



Capability of electronic monitoring system to inform the hauling process of French tuna purse seiners catch

Karine Briand, Philippe S. Sabarros, Alexandra Maufroy, Anne-Lise Vernet,
Arthur Yon, Aude Relot-Stirnemann, Antoine Bonnieux, Michel Goujon,
Pascal Bach

► To cite this version:

Karine Briand, Philippe S. Sabarros, Alexandra Maufroy, Anne-Lise Vernet, Arthur Yon, et al.. Capability of electronic monitoring system to inform the hauling process of French tuna purse seiners catch. 2022. ird-03382655v2

HAL Id: ird-03382655

<https://ird.hal.science/ird-03382655v2>

Preprint submitted on 25 Jul 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Capability of electronic monitoring system to inform the hauling process of French tuna purse seiners catch

Karine Briand^{1,2,*}, Philippe S. Sabarros^{1,2}, Alexandra Maufroy³, Anne-Lise Vernet⁴, Arthur Yon⁴, Aude Relot-Stirnemann⁴, Antoine Bonnieux⁵, Michel Goujon³, Pascal Bach^{1,2}

¹MARBEC, Univ Montpellier, CNRS, Ifremer, IRD, Sète, France

²IRD, Ob7, Sète, France

³ORTHONGEL, Concarneau, France

⁴Bureau Veritas Living Resources, Cesson-Sévigné, France

⁵CFTO, Concarneau, France

*Corresponding author: karine.briand@ird.fr

Abstract

Electronic monitoring systems (EMS) have increasingly been used as an alternative technology to complement onboard observer programs and improve the management of tuna fisheries. EMS was installed on French purse seiners in 2014 in the frame of the OCUP program and pilot studies have shown that the system allows in-depth monitoring of fishing activities by providing information on catch composition and handling on deck and below deck. In this study, we further explore the potential of EMS for monitoring the hauling process of tropical tuna purse seiners' catch from the net to the deck. Using information collected during brailing (number of brailers, timing, fullness) on board 5 vessels of the Indian Ocean during 2018-2019, we evaluate the suitability of EMS as a tool to describe the main trends in brailing operations over 50 fishing sets. Our results indicate a large variability in brailer fullness among fishing sets and a relatively fast loading of the catch onto the deck with brailing operations generally consisting of 4 to 5 brailers transferred on board in less than 15 minutes. Results confirm the potential of EMS for collecting complementary data to monitor brailing operations of tropical tuna purse seiners.

Keywords

Electronic monitoring system | Tropical tuna | Purse seine fishery | Brailing operations

1. Introduction

Implementation of Electronic Monitoring Systems (EMS) has grown exponentially during the last two decades and EMS is currently being used in numerous fisheries as an independent monitoring tool to provide information on catch, bycatch and discards to be used for stock assessment and management (Cahalan et al., 2010; Gilman et al., 2019b; Helmond et al., 2020; McElderry, 2008; Michelin et al., 2018). In the case of tuna fisheries, EMS has been tested as an additional method to complement onboard observation and increase observer coverage, especially for vessels that cannot embark observers (Chavance et al., 2013; Emery et al., 2018; Gilman and Zimring, 2018; Hosken et al., 2016; Monteagudo et al., 2015; Ruiz et al., 2014). EMS has also received growing attention for the purpose of monitoring, control and surveillance (MCS) of fisheries (EFCA, 2019; Fujita et al., 2018; Gilman et al., 2019a; Helmond et al., 2020; Michelin et al., 2020; Stobberup et al., 2021). Ongoing discussions for the revision of the European Union *Control Regulation* are notably inviting Members States to further use EMS to document catch composition, catch handling and discarding practices, and to report mandatory data to relevant fisheries authorities upon request (Règlement (CE) n° 1224/2009/Article 25bis, EU Control regulation, 2021).

Minimum requirements for EMS installation and configuration on board fishing vessels consist in an integrated video acquisition system (cameras, sensor, GPS, computer hardware interface, encrypted video storage) adapted to each vessel configuration (EFCA, 2019; Michelin et al., 2020; Restrepo et al., 2014). In the case of tropical tuna purse seiners, a minimum of four cameras is needed to capture the different catch handling processes on the upper and lower decks (Restrepo et al., 2014; Ruiz et al., 2017). These handling processes include the loading of the catch from the net onto a platform (the hopper) on the upper deck using a brailer, the pre-sorting of the catch in the hopper, the transfer of the catch to the lower deck through the loading hatch, additional sorting operations in the lower deck, and finally the dispatch of the sorted catch into the wells (Hall and Roman, 2013). The footages of each camera are stored digitally on hard drives and data are transmitted to “onland” electronic observers at the end of each fishing trip for analysis with an dedicated software (Michelin et al., 2020; Restrepo et al., 2014).

Since 2013, the producer organization ORTHONGEL representing French and Italian tropical tuna purse seiners has implemented the OCUP (*Common Unique and Permanent Observer*) program with the objective of complementing existing observer programs in order to reach 100% of observer coverage in the Atlantic and Indian Oceans (Goujon et al., 2018). An EMS pilot project called *Electronic Eye Optimisation Project for the Future* was implemented in 2014 as part of the OCUP program to compensate for insufficient spatial and temporal observer coverage at sea on tropical tuna purse seiners due, notably, to the presence piracy protection teams on board in the Indian Ocean. Overall, ten CFTO (*Compagnie Française du Thon Océanique*) vessels were equipped with four to five digital cameras. Since the end of this pilot project in 2019, the objective behind the development of EMS on French purse seiners remains not to replace onboard observers with electronic observations but rather to use EMS as an alternative when embarking observers is not possible.

