Improving the sampling protocol of electronic and human observations of the tropical tuna purse seine fishery discards

Karine Briand[1,2], Philippe S. Sabarros[1,2,*], Alexandra Maufroy[1], Aude Relot-Stirnemann[3], Sarah Le Couls[4], Michel Goujon[1], Pascal Bach[5]

[1]ORTHONGEL, Concarneau, France
[2]IRD, MARBEC, Ob7, Sète, France
[3]Oceanic Développement, Concarneau, France
[4]CFTO, Concarneau, France
[5]IRD, MARBEC, Ob7, Victoria, Seychelles
*corresponding author, email: philippe.sabarros@ird.fr

Abstract

Observer programs have been implemented for many years in tuna purse seine fisheries to assess their impact on pelagic ecosystems by monitoring tuna discards and bycatch among which sensitive species such as sharks or rays. On board observers estimate discards using sampling and extrapolation methods when counting exhaustively is not possible. However, the flow of discards may be heterogeneous on the discard belt, and as a result, extrapolations may lead to over/underestimated estimations. Electronic monitoring system (EMS) on tuna fishing vessels has been tested as an alternative technology to complement and improve on board observer programs. EMS allows monitoring discards (of tuna and non-target species) at an acceptable species identification level and allows exhaustive counts on the discard belt. In this study, we used EMS “counts per minute” data from four French and one Italian purse seine vessels operating in Indian Ocean to analyse total discards in numbers, as well as discards by species for each set. We analysed 48 fishing sets realised in 2017 and simulated different observer sampling strategies in order to optimise (i) the total sampling duration and (ii) the duration of sampling sequences. We finally propose an optimised sampling strategy for estimating discards applicable to both electronic and human that reduces sampling time with minimum estimation bias.

Keywords

Sampling strategy | Electronic monitoring system | Observer | Tropical tuna | Purse seine fishery | Non-target species | Discards

1. Introduction

Observer data are essential for monitoring fisheries with the purpose of sustainable management as it provides important information used to assess the state of fish stocks and the impact of fishing pressure on marine ecosystems. The role of on board observers is to collect independent, accurate and reliable data on fishing operations, catches and interactions of the vessel and its fishing gear with the environment. In the case of the tropical tuna purse seine fishery, observers are primarily focused on estimating tuna discards (in order to complement landings that are available on logbooks), bycatch of non-target species including sensitive species. On board scientific observer programs have been implemented on tropical tuna purse seine since the 1980's in the Atlantic and Indian oceans.

In addition to the minimum observer coverage of 5% of fishing activities required by regional observer schemes of tuna Regional Fisheries Management Organizations (t-RFMOs) and 10% by the European Union (EU) that is ensured via EU-funded data collection programs, purse seine fleets have developed voluntary programs to increase observer coverage in order to comply with tRFMOs and EU conservation measures, fishing agreement obligations, and responsible fishing schemes of fishing companies (e.g. best practices for releasing sensitive species such as sharks, rays and turtles). The producer organization ORTHONGEL representing French and Italian purse seiners operating in the Atlantic and Indian oceans has for example implemented the OCUP (*Common Unique and Permanent Observer*) program since July 2013 with the objective of reaching 100% of observer coverage (Goujon *et al.*, 2017).

Since 2014, Electronic Monitoring System (EMS) has been also tested on tuna purse seine vessels as an alternative observation tool to complement on board human observation and increase observer coverage, especially for vessels that cannot embark observers. EMS consists in a video acquisition system (cameras, sensor, GPS, computer hardware interface, hard drive, etc.) that records and stores the vessel fishing activities, and a software to review and analyse recorded activities with electronic (or "on land") observers. In the case of the French and Italian purse seine fleet of the Atlantic and Indian oceans, the OCUP program was recently complemented with the CAT OOE project (*Contrat d'Avenir Thonier- Optimisation de l'Oeil Electronique* - Tuna Contract for the future – Electronic Eye Optimization) to compensate for insufficient spatial and temporal observer coverage at sea due, notably, to piracy-related security risks in the Indian Ocean. The objective was not to replace human observers but rather to use EMS when embarking human observers was not possible.

Pilot studies have showed that EMS can be a valid tool to monitor tropical purse seine fishery tuna discards and bycatch (Ruiz *et al.*, 2015; Ruiz *et al.*, 2016a; Ruiz *et al.*, 2016b; Briand *et al.*, 2018). Preliminary analyses of the data collected on board French and Italian tuna purse seiners have for instance indicated that in most cases, EMS allowed to monitor discards and bycatch at an acceptable species identification resolution, and provided comparable estimates to actual on board observations, especially for species which are systematically discarded (Bonnieux and Relot-Stirnemann, 2016; Briand *et al.*, 2018). It was also noted that when the flow of discards is important EMS could be more efficient than on board observers at estimating the total number of individuals by species since it allows exhaustive counts on the discard belt (Ruiz *et al.*, 2017; Briand *et al.* 2018). Despite the validation of EMS as a useful observation tool for the tropical purse seine, and knowing that reviewing EMS records is time consuming (and therefore costly), none of the studies has proposed to optimise the sampling strategy of EMS records in order to reduce the cost of analysing such data.

Also, even though several authors have advocated that EMS could be used to improve data quality in observer programs (Hosken *et al.*, 2016; Larcombe *et al.*, 2016), the potential to use EMS to enhance data collection by on board observers has not been examined yet. Indeed, for large sets where the flow of discards on the discard belt is too important and therefore counting individuals exhaustively is not possible, observers usually use sub-sampling and extrapolation methods to estimate the total number of individuals as described in the French IRD observer manual (IRD-OT, 2016). Observers would typically (i) count the discards from one brailer (large scoop that is used to pull aboard the catch from the net by the side of the vessel) and extrapolate to the total number of brailers within the fishing set, or (ii) sample fish on the discard belt for a given period of time and then extrapolate to the total sorting time. However, fishes usually come in batches on the discard belt after each unloading of the brailer which cause the flow of discards on the discard belt to be heterogeneous over time. Even though observers are instructed to be pragmatic and use the best available method, this may lead to biased estimates of discards. The analysis of EMS records could therefore provide additional guidance to on board observers on how to collect samples at appropriate moments of the brailing operations and during sufficient time periods.

