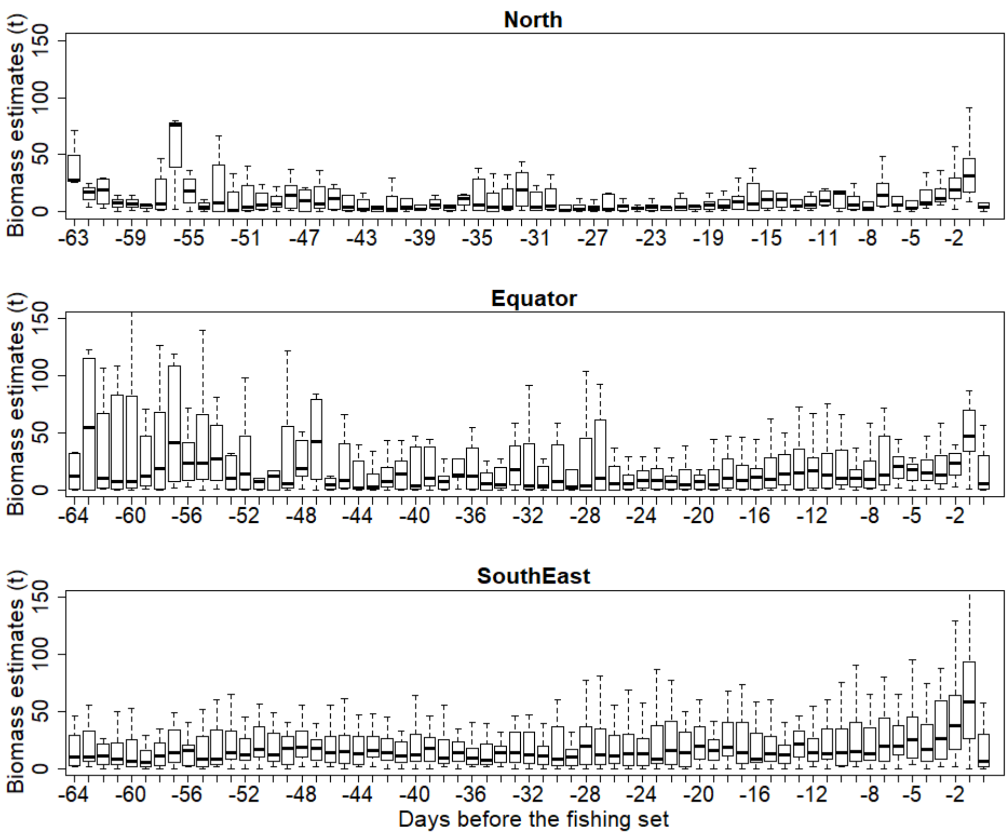

Figure 12. Evolution of the maximum daily biomass estimates from Satlink echo-sounder buoys each day before a fishing set, per areas of the WCPO.

7. Spatial distribution and links with CPUE

The annual distribution of the positions of each buoy, with the maximum estimated biomass per 5-day period, shows higher biomass in the eastern WCPO from 2°S to 10°S and 2°N to 5–10°N (Figure 13). It should, however, be noted that the distribution of the buoys is highly linked to the main fishing grounds of the two fishing companies. In turn, data from the two buoy brands with different characteristics were compiled to produce the maps, which adds a bias in the visualisation of maximum estimated biomass. The spatial distribution of buoys and estimated biomass was compared to the total CPUE from associated sets (all fleets). In general, areas with higher CPUE corresponded to areas with a high biomass. For instance, southeast of the WCPO in 2016, or northwest in 2017 (Figure 13).