Preliminary analyses of the data collected on board French and Italian tuna purse seiners have indicated that in most cases, EMS allows to monitor discards and non-target catch at a certain level of species identification, and provides comparable estimates to onboard observations for certain groups of species, especially for species which are systematically discarded (Bonnieux and Relot-Stirnermann, 2016; Briand et al., 2018). Despite the recognition of EMS as a useful observation tool for the tropical purse seine fisheries, none of the previous studies have addressed the potential of EMS to describe handling practices. Until very recently, IRD (French National Research Institute for Sustainable Development) onboard observation protocols allowed observers to monitor a sample of brailing operations and extrapolate this sample (based on the number of brailers or fraction of time) for the estimation of discards when counting exhaustively is not possible (IRD-Ob7, 2016). However, brailing operations of French purse seine vessels of the Indian Ocean have not yet been fully described to ensure that estimations based on these extrapolations are actually robust. In consequence, the primary objective of this work was to describe brailing activities in order to improve onboard observation protocols. Indeed, a better understanding of the main trends in brailing operations should help observers use appropriate extrapolation method as well as better organizing their tasks on board. In addition, since the level of control of fishing fleets is increasing worldwide with positive impact on major fish stock management (Hilborn et al., 2020), it seems important to confirm the ability of EMS to provide information on brailing operations (brailing capacity, number of brailers, brailer fullness) that could be also used in the future for the estimation of total catch for control purposes.

In this context, the present study aims at pursuing the overall exploration of the potential of EMS for monitoring French tropical tuna purse seine fleet activities in the Indian Ocean (Briand et al., 2018). Particular attention is paid to the provision of detailed information on catch handling operations in time (throughout the duration of such operations) by using in-depth viewing camera records. Our main objective here is to evaluate EMS as a tool to describe the main trends in brailing operations. This study takes into account differences in vessel configuration that exist among French purse seine vessels as well as the diversity of fishing set durations that can be registered during a fishing trip.

2. Material and Methods

Detailed information on camera installations and routine EMS data collection on board French tropical tuna purse seiners is provided in Briand et al. (2018).

For the purpose of the present study, data were collected by electronic observers using EMS recording of 5 purse seine vessels of the Indian Ocean (**Table 1**). A total of 50 fishing sets from 9 different fishing trips carried out between August 2018 and September 2019 were chosen based on criteria of data availability and vessel configuration (3 different vessel configurations were considered) and recording quality. The distribution of sampled fishing sets per vessel is presented in Table 1.

For each fishing set, detailed information on brailing operations including (i) total brailing duration, (ii) intervals between consecutive brailers, (iii) total number of brailers, and (iv) brailer fullness were monitored using the desk camera of the upper deck. In addition, the overall trends in catch quantities (volume) and brailing capacity were analysed by comparing the total number of brailers used by fishing set against the estimated total catch declared in logbooks.

3. Results

Eighty-two percent (82%) of brailing operations lasted less than 20 minutes (N = 41; **Table 2**). Brailing operations lasted between 5 and 15 minutes for a majority of fishing sets (N = 34) and the rest of the cases were evenly distributed between 5-10 and 10-15 minutes (see **Table 2**, **Figure 1a**). Very few fishing sets were registered within 0-5 minutes (N = 4) and more than 30 minutes (N = 3; **Table 2**). The maximum brailing duration in the 50 fishing sets was 38 minutes (**Figure 1a**).

The time interval between the opening of two successive brailers was relatively regular over the 50 fishing sets with a large majority (~ 63% of the observations) between 1 and 2 minutes (mean = 1.65 minutes with standard deviation = 0.23; **Table 3**; **Figure 1b**). About 97% of observations (N = 312) were comprised between 1 and 4 minutes (mean = 1.93 minutes with standard deviation = 0.49; **Table 3**). Other cases (> 4 minutes) were rare and were either related to the presence of voluminous and/or dangerous species in the brailer or to incidents related to the brailer itself.

The number of brailers by fishing set increased with the volume of the catch (**Figure 1d**). At least 3 brailers were needed for each fishing set, and that for the majority of fishing sets (58 %), the catch was loaded on board with 3 to 6 brailers (**Table 4**; **Figure 1c**). The repartition of fishing sets within this range was evenly distributed but 5 brailers (18%) is the most common to unload the total catch onto the deck, followed by 4 brailers (16%) (**Table 4**; **Figure 1c**).

In the 50 fishing sets, the total catch ranged from 7 to 28 t (**Figure 1d**). Operations with more than 10 brailers (> 50 t) were quite rare and represent only 18% of the fishing sets (**Table 4**; **Figure 1c,d**). Moreover, two fishing sets with 22 brailers were registered on board two different vessels (Vessel 1 and 2) associated with a total catch > 110 t (150 and 112 t respectively) (**Figure 1c**; **Figure 1d**).