In this study, we propose a methodology that can be used to optimize the analysis of EMS records by on land electronic observers and to improve the existing sampling protocol of human observers on board tropical tuna purse seiners. We used EMS collected on 5 vessels operating in the Indian Ocean in 2017, and specifically “counts per minute” data (that are not part of the current EMS observation protocol but were specifically prepared for the present analysis) to test a range of sampling methods in order to optimise the estimations of total discards in numbers for each fishing set as well as for each species. The objective here is to optimise the total sampling time while maintaining robust estimates of discards (number of individuals) by species and reducing the variance of these estimates. We used random sampling techniques and bootstrap analysis to (i) identify the optimal total sampling duration, and (ii) test the use of random sampling sequences from 1 to 4 minutes. Analyses were carried out for total discards and separately for each of the common bycatch species such as the rough triggerfish (*Canthidermis maculata* CNT), rainbow runner (*Elegatis bipinnulata* RRU), mackerel scad (*Decapterus macarellus* MSD), silky shark (*Carcharhinus falciformis* FAL), wahoo (*Acanthocybium solandri* WAH) and dolphinfish (*Coryphaena hippurus* DOL) (Figure S1).

2. Material and Methods

2.1. EMS data

2.1.1. Camera installation on board purse seiners

Five purse seine vessels (4 French and 1 Italian) operating in the Indian Ocean were equipped by Thalos Company with at least five HD MOBOTIX digital cameras with 6 MP resolution (Briand *et al.*, 2018; Figure 1). One wide-angle camera is installed in the crow's nest to cover the port side of the boat and to follow general fishing activity including setting, pursing, and brailing. Another camera is placed on the desk and used to record brailing operations and discard activities on deck. Two or three other cameras with higher frequency (5 frames/second) are placed below the deck along the conveyor belt to monitor sorting operations. Finally, one camera is placed at the end of the discard belt. This camera was placed so discarded individuals could be counted and species identified. The image acquisition system is connected to the vessel's GPS so each video frame (one position per minute) can be geolocalised. Crow's nest cameras were set to record continuously whereas desk and below deck cameras were triggered by vessel speed to record fishing operations only. Image data were stored digitally on hard disks that were transmitted to *Oceanic Développement* for analysis.

2.2.2. EMS "counts per minute" data

Electronic observers at *Oceanic Développement* receive EMS records after the end of the fishing trip. Data collection forms were adapted to EMS observations but most of the collected data is similar to the information routinely collected by on board observers. However, unlike human observations, full recording of fishing operations and in-depth viewing of the records by cameras placed at different locations on board allowed exhaustive counting of discarded individuals both on the deck and below deck. EMS recordings were analysed using the *Oceanlive* software developed by *Thalos*.

Since the present study mainly focuses on non-target catch, we considered here only fishing sets on floating objects (FOB) that typically involve large amounts of bycatch compared to free-school fishing sets (Amandè *et al.*, 2010). Records from 48 fishing sets made in 2017 were broken down into sequences of one minute and individuals were counted exhaustively during these 1-minute sequences. Details on the number of fishing sets by per fishing trip are presented in Table 1. The total number of individuals by fishing set represents the "observed" value that will constitute the reference value when testing various sampling strategies (see section 2.2.).

2.2. Testing sampling strategies

We simulated custom sampling strategies that an on board or an electronic observer could use to estimate the total number of individuals by species. Two variables of the sampling strategy were considered: (i) the total sampling duration and (ii) the duration of sampling sequences. These simulations were made by resampling the actual "counts per minute" data. In each simulation, the number of discards (total and per species) was calculated by extrapolating the number of individuals counted over a given period to the total sorting time. From this metric we calculated the bias to the reference value (difference between the estimated and reference value; the bias can be positive of negative), the absolute bias and the coefficient of variation (CV) to assess the efficiency of the sampling strategies (Efron and Tibshirani, 1993). We expected that the bias and CV would decrease when increasing the sampling time, and we wanted to identify the inflexion point or the moment where the bias and CV are sufficiently low so the extrapolations are robust.

(Eq. 1) $Bias = N\ estimated - N\ reference$

(Eq. 2) $Absolute\ bias = |\ N\ estimated - N\ reference\ |$

(Eq. 3) $CV = Standard\ deviation\ /\ Mean\ of\ N\ estimated$

2.2.1. Total sampling duration

We sampled random minutes (without replacement) from one minute to the total duration of the sorting operations and then extrapolated the total number of discards. This operation was done for each of the 48 fishing sets and was repeated 100 times for each tested sampling duration (bootstrap). The bootstrapped mean and confidence intervals of the bias, absolute bias and CV of the extrapolations were then calculated (Figure 3; Figure S2). The objective was to identify an optimal sampling duration (sum of 1-minute sequences) for which the absolute bias and CV of discard estimates would strongly decrease to become reasonably acceptable.

2.2.2. Sampling sequences

This strategy consists in repeating sampling sequences of a given time throughout sorting operations. For each fishing set, we tested sampling sequences of 2, 3 and 4 consecutive minutes randomly chosen over the total duration of each fishing set, that were repeated from 1 sequence to the total number of possible sequences within each fishing set. This operation was repeated 100 times within a bootstrap procedure so as to provide means and confidence intervals. We then represented the bootstrapped mean of the absolute bias, and CV, as a function of the total cumulated sampling time found for each sampling sequence length (Figure 4). The objective was to find an optimal sampling sequence duration that minimises bias and CV of discard estimates.

3. Results

3.1. General discard flow

Most individuals (88%) arrive on the discard belt within the first 21 minutes with very few individuals counted in the first two minutes and an intense period with the maximum number of individuals between the 3rd and 9th minutes (Figure 2). The highest densities of discards were found for the CNT, RRU and MSD around 9 minutes. CNT was the most frequent species present in the early part of the sorting operations but large numbers (smaller peaks) were also discarded at the middle and at the end of the largest fishing sets. DOL, WAH, and FAL were less frequent (generally less individuals) over the totality of the fishing sets. However, small amounts of DOL and WAH were also found at the end of the longest fishing operations.

3.2. Total sampling duration

Figure 3 presents the effect of sampling duration on the extrapolated total number of discarded individuals. Whatever the duration of the sampling, the bias in the extrapolated number of discarded individuals was on average around zero. However, the variance of extrapolated numbers, illustrated by the confidence intervals on the top panel figure is important for short sampling durations but decreases over time. Also, the coefficient of dispersion (CV) of the extrapolated total number of discarded individuals stabilised (CV < 1) after 10 minutes of random sampling for all 48 fishing sets. After 15 minutes of sampling, the mean absolute bias was below 10 individuals.