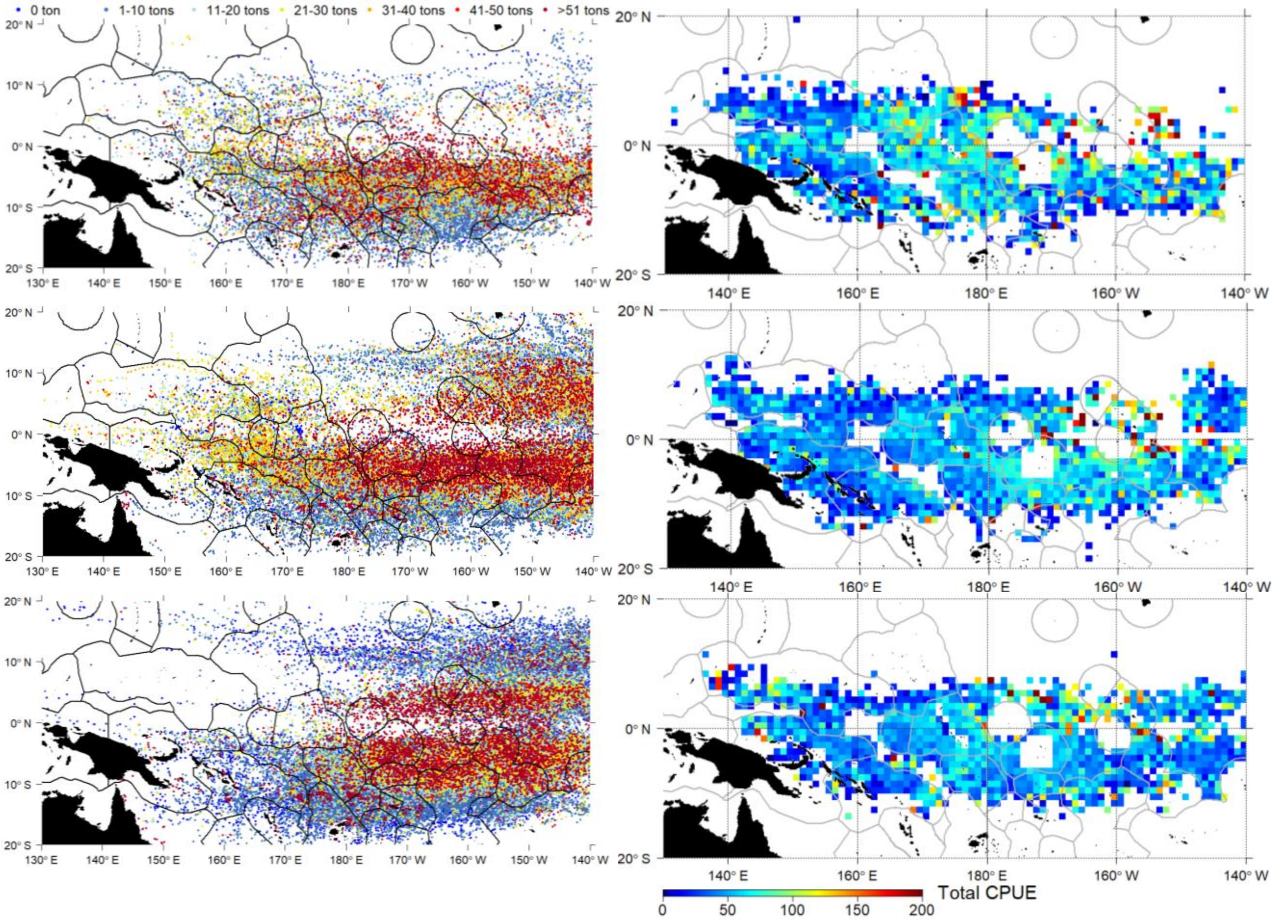

Figure 13. Mean biomass estimates from Satlink and Zunibal echo-sounder buoys per 5-day period (left) and total CPUE from associated sets (right) per year (2016 top; 2017 middle; and 2018 bottom). Note that biomass estimates are from the two different buoy brands, which may not be comparable; and that data from 2018 are incomplete.

8. Discussion and Conclusion

This reports presents data from over 5000 echo-sounder buoys, from Satlink and Zunibal brands, deployed on FADs in the WCPO from 2016 to 2018 by two commercial fishing companies. Both brands presented different characteristics, including the algorithm used to estimate total aggregated biomass, making inter-brand comparison difficult. Colonization and recolonization (i.e. after a fishing set) patterns were studied using echo-sounder and catch data. However, although buoy deployments could be easily identified, it remains challenging to identify whether it corresponds to newly deployed FADs or re-deployments. Biomass estimates in relation to total catch per set were investigated but the raw biomass estimates from echo-sounder data were highly variable.

Although it is clear that additional analyses are needed (Baidai et al., 2018; Lopez et al., 2016), in particular to link biomass estimates with catch per set, the preliminary analyses presented in this paper highlight the need for accessing a larger dataset covering all WCPO fishing grounds. Nevertheless, a general increase in biomass, and/or a long-term signal of relatively high biomass before a fishing set, indicated the potential for the derivation, using echo-sounder data, of an index of abundance that could be used in stock assessments. In addition, we were able to match the acoustic dataset with fisheries data and hence achieved catch per set. Results from this scoping project therefore highlight the feasibility for additional research on two main objectives stated in the introduction:

1) Investigate the potential use of acoustic buoys on drifting FADs to provide new fishery-independent data, and in particular indices of abundance, for stock assessments;
2) Investigate the link between high aggregated biomass and the proportion of bigeye and yellowfin in the catch.