Details on brailer fullness indicated that brailers were not filled homogeneously within each fishing set. In most cases, each fishing set was a combination of “full” brailers (75-100% fullness) and partially filled brailers (from 0-25 % to 50-75%) (**Figure 2**). Moreover, further results showed that the first brailers were always more filled than the following ones (**Figure 3**). This can be explained by the fact that fishes are more accessible to the brailers when the purse seine net is full. The “full” brailer category had the highest representation over all categories (48.5%) (**Table 5**; **Figure 2**). “Full” brailers also appeared in higher proportion for fishing sets with the highest number of brailers (see V1-1a-28, V2-2-19 and V2-2-3 examples in **Figure 2**). Brailer fullness categories of 0-25%, 25-50% and 50-75% were found in

comparable proportions, respectively 19%, 17% and 15% of the observations (**Table 5**). Variability in brailer fullness shows that this data is particularly important to collect for a valid estimation of total catch by set.

4. Discussion

The present study confirms the potential of EMS to improve the monitoring of the total catch by tropical tuna fisheries, as already suggested in recent studies (Emery et al., 2019; Gilman and Zimring, 2018; Michelin et al., 2020). Our results confirm that EMS can be used to provide key information on brailing operations on the upper deck. Such information could be used to improve both the scientific monitoring (e.g., by contributing to improve onboard observation protocols), and the management (e.g., to estimate total catches via observed brailing information) of tropical tuna purse seine fisheries.

Our results specifically demonstrated that EMS installed on French purse seine vessels has the capacity to provide continuous information on brailing operations that onboard observers do not necessarily have time to collect during the fishing set, especially when they are collecting information on discards below deck. By analysing brailing operations, we found that in the majority of fishing sets (76%) the total catch is processed on board within the first 15 minutes, using less than 10 brailers for corresponding catch below 50 t. Previous studies have indicated that the duration of brailing operations varies with the volume of the total catch on board tropical purse seiners (Hall and Roman, 2013) but this relationship had never been documented in details for the French fleet until the present study. Also, we conclude that in most cases 4 to 6 brailers (corresponding to 10-30 t with on average 22 t) suffice to load the catch on board, and that very few fishing sets necessitated more than 15 brailers (> 50 t). This information could notably be useful to onboard observers to calibrate their sampling work before brailing operations based on the captain's estimates of fish circled within the net.

In addition, our study indicates a high regularity in the time between consecutive brailers that was estimated to 1.5 minutes on average for the majority of brailing operations. Overall, operations occurring between consecutive brailers are fast (less than 2 minutes) and confirm that a fast loading of the catch into fishing wells occurs, likely so to avoid the formation of histamine. This regularity between brailers could also be a good indicator for onboard observers to manage their time on and below deck. On the other hand, our results also underline a high variability in brailer fullness. This result is particularly important for purse seine fisheries management and potential future estimations of total catch via EMS as it shows that measures of catch should to be done at brailer level to ensure accurate estimations. Variability in brailer fullness might also result in a heterogeneous flow of retained and discarded fish on the conveyor and discard belts. This information is critical to design a suitable protocol for onboard observers, who would usually sample a fraction of the fish on the discard belt when the amount of bycatch is important (either for a portion of time or for a portion of brailers) and then extrapolate the samples to the total duration of sorting operations or the total number of brailers. The results we obtain here question the validity of such an extrapolation method to estimate the

total amount of discards by using the time or the brailer as a sample unit. Indeed, our study clearly shows that extrapolation based on one single brailer unit value would lead to large sources of errors in final discard estimates since the fullness of brailers greatly varies within a given fishing set. In fact, this consideration was used as a basis to revise and update the sampling protocol for onboard observers in the latest version of IRD's observer manual so not to allow such extrapolation (IRD-Ob7, 2020).

5. Conclusion

This study presents a summary of brailing practices observed with EMS that had never been documented with such level of details for French purse seiners operating in Indian Ocean. Our study demonstrates that EMS, as installed on board French purse seiners, can provide useful information on catch handling operations that is currently not routinely collected through on board human observer programs. This includes information on brailing operations that could be further used to estimate total catch and cross check logbook declarations for control purposes.

In summary, EMS proves to be an important scientific asset that clearly has a place in the future monitoring and management of the French tropical tuna purse seine fishery in the Indian Ocean, as a complement to onboard human observation. As a flexible tool, it can be adapted to address clear objectives, and refined to better serve science and management needs.

6. Acknowledgements

We would like to thank Thalos teams for their technical support on EMS both on board and on land. We also thank CFTO and crew members for their collaboration on the OCUP program and EMS-dedicated programs.