Detailed results for the 6 most common non-target species are presented in Figure S2. The absolute bias and CV decreased with sampling duration, and the CV was stabilised at around 20 minutes for all species. The CV passed below 1, meaning an error on the estimate of 1%, after 4 minutes for CNT, 5 for RRU and MSD, 6 for DOL, 7 for FAL, and 10 for WAH (Figure S3).

3.3. Sampling sequences

Figure 4 shows the comparison of the absolute bias for the estimation of the total number of discarded individuals for sampling sequences of 1 to 4 minutes. In all 4 cases, the bias decreased with the total sampling duration as well as associated confidence intervals. Despite marginal differences, the absolute bias of discard estimates and confidence intervals are comparable among the 4 tested sampling sequences. Such differences are also reflected in the CV where the mean CV of 1-minute strategy is below the CV of 2-minute strategy between 2 to 21 minutes of total sampling. Idem between 2-minute and 3-minute random sequence strategies, as well as between 3-minute and 4-minute. However, the overlap of confidence intervals suggest that these differences are not significant and therefore that the duration repeated sequences has no effect on discard estimates.

4. Discussion

This study describes for the first time the patterns in the flow of discards on the discard belt of tropical tuna purse seiners operating in the Indian Ocean. Onboard French and Italian vessels, most of the discards could be counted within the first 21 minutes after what the flow of discard dramatically decreased. This is due to the fact that the first brailer(s) is(are) usually fuller than the last ones, and therefore the amount of bycatch greater in the early part of sorting operations. In terms of sampling by on board or electronic/on land observers, this suggests that it is crucial for on board observers to monitor discards at the beginning of sampling operations in order to obtain accurate estimates of discards. This result suggests that the sampling method consisting in sampling one brailer and then extrapolating to the total number of brailers is not recommended at all since it would most likely lead to biased estimations. Current extrapolation methods (based on brailers or time) actually rely on the assumption of an homogeneous (linear) discard flow but the heterogeneity in the discard flow would require extrapolation methods to take this into account.

Random sampling simulations showed that sampling a total of 15-20 minutes (not necessarily consecutive minutes) is sufficient to obtain robust estimates of total number of discarded individuals as well as number of discarded individuals per species after extrapolation. However, we expect that for rarer species that the ones investigated in this study, longer sampling time would be necessary to reduce the risk of missing their occurrence. Out of the 48 fishing sets studied, 15 fishing sets were below 20 minutes (Figure S1) which means that in such case, sampling the entire sorting operations exhaustively would be necessary. Though this should not be a problem for electronic observers, this does not however take into account how much fish a human observer can handle onboard at a given time. For fishing sets above 20 minutes, our results indicate that the mean bias would remain below 10 individuals for 20 minutes of sampling. A protocol based on a total sampling duration of 15 to 20 minutes seems therefore reasonable for robust estimations of discards for both on board and on land observers.

In addition, it is worth noting that very few individuals were counted during the first minute of sorting operations. This may be explained by the delay between the moment the brailer releases fish onto the deck and the moment when the first individuals arrive on the discard belt. Besides, we noted that some species peaked at specific moments of the sorting process, notably dolphinfish and wahoo near the end of sorting operations. The individuals of such species are often pre-sorted and retained on the deck for crew consumption purposes, and unnecessary individuals are then discarded when sorting operations are nearly finished. In terms of sampling protocol, this may indicate that sampling the last minutes of sorting operations may improve discard estimates.

Moreover, simulations using sampling sequences of 1 to 4 minutes suggested that the length of sequences does not have much effect on the bias of estimations. While sampling random individual minutes seems not feasible in practice, sampling by sequences of 2 to 4 minutes seems a reasonable and pragmatic method especially for on board observers that are alternatively collecting data on the deck and in the lower deck.

Finally, it should be noted that this study was only carried out with data collected on purse seiners operating in the Indian Ocean. Considering that bycatch composition and quantities may be different from one ocean to the other (Hall and Roman, 2013), notably in the Atlantic Ocean where the amount of bycatch is generally greater (Briand *et al.*, 2018), it would be interesting to complement this study with data from other oceans to see identify potential differences in the patterns identified here.

5. Conclusion

EMS is a promising alternative tool for monitoring discards of tuna and non-target species for the tropical tuna purse seine fisheries, and it can also allow developing and optimising sampling protocols as shown in this study. We propose here an optimal sampling protocol in which on board and on land observers sample a total of 20 minutes in random sequences of 2 to 4 minutes (at convenience) mostly distributed in the early part of sorting operations and covering the last minutes if possible.

6. Acknowledgements

We would like to thank France Filière Pêche (www.francefilierepeche.fr) for funding the “CAT OOE” project and Thalos Company for delivering technical EMS support both on board and on land. We thank Oceanic Developpement for providing the counts per minute dataset, especially A. Bonnieux, W. Le Dantec and A.-L. Vernet. We also thank CFTO vessel owners and crew members for their collaboration on the OCUP program and on electronic monitoring program studies.

7. References

Amandé, J. M., Ariz, J., Chassot, E., Delgado de Molina, A., Gaertner, D., Murua, H, Pianet, R., Ruiz, J., Chavance P. 2010. Bycatch of the European purse seine tuna fishery in the Atlantic Ocean for the 2003-2007 period. Aquat. Living Resour. 23 (4): 353-362.

Bonnieux, A. and. Relot-Stirnemann A, 2016. Exploitation et comparaison des données d’une marée mixte Observateur embarqué/Oeil électronique. Marée 141 du Torre Giulia (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, 16 pp.

Briand K., Bonnieux A., Le Dantec W., Le Couls S., Bach P., Maufroy A., Relot-Stirnemann A., Sabarros P.S., Vernet A.-L., Jehenne F., Goujon M. 2018. Comparing electronic monitoring system with observer data for estimating non-target species and discards on French tropical tuna purse seine vessels. Col Vol Sci Pap ICCAT 74:3813–3831.

Efron, B. and Tibshirani, R. 1993. An Introduction to the Bootstrap. Boca Raton, FL: Chapman & Hall/CRC. ISBN 0-412-04231-2.