Potential additional research topics include:

- Further investigate the relationship between biomass estimates, raw or corrected biomass, and catch per set. Acoustic estimates per depth bin and catch per species should be accounted for, including accessing bycatch estimates from observer data.
- Comparison with newly deployed FADs could be performed, to access acoustic signal of non-tuna species only.
- Study recolonization patterns after a fishing set.
- Identify deployment of FADs initially-deployed at the same time as the buoy. This could be facilitated by accessing the whole trajectory of a FAD, including data from the EPO for FADs deployed there.
- Perform further analyses to compare the estimated biomass between satellite echo-sounder buoy brands.
- Although we have used logsheet catch estimates to ‘ground-truth’ buoy estimates of biomass, there are significant assumptions that must be made when doing so. Direct comparisons between e.g. vessel systems that can be compared directly to those from neighbouring FAD buoys would supplement these evaluations. Field-trials may be required to undertake these analyses.
- Current echo-sounder biomass estimates are based upon an assumption that tuna are skipjack. Refinement of biomass estimates for species will be an important development, particularly when considering their use as abundance estimates for stock assessment.

We invite WCPFC-SC15 to:

- Note results from this preliminary analysis of acoustic data from echo-sounder buoys deployed on FADs.
- Note the potential, over the longer-term, to derive an index of abundance that could be used in stock assessments.

- Note that given the high variability in the acoustic data, and the various parameters to be accounted for, there is a need for accessing a larger dataset covering the whole WCPO.
- Endorse the continued cooperative relationship with the fishing community to obtain business confidential data for analysis by regional scientists, particularly with regard to FADs, and the fishing strategies involved in their use.

Acknowledgments

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References

Baidai, Y., Capello, M., Amandè, M.J., Gaertner, D., Dagorn, L., 2018. Supervised learning approach for detecting presence-absence of tuna under FAD from echo-sounder buoys data. Collect. Vol. Sci. Pap. ICCAT, SCRS/2018/125.

Escalle, L., Brouwer, S., Pilling, G., PNAO, 2018. Estimates of the number of FADs active and FAD deployments per vessel in the WCPO. WCPFC Sci. Comm. WCPFC-SC14-2018/MI-WP-10.

Escalle, L., Muller, B., Scutt Phillips, J., Brouwer, S., Pilling, G., PNAO, 2019. Report on analyses of the 2016/2019 PNA FAD tracking programme. WCPFC Sci. Comm. WCPFC-SC15-2019/MI-WP-12.

Gershman, D., Nickson, A., O'Toole, M., 2015. Estimating the use of FAD around the world, an updated analysis of the number of fish aggregating devices deployed in the ocean. Pew Environ. Gr. 1–24.

Lopez, J., Moreno, G., Boyra, G., Dagorn, L., 2016. A model based on data from echosounder buoys to estimate biomass of fish species associated with fish aggregating devices. Fish. Bull. 114, 166–178. https://doi.org/10.7755/FB.114.2.4

Lopez, J., Moreno, G., Sancristobal, I., Murua, J., 2014. Evolution and current state of the technology of echo-sounder buoys used by Spanish tropical tuna purse seiners in the Atlantic, Indian and Pacific Oceans. Fish. Res. 155, 127–137. https://doi.org/10.1016/j.fishres.2014.02.033

Maufroy, A., Chassot, E., Joo, R., Kaplan, D.M., 2015. Large-scale examination of spatio-temporal patterns of drifting fish aggregating devices (dFADs) from tropical tuna fisheries of the Indian and Atlantic Oceans. PLoS One 10, 1–21. https://doi.org/10.1371/journal.pone.0128023

Moreno, G., Dagorn, L., Capello, M., Lopez, J., Filmalter, J., Forget, F., Sancristobal, I., Holland, K., 2016. Fish aggregating devices (FADs) as scientific platforms. Fish. Res. 178, 122–129. https://doi.org/10.1016/J.FISHRES.2015.09.021

Williams, P., Reid, C., 2018. Overview of Tuna Fisheries in the Western and Central Pacific Ocean, including Economic Conditions - 2017. WCPFC Sci. Comm. SC14-2018/GN-WP-01 66pp.