7. References

- Bonnieux, A., Relot-Stirnermann, A., 2016. Exploitation et comparaison des données d'une marée mixte Observateur embarqué/Oeil électronique. Marée 141 du Torre Guilia (20/09/15 au 14/12/15). (Rapport d'expertise dans le cadre de la mise en œuvre de la composante "oeil électronique" du programme OCUP). Oceanic Développement.
- Briand, K., Bonnieux, A., Dantec, W.L., Couls, S.L., Bach, P., Maufroy, A., Relot-Stirnermann, A., Sabarros, P.S., 2018. Comparing electronic monitoring system with observer data for estimating non-target species and discards on French tropical tuna purse seine vessels. https://www.iccat.int/en/pubs_CVSP.html, Collect. Vol. Sci.Pap. ICCAT 74, 3813–3831.
- Cahalan, J., M. Leaman, B., H. Williams, G., H. Mason, B., A. Karp, W., 2010. Bycatch characterization in the Pacific halibut fishery: A field test of electronic monitoring technology. (U.S. Dep. Commer., NOAA Tech. Memo. No. NMFS-AFSC-213).
- Chavance, P., Batty, A., McElderry, H., Dubroca, L., Dewals, P., Cauquil, P., Restrepo, V., Dagorn, L., 2013. Comparing observer data with video monitoring on a French purse seiner in the Indian Ocean (No. 09–43). IOTC, WPEB.
- EFCA, 2019. Technical guidelines and specifications for the implementation of Remote Electronic Monitoring (REM) in EU fisheries. European Fisheries control agency, Vigo, p. 43.
- Emery, T., Noriega, R., Williams, A., Larcombe, J., 2019. Measuring congruence between electronic monitoring and logbook data in Australian Commonwealth longline and gillnet fisheries. *Ocean and Coastal Management* 168, 307–321. <https://doi.org/10.1016/j.ocecoaman.2018.11.003>
- Emery, T., Noriega, R., Williams, A., Larcombe, J., Nicol, S., Williams, P., Smith, N., Pilling, G., Hosken, M., Brouwer, S., Tremblay-Boyer, L., Peatman, T., 2018. The use of electronic monitoring within tuna longline fisheries: implications for international data collection, analysis and reporting. *Reviews in Fish Biology and Fisheries*. <https://doi.org/10.1007/s11160-018-9533-2>
- Fujita, R., Cusack, C., Karasik, R., Takade-Heumacher, H., 2018. Designing and Implementing Electronic Monitoring Systems for Fisheries: A supplement to the catch share design manual (Design manual). Environmental Defense Fund, San Francisco, CA.
- Gilman, E., Castejón, V., Loganimoce, E., Chaloupka, M., 2019a. Capability of a pilot fisheries electronic monitoring system to meet scientific and compliance monitoring objectives. *Marine Policy*. <https://doi.org/10.1016/j.marpol.2019.103792>
- Gilman, E., Legorburu, G., Fedoruk, A., Heberer, C., Zimring, M., Barkai, A., 2019b. Increasing the functionalities and accuracy of fisheries electronic monitoring systems. *Aquatic Conservation: Marine and Freshwater Ecosystems* 29, 901–926. <https://doi.org/10.1002/aqc.3086>
- Gilman, E., Zimring, M., 2018. Meeting the objectives of fisheries observer programs through electronic monitoring (Technical Report), Indo Pacific Tuna Program. The Nature Conservancy, Honolulu, Hawaii.
- Goujon, M., Maufroy, A., Relot-Stirnermann, A., Moec, E., Amandé, M.J., Cauquil, P., Sabarros, P.S., Bach, P., 2018. Collecting data on board French tropical tuna purse seiners with common observers: results of Orthongel's voluntary observer program OCUP in the Atlantic Ocean (2013-2017). *Collective Volume of Scientific Papers = Recueil de documents scientifiques - ICCAT 74*, 3784–3805.
- Hall, M., Roman, M., 2013. Bycatch and non-tuna catch in the tropical tuna purse seine fisheries of the world. *FAO Fisheries and Aquaculture Technical Paper No. 568*. <https://doi.org/10.13140/2.1.1734.4963>

- Helmond, A.T.M. van, Mortensen, L.O., Plet-Hansen, K.S., Ulrich, C., Needle, C.L., Oesterwind, D., Kindt-Larsen, L., Catchpole, T., Mangi, S., Zimmermann, C., Olesen, H.J., Bailey, N., Bergsson, H., Dalskov, J., Elson, J., Hosken, M., Peterson, L., McElderry, H., Ruiz, J., Pierre, J.P., Dykstra, C., Poos, J.J., 2020. Electronic monitoring in fisheries: Lessons from global experiences and future opportunities. *Fish and Fisheries* 21, 162–189. <https://doi.org/10.1111/faf.12425>
- Hilborn, R., Amoroso, R.O., Anderson, C.M., Baum, J.K., Branch, T.A., Costello, C., Moor, C.L. de, Faraj, A., Hively, D., Jensen, O.P., Kurota, H., Little, L.R., Mace, P., McClanahan, T., Melnychuk, M.C., Minto, C., Osio, G.C., Parma, A.M., Pons, M., Segurado, S., Szuwalski, C.S., Wilson, J.R., Ye, Y., 2020. Effective fisheries management instrumental in improving fish stock status. *PNAS* 117, 2218–2224. <https://doi.org/10.1073/pnas.1909726116>
- Hosken, M., Williams, P., Smith, N., 2016. Update on the Implementation of Electronic Monitoring (EM) and Electronic Reporting (ER) Technologies in the WCPO (report). WCPFC, Bali, Indonesia.
- IRD-Ob7, 2020. Manuel à l’usage des observateurs embarqués à bords des thoniers senneurs tropicaux: Instruction pour la collecte de données (No. Version 2.1). IRD, Sète, France.
- IRD-Ob7, 2016. Manuel à l’usage des observateurs embarqués à bords des thoniers senneurs tropicaux: Instruction pour la collecte de données (No. Version 1.4.). IRD, Sète, France.
- McElderry, H., 2008. At-Sea Observing Using Video-Based Electronic Monitoring. The North Pacific Fishery Management Council, Seattle, Washington, U.S.A.
- Michelin, M., Elliott, M., Bucher, M., Zimring, M., 2018. Catalyzing the growth of electronic monitoring in fisheries, Building Greater Transparency and Accountability at Sea. California environmental associates, California, US.
- Michelin, M., Sarto, N.M., Gillett, R., 2020. Roadmap for Electronic Monitoring in RFMOs. CEA consulting, San Fransisco, CA.
- Monteagudo, J.P., Legorburu, G., Justel-Rubio, A., Restrepo, V., 2015. Preliminary Study About the Suitability of an Electronic Monitoring System to Record Scientific and Other Information From the Tropical Tuna Purse Seine Fishery. Col. Vol. Sci. Pap. ICCAT 71, 440–459.
- Restrepo, V., Ariz, J., Ruiz, J., Justel-Rubio, A., Chavance, P., 2014. Updated Guidance on Electronic Monitoring Systems for Tropical Tuna Purse Seine Fisheries. (ISSF Technical Report 2014-08).
- Ruiz, J., Batty, A., Pierre, C., McElderry, H., Restrepo, V., Sharples, P., Santos, J., Urtizberea, A., 2014. Electronic monitoring trials on in the tropical tuna purse-seine fishery. *ICES Journal of Marine Science* 72, 1201–1213. <https://doi.org/10.1093/icesjms/fsu224>
- Ruiz, J., Justel-Rubio, A., Krug, I., Restrepo, V., Hammann, G., Gonzalez, O., Legorburu, G., Alayón, P.J., Bach, P., Bannerman, P., Galán, T., 2017. Minimum standards for the implementation of electronic monitoring systems for the tropical tuna purse seine fleet 818–828.
- Stobberup, K., Anganuzzi, A., rthur-Dadzie, M., Baidoo-Tsibu, G., Hosken, M., Kebe, P., Kuruc, M., Loganimoce, E., Million, J., Scott, G., Spurrier, L., Tavaga, N., 2021. Electronic monitoring in tuna fisheries: Strengthening monitoring and compliance in the context of two developing states, in: *FAO Fisheries and Aquaculture Technical Paper*. Rome, p. 71. <https://doi.org/10.4060/cb2862en>