Goujon, M., Maufroy, A., Relot-Stiremann, A., Moëc, E., Bach, P., Cauquil, P., Sabarros, P.S. 2017. Collecting data on board French and Italian tropical purse seiners with common observers: Results of Orthongel’s voluntary observer program OCUP (2013-2017) in the Indian Ocean. IOTC-2017-WPDCS13-22. Presented at the 13th Session of the IOTC Working Party on Data Collection and Statistics, Mahé, Seychelles.

Hall, M., Roman, M. 2013. By-catch and non-tuna catch in the tropical tuna purse seine fisheries of the world. FAO Fisheries and Aquaculture Technical Paper No. 568. Rome, FAO. 249 pp.

Hosken, M., Williams, P., Smith, N. 2016. Update on the implementation of electronic monitoring (EM) and electronic reporting (ER) technologies in the WCPO. WCPFC-SC12-2016/ST IP-04. Bali Indonesia, 3-11 August 2016, 122 pp.

Larcombe, J., Noriega, R., Timmiss, T. 2016. Catch reporting under E-monitoring in the Australian Pacific longline fishery. 2nd Meeting of the Electronic Reporting and Electronic Monitoring Intersessional Working Group. WCPFC-2016-ER and EMWG2-DP01, Bali Indonesia, 22 July 2016, 26 pp.

Observatoire Thonier IRD 2016. Manuel à l'usage des observateurs embarqués à bords des thoniers senneurs tropicaux: Instruction pour la collected de données. Version 1.4.

Ruiz, J., Bach, P., Krug, I., Briand, K., Murua, H., Bonnieux, A. 2017. Strength and weakness of the data elements currently collected through Electronic Monitoring Systems in the Indian Ocean. IOTC-201-WPDCS13-26. Presented at the 13th Session of the IOTC Working Party on Data Collection and Statistics, Mahé, Seychelles.

Ruiz, J., Batty, A., Chavance, P., McElderry, H., Restrepo, V., Sharples, P., Santos, J., Urtizberea, A., 2015. Electronic monitoring trials on in the tropical tuna purse-seine fishery. ICES Journal of Marine Science 72, 1201–1213.

Ruiz, J., Batty, A., Chavance, P., McElderry, H., Restrepo, V., Sharples, P., Santos, J., Urtizberea, A., 2015. Electronic monitoring trials on in the tropical tuna purse-seine fishery. ICES Journal of Marine Science 72, 1201–1213.

Ruiz, J., Krug I., Gonzalez O., and Hammann G. 2016a. E-EYE PLUS: electronic monitoring trial on the tropical tuna purse seine fleet. ICCAT/SCRS/2016/181, 15 pp.

Ruiz, J., Krug, I., Justel-Rubio, A., Restrepo, V., Hammann, G., Gonzalez, O., Legorburu, G., Pascual Alayon., J. P., Bach, P., Bannerman, P., Galán, T. 2016b. Minimum standards for the implementation of electronic monitoring systems for the tropical purse seine fleet. Collect. Vol. Sci. Pap. ICCAT, 73(2): 818-828.

8. Tables

Table 1. Number of available sets by vessel (anonymised) and trip.

Vessel	Trip	N sets
V1	147A	7
V1	147B	7
V2	82	14
V3	127A	5
V4	85B	2
V5	159	13
5	**6**	**48**

9. Figures

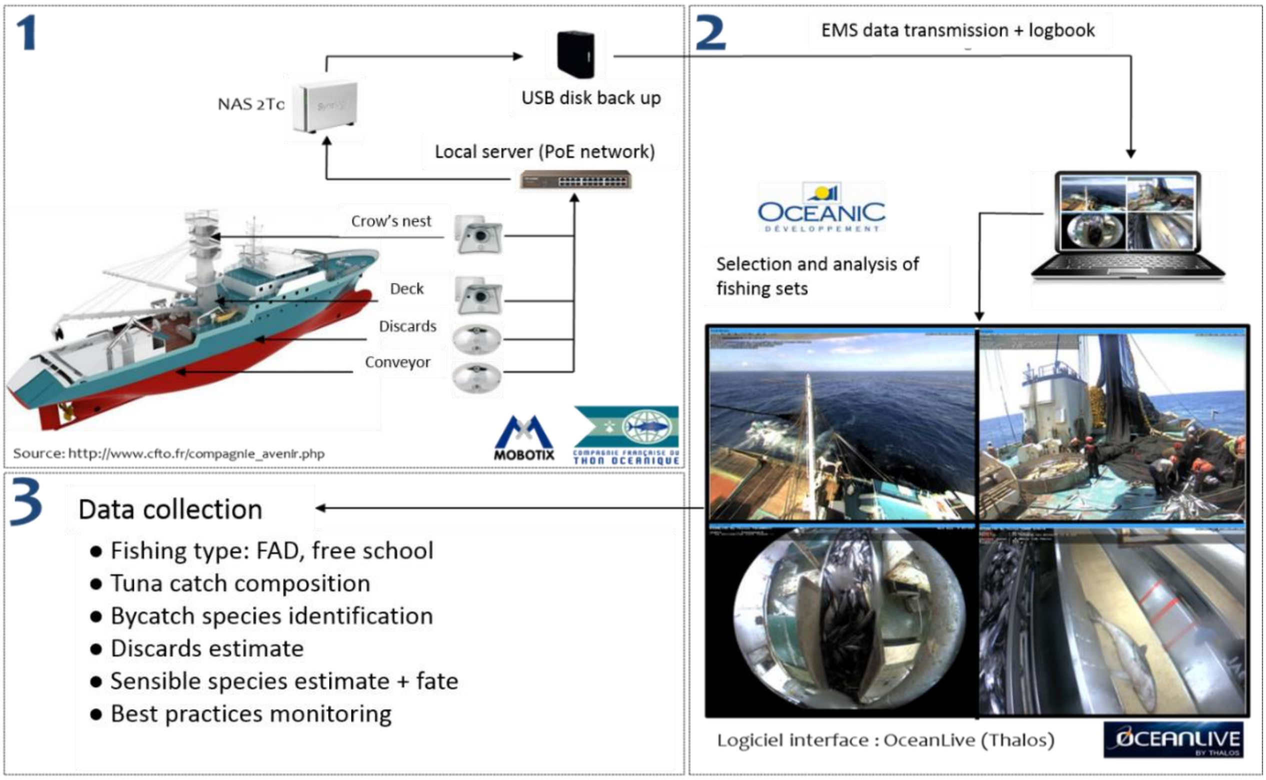

Figure 1. Schematic representation of the EMS installation and the process of data collection.