- Bonnieux, A., Relot-Stirnermann, A., 2016. Exploitation et comparaison des données d'une marée mixte Observateur embarqué/Oeil électronique. Marée 141 du Torre Guilia (20/09/15 au 14/12/15). (Rapport d'expertise dans le cadre de la mise en œuvre de la composante "œil électronique" du programme OCUP). Oceanic Développement.
- Briand, K., Bonnieux, A., Dantec, W.L., Couls, S.L., Bach, P., Maufroy, A., Relot-Stirnermann, A., Sabarros, P.S., 2018. Comparing electronic monitoring system with observer data for estimating non-target species and discards on French tropical tuna purse seine vessels. https://www.iccat.int/en/pubs_CVSP.html, Collect. Vol. Sci.Pap. ICCAT 74, 3813–3831.
- Cahalan, J., M. Leaman, B., H. Williams, G., H. Mason, B., A. Karp, W., 2010. Bycatch characterization in the Pacific halibut fishery: A field test of electronic monitoring technology. (U.S. Dep. Commer., NOAA Tech. Memo. No. NMFS-AFSC-213).
- Chavance, P., Batty, A., McElderry, H., Dubroca, L., Dewals, P., Cauquil, P., Restrepo, V., Dagorn, L., 2013. Comparing observer data with video monitoring on a French purse seiner in the Indian Ocean (No. 09–43). IOTC, WPEB.
- EFCA, 2019. Technical guidelines and specifications for the implementation of Remote Electronic Monitoring (REM) in EU fisheries. European Fisheries control agency, Vigo, p. 43.
- Emery, T., Noriega, R., Williams, A., Larcombe, J., 2019. Measuring congruence between electronic monitoring and logbook data in Australian Commonwealth longline and gillnet fisheries. *Ocean and Coastal Management* 168, 307–321. <https://doi.org/10.1016/j.ocecoaman.2018.11.003>
- Emery, T., Noriega, R., Williams, A., Larcombe, J., Nicol, S., Williams, P., Smith, N., Pilling, G., Hosken, M., Brouwer, S., Tremblay-Boyer, L., Peatman, T., 2018. The use of electronic monitoring within tuna longline fisheries: implications for international data collection, analysis and reporting. *Reviews in Fish Biology and Fisheries*. <https://doi.org/10.1007/s11160-018-9533-2>
- Fujita, R., Cusack, C., Karasik, R., Takade-Heumacher, H., 2018. Designing and Implementing Electronic Monitoring Systems for Fisheries: A supplement to the catch share design manual (Design manual). Environmental Defense Fund, San Francisco, CA.
- Gilman, E., Castejón, V., Loganimoce, E., Chaloupka, M., 2019a. Capability of a pilot fisheries electronic monitoring system to meet scientific and compliance monitoring objectives. *Marine Policy*. <https://doi.org/10.1016/j.marpol.2019.103792>
- Gilman, E., Legorburu, G., Fedoruk, A., Heberer, C., Zimring, M., Barkai, A., 2019b. Increasing the functionalities and accuracy of fisheries electronic monitoring systems. *Aquatic Conservation: Marine and Freshwater Ecosystems* 29, 901–926. <https://doi.org/10.1002/aqc.3086>
- Gilman, E., Zimring, M., 2018. Meeting the objectives of fisheries observer programs through electronic monitoring (Technical Report), Indo Pacific Tuna Program. The Nature Conservancy, Honolulu, Hawaii.
- Goujon, M., Maufroy, A., Relot-Stirnermann, A., Moec, E., Amandé, M.J., Cauquil, P., Sabarros, P.S., Bach, P., 2018. Collecting data on board French tropical tuna purse seiners with common observers: results of Orthongel's voluntary observer program OCUP in the Atlantic Ocean (2013-2017). *Collective Volume of Scientific Papers = Recueil de documents scientifiques - ICCAT 74*, 3784–3805.
- Hall, M., Roman, M., 2013. Bycatch and non-tuna catch in the tropical tuna purse seine fisheries of the world. *FAO Fisheries and Aquaculture Technical Paper No. 568*. <https://doi.org/10.13140/2.1.1734.4963>
- Helmond, A.T.M. van, Mortensen, L.O., Plet-Hansen, K.S., Ulrich, C., Needle, C.L., Oosterwind, D., Kindt-Larsen, L., Catchpole, T., Mangi, S., Zimmermann, C., Olesen,