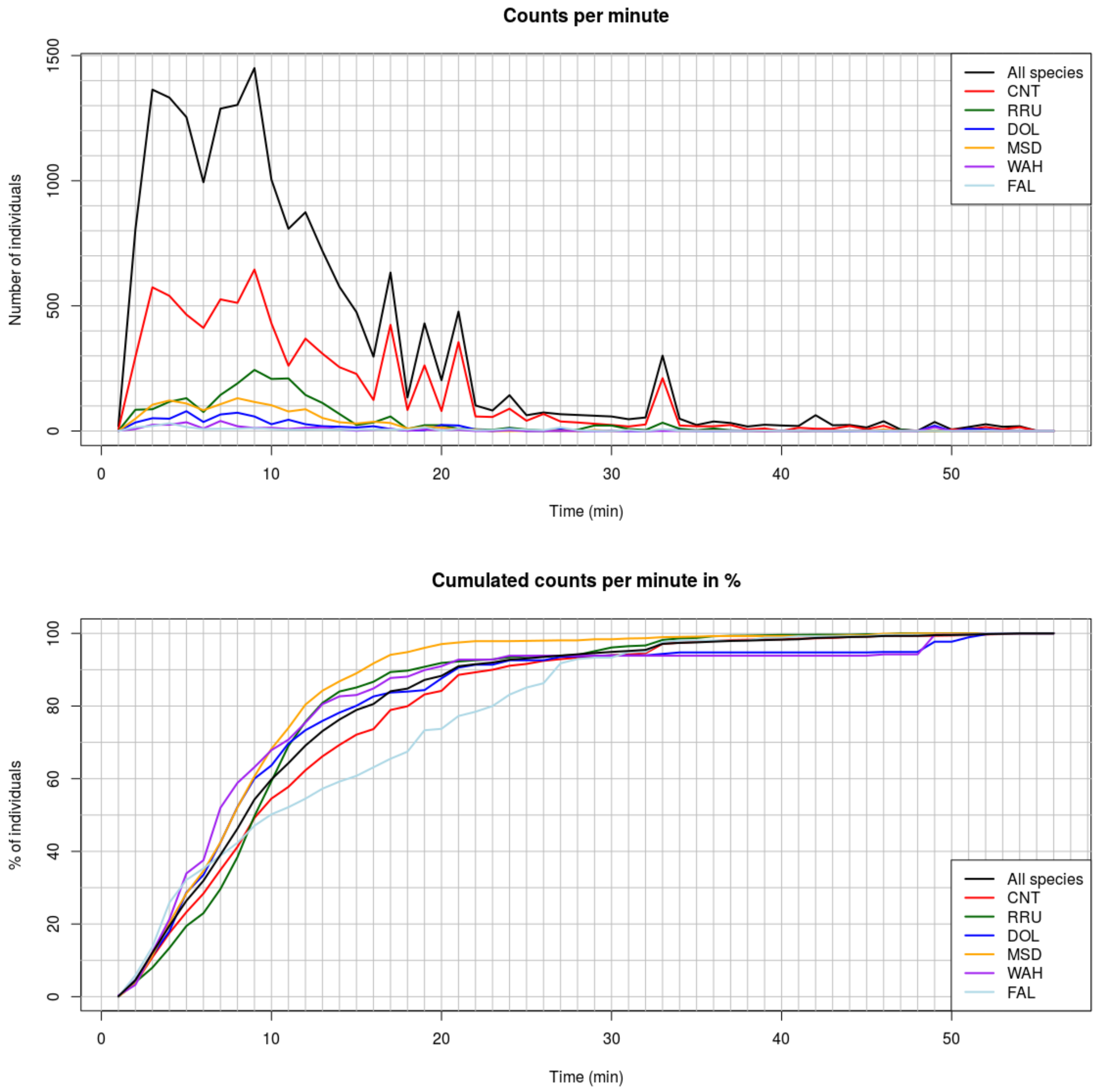

Figure 2. Counts per minute and cumulated percentage combining all 48 fishing sets. Total individuals are displayed with the solid black line and counts for five most common species are displayed in solid colored lines.

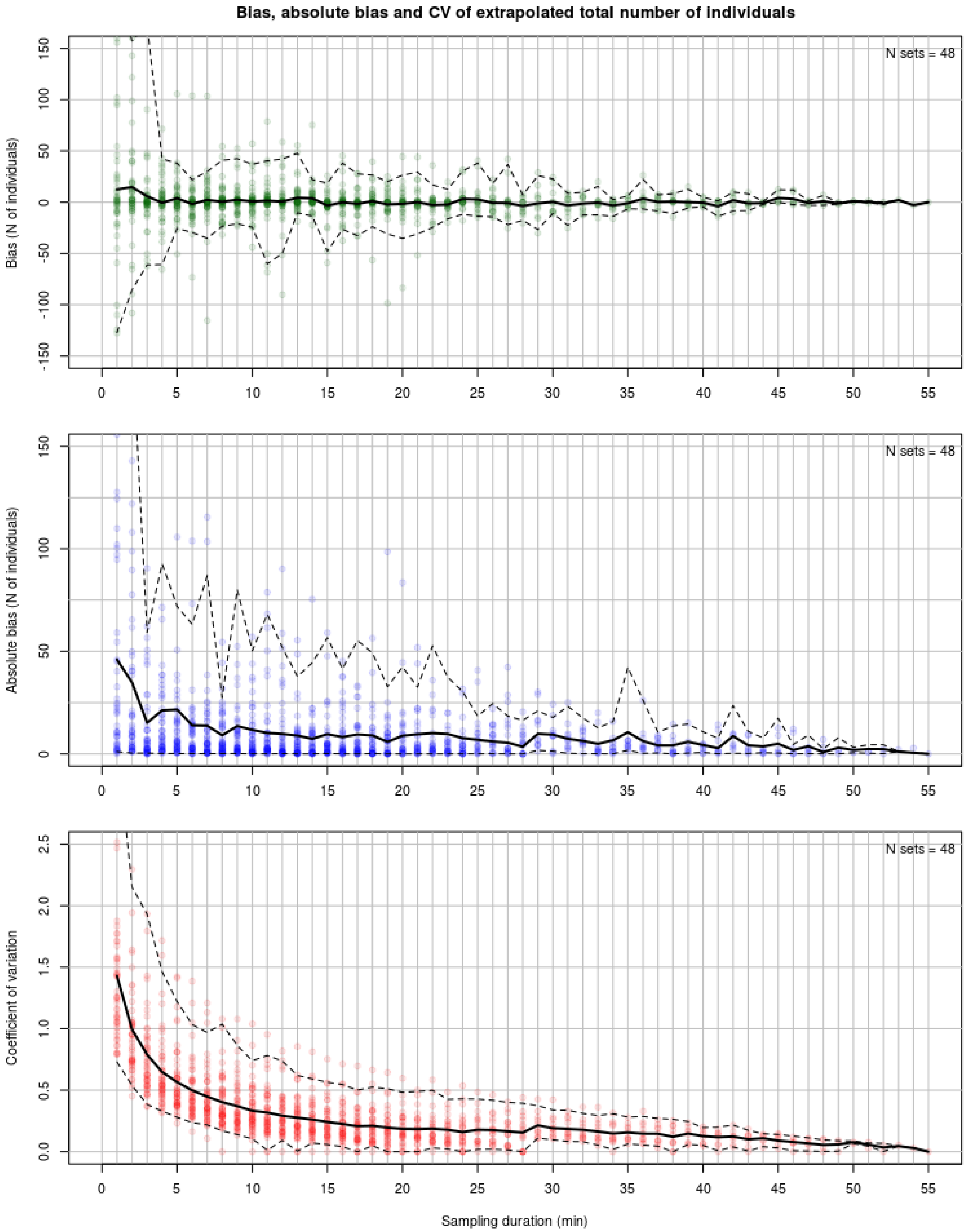

Figure 3. Bias, absolute bias and coefficient of variation (CV) of the total number of discards estimated as a function of sampling duration. The bias and CV were calculated on 100 bootstraps (resampling without replacement) for each fishing set. The solid line represents the median and the broken lines the 95% confidence interval.

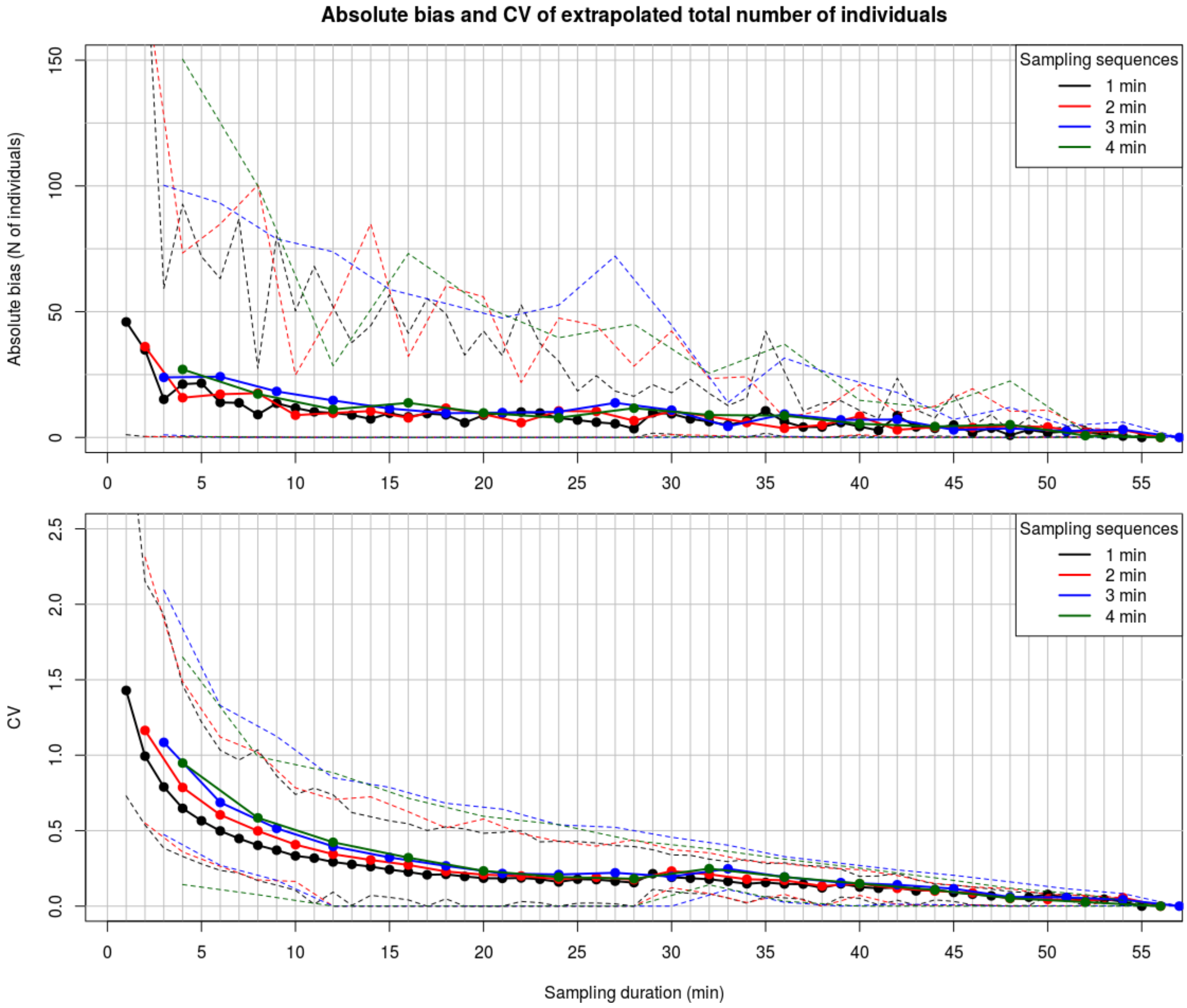

Figure 4. Mean absolute bias of the total number of discards estimated as a function of cumulated sampling duration when random sampling sequences are 1, 2, 3 and 4 minutes.

10. Supplementary material

Table S1. List and occurrence of species in the 48 fishing sets.