- H.J., Bailey, N., Bergsson, H., Dalskov, J., Elson, J., Hosken, M., Peterson, L., McElderry, H., Ruiz, J., Pierre, J.P., Dykstra, C., Poos, J.J., 2020. Electronic monitoring in fisheries: Lessons from global experiences and future opportunities. *Fish and Fisheries* 21, 162–189. <https://doi.org/10.1111/faf.12425>
- Hilborn, R., Amoroso, R.O., Anderson, C.M., Baum, J.K., Branch, T.A., Costello, C., Moor, C.L. de, Faraj, A., Hively, D., Jensen, O.P., Kurota, H., Little, L.R., Mace, P., McClanahan, T., Melnychuk, M.C., Minto, C., Osio, G.C., Parma, A.M., Pons, M., Segurado, S., Szuwalski, C.S., Wilson, J.R., Ye, Y., 2020. Effective fisheries management instrumental in improving fish stock status. *PNAS* 117, 2218–2224. <https://doi.org/10.1073/pnas.1909726116>
- Hosken, M., Williams, P., Smith, N., 2016. Update on the Implementation of Electronic Monitoring (EM) and Electronic Reporting (ER) Technologies in the WCPO (report). WCPFC, Bali, Indonesia.
- IRD-Ob7, 2020. Manuel à l'usage des observateurs embarqués à bords des thoniers senneurs tropicaux: Instruction pour la collecte de données (No. Version 2.1). IRD, Sète, France.
- IRD-Ob7, 2016. Manuel à l'usage des observateurs embarqués à bords des thoniers senneurs tropicaux: Instruction pour la collecte de données (No. Version 1.4.). IRD, Sète, France.
- McElderry, H., 2008. At-Sea Observing Using Video-Based Electronic Monitoring. The North Pacific Fishery Management Council, Seattle, Washington, U.S.A.
- Michelin, M., Elliott, M., Bucher, M., Zimring, M., 2018. Catalyzing the growth of electronic monitoring in fisheries, Building Greater Transparency and Accountability at Sea. California environmental associates, California, US.
- Michelin, M., Sarto, N.M., Gillett, R., 2020. Roadmap for Electronic Monitoring in RFMOs. CEA consulting, San Francisco, CA.
- Monteagudo, J.P., Legorburu, G., Justel-Rubio, A., Restrepo, V., 2015. Preliminary Study About the Suitability of an Electronic Monitoring System to Record Scientific and Other Information From the Tropical Tuna Purse Seine Fishery. *Col. Vol. Sci. Pap. ICCAT* 71, 440–459.
- Restrepo, V., Ariz, J., Ruiz, J., Justel-Rubio, A., Chavance, P., 2014. Updated Guidance on Electronic Monitoring Systems for Tropical Tuna Purse Seine Fisheries. (ISSF Technical Report 2014-08).
- Ruiz, J., Batty, A., Pierre, C., McElderry, H., Restrepo, V., Sharples, P., Santos, J., Urtizberea, A., 2014. Electronic monitoring trials on in the tropical tuna purse-seine fishery. *ICES Journal of Marine Science* 72, 1201–1213. <https://doi.org/10.1093/icesjms/fsu224>
- Ruiz, J., Justel-Rubio, A., Krug, I., Restrepo, V., Hammann, G., Gonzalez, O., Legorburu, G., Alayón, P.J., Bach, P., Bannerman, P., Galán, T., 2017. Minimum standards for the implementation of electronic monitoring systems for the tropical tuna purse seine fleet 818–828.
- Stobberup, K., Anganuzzi, A., rthur-Dadzie, M., Baidoo-Tsibu, G., Hosken, M., Kebe, P., Kuruc, M., Loganimoce, E., Million, J., Scott, G., Spurrier, L., Tavaga, N., 2021. Electronic monitoring in tuna fisheries: Strengthening monitoring and compliance in the context of two developing states, in: *FAO Fisheries and Aquaculture Technical Paper*. Rome, p. 71. <https://doi.org/10.4060/cb2862en>

Table 1. Number of fishing sets per vessel with associated fishing trip.

Vessel	Fishing Trip	Total
V1	1a,1b	21
V2	2	12
V3	3a,3b	5
V4	4a,5a	4
V5	6,7a,7b	8
		50

Table 2. Numbers of sets by total brailing time duration categories. Categories are defined by 5-minute intervals. T_0 corresponds to the moment where the first brailer open and is used as a starting point for all duration measures.