FAO code	Scientific name	Common name	N discarded
CNT	*Canthidermis maculata*	Rough triggerfish	8080
RRU	*Elagatis bipinnulata*	Rainbow runner	2163
MAX	*Scombridae*	Mackerels nei	1470
FRZ	*Auxis spp*	Frigate and bullet tunas	1433
MSD	*Decapterus macarellus*	Mackerel scad	1357
XXX	Undetermined	Undetermined	1284
DOL	*Coryphaena hippurus*	Common dolphinfish	743
KYP	*Kyphosus spp*	Kyphosus sea chubs nei	469
WAH	*Acanthocybium solandri*	Wahoo	277
FAL	*Carcharhinus falciformis*	Silky shark	255
SKJ	*Katsuwonus pelamis*	Skipjack tuna	158
TUS	*Thunnus spp*	True tunas nei	133
ALM	*Aluterus monoceros*	Unicorn leatherjacket filefish	51
GBA	*Sphyraena barracuda*	Great barracuda	29
RSK	*Carcharhinidae spp*	Requiem sharks nei	14
LOB	*Lobotes surinamensis*	Tripletail	13
YTL	*Seriola rivoliana*	Longfin yellowtail	11
CXS	*Caranx sexfasciatus*	Bigeye trevally	10
BAF	*Ablennes hians*	Flat needlefish	5
NAU	*Naucrates ductor*	Pilotfish	5
ALN	*Aluterus scriptus*	Scribbled leatherjacket filefish	4
BIL	*Istiophoridae*	Marlins,sailfishes,etc. nei	4
KAW	*Euthynnus affinis*	Kawakawa	3
OCS	*Carcharhinus longimanus*	Oceanic whitetip shark	2
BAO	*Platax teira*	Longfin batfish	1
DIY	*Diodon hystrix*	Spot-fin porcupinefish	1

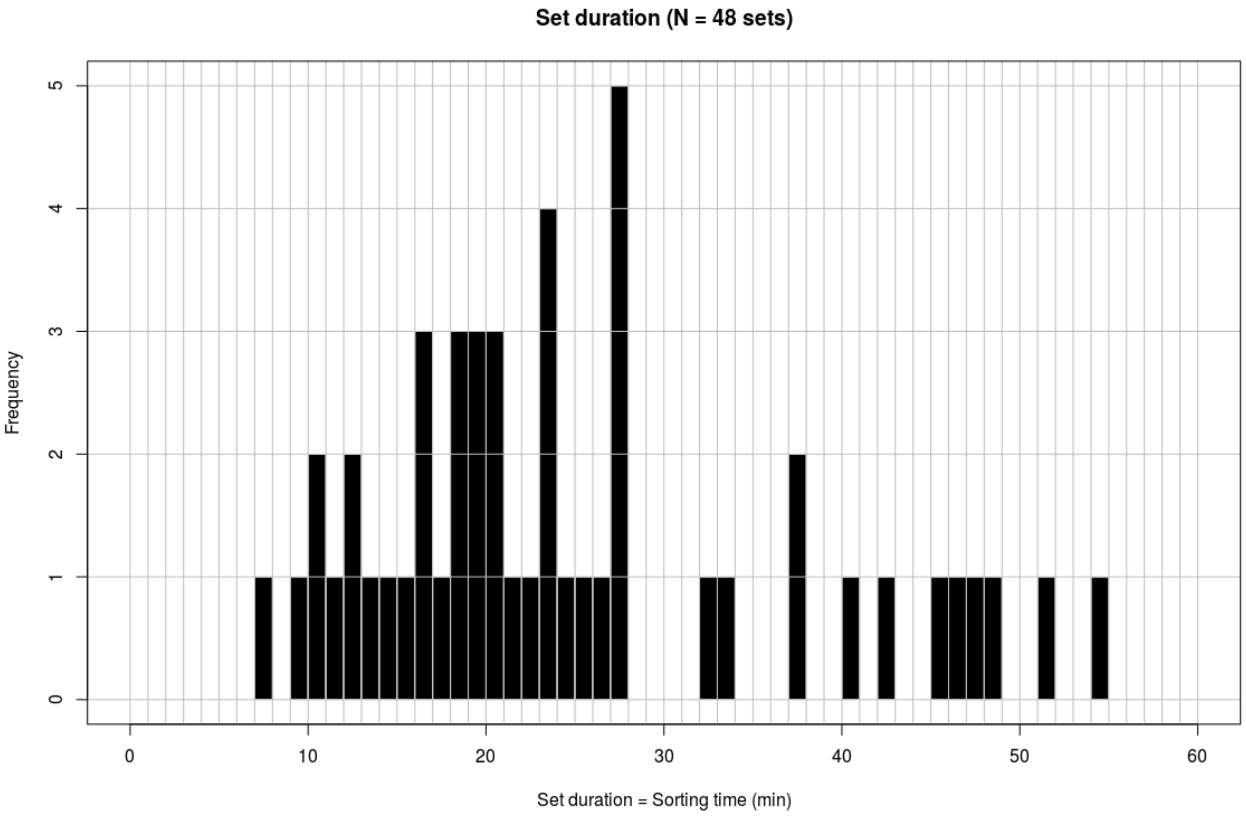

Figure S1. Distribution of fishing set duration (sorting time) in minutes.