Total brailing duration (minutes)	Number of sets	% of sets
0-5	4	8
5-10	17	34
10-15	17	34
15-20	3	6
20-25	3	6
25-30	3	6
30-35	1	2
35-40	2	4
Total	50	100

Table 3. Time intervals between two brailers classified by 1-minute categories for all fishing sets (N = 50) combined.

Interval (minute)	Number of observations
0-1	2
1-2	200
2-3	96
3-4	14
4-5	2
5-6	2
6-7	1
7-8	0
8-9	1
9-10	1
Total	319

Table 4. Number of brailers used by set and percentage of occurrence.

Numbers of brailers	Number of sets	% of occurrence
3	5	10
4	8	16
5	9	18
6	7	14
7	3	6
8	3	6
9	4	8
10	2	4
11	3	6
12	1	2
13	1	2
16	2	4
22	2	4
Total	50	100

Table 5. Distribution of brailers by classes of fullness for all fishing sets (N = 50) combined. Brailer fullness is divided in 4 percentage categories: 0-25, 25-50, 50-75 and 75-100% of fullness.

Brailing fullness (%)	Number of observations	% of observations
0-25	70	19
25-50	64	17,3
50-75	56	15,2
75-100	179	48,5
Total	369	100

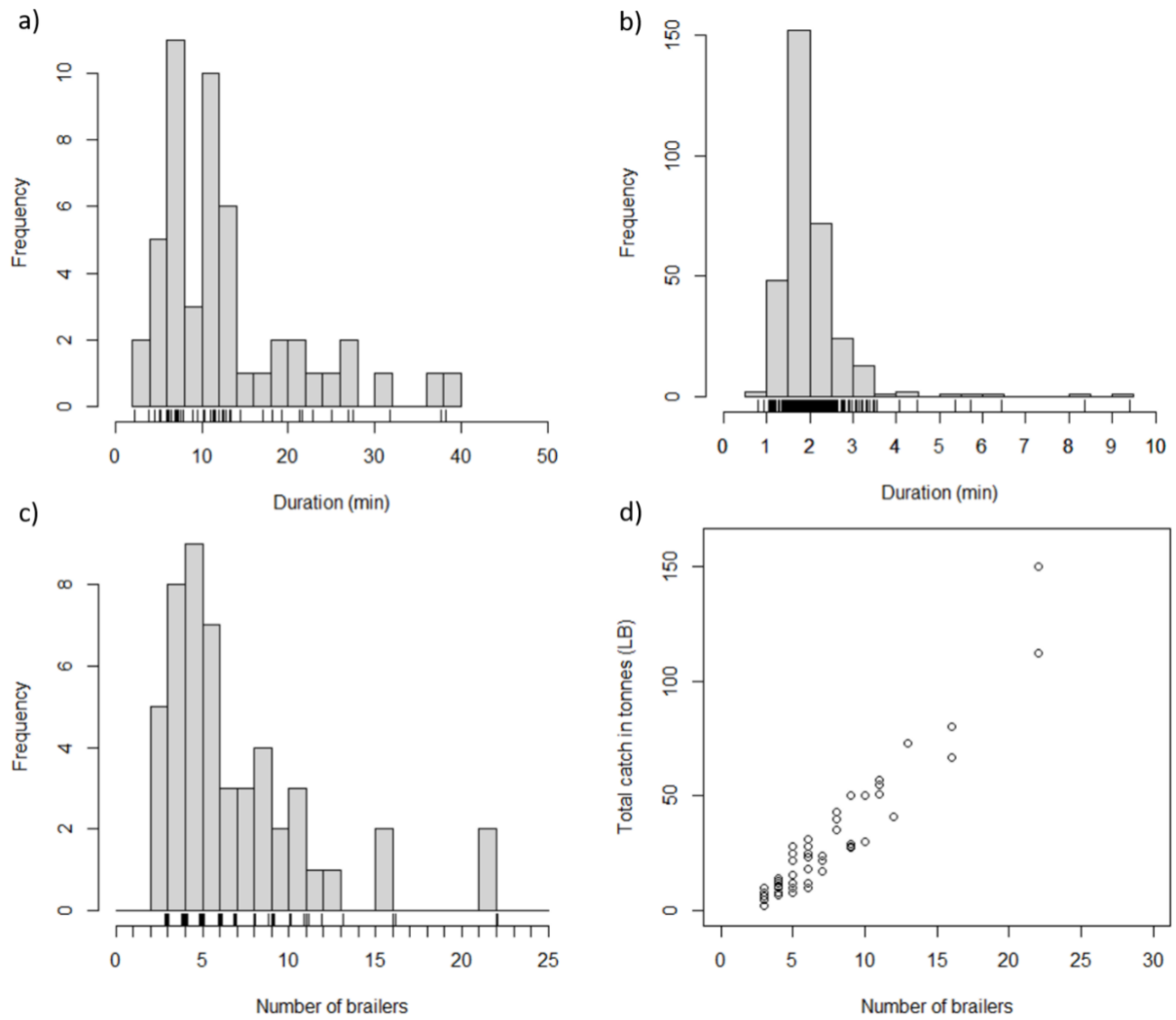


Figure 1. Details on brailing operations. **a)** frequency distribution of the total brailing duration **b)** time interval between brailers, **c)** number of brailers, **d)** number of brailers as a function of the total catch estimated from logbooks by fishing set (N = 50 fishing sets).

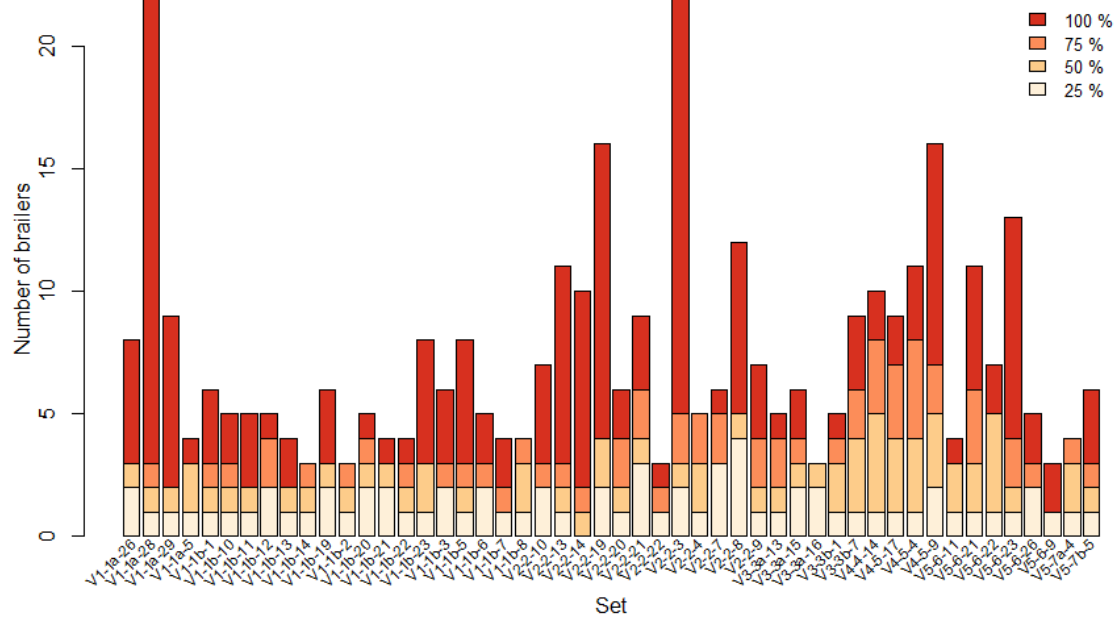


Figure 2. Brailer fullness for all 50 fishing sets: 0-25% (pale yellow), 25-50% (pale orange), 50-75% (orange) and 75-100% (red) of fullness. Each fishing set is identified by an abbreviated combination of Vessel-Trip-Set.

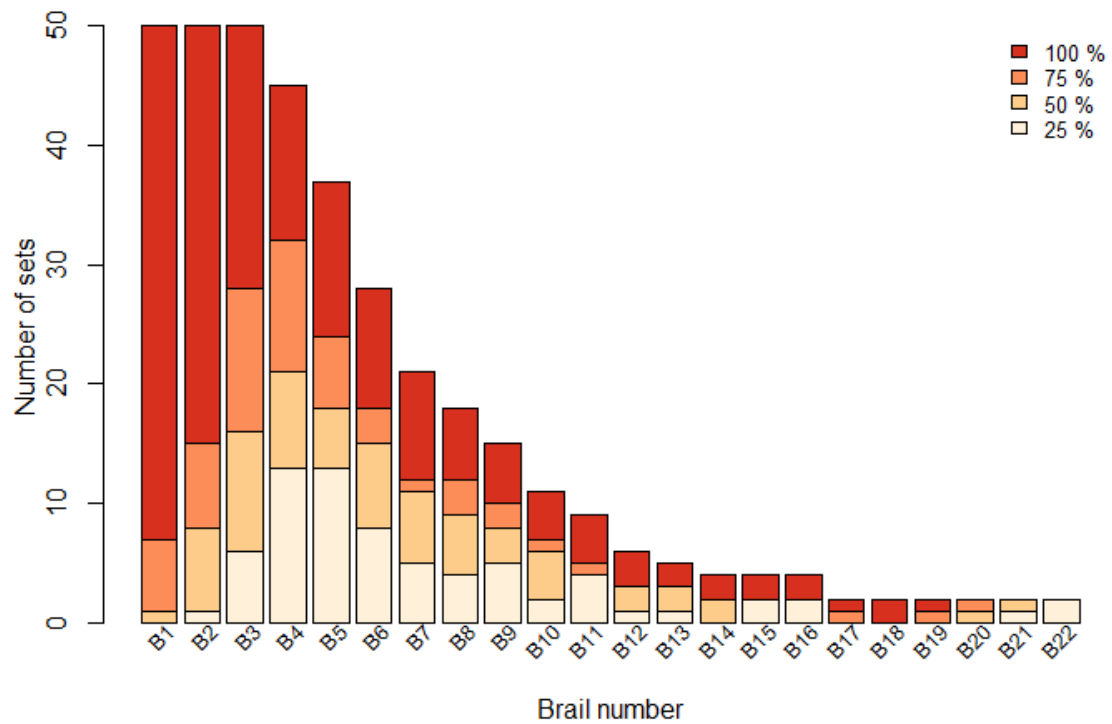


Figure 3. Brailer fullness by brail order summarized for all 50 fishing sets: 0-25% (pale yellow), 25-50% (pale orange), 50-75% (orange) and 75-100% (red) of fullness. B1 represents the first brailer.