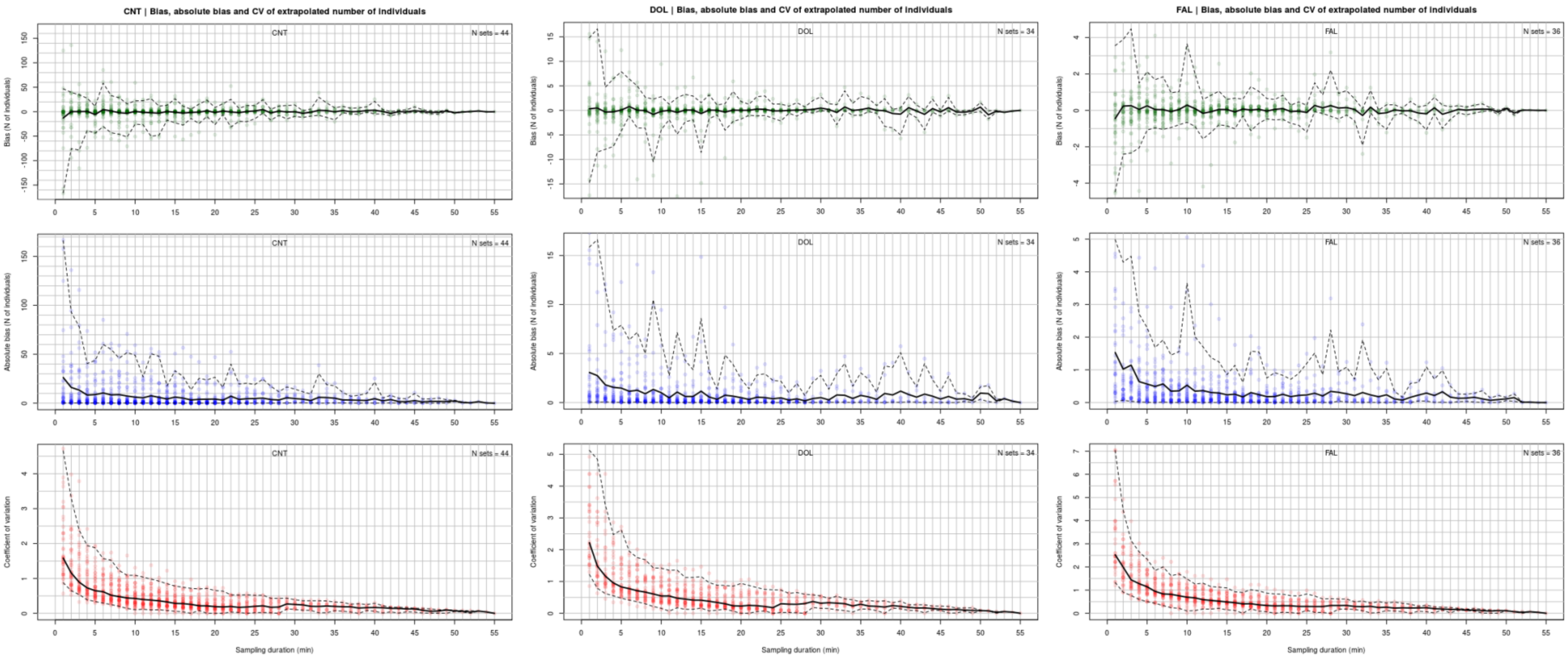

Figure S2. Bias, absolute bias and coefficient of variation (CV) of the extrapolated number of CNT, DOL, FAL, MSD, RRU and WAH as a function of sampling duration. The bias, absolute bias and CV were calculated on 100 bootstraps (sampling random minutes without replacement) for each fishing set. The solid line represents the mean and the broken lines the 95% confidence interval. The scale of Y-axes may differ among species.

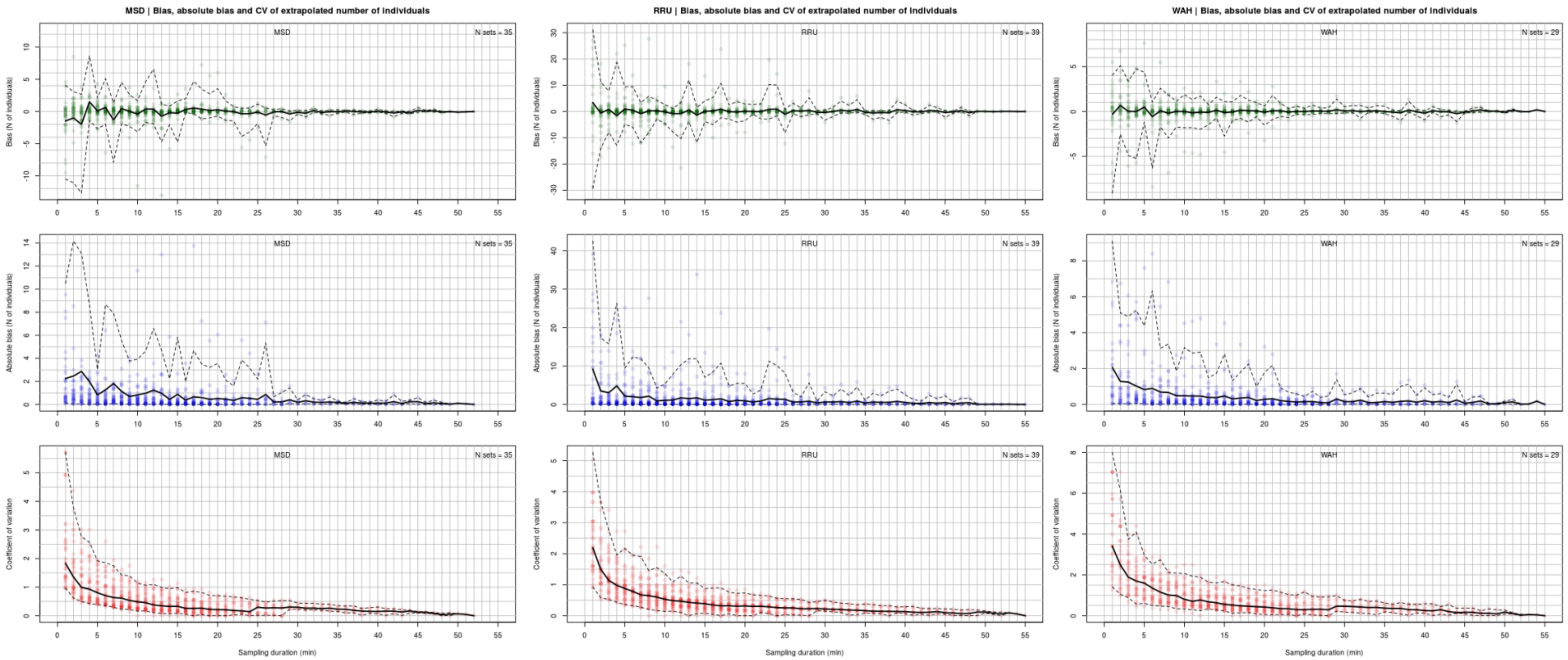

Figure S2 (continued). Bias, absolute bias and coefficient of variation (CV) of the extrapolated number of CNT, DOL, FAL, MSD, RRU and WAH as a function of sampling duration. The bias, absolute bias and CV were calculated on 100 bootstraps (sampling random minutes without replacement) for each fishing set. The solid line represents the mean and the broken lines the 95% confidence interval. The scale of Y-axes may differ among species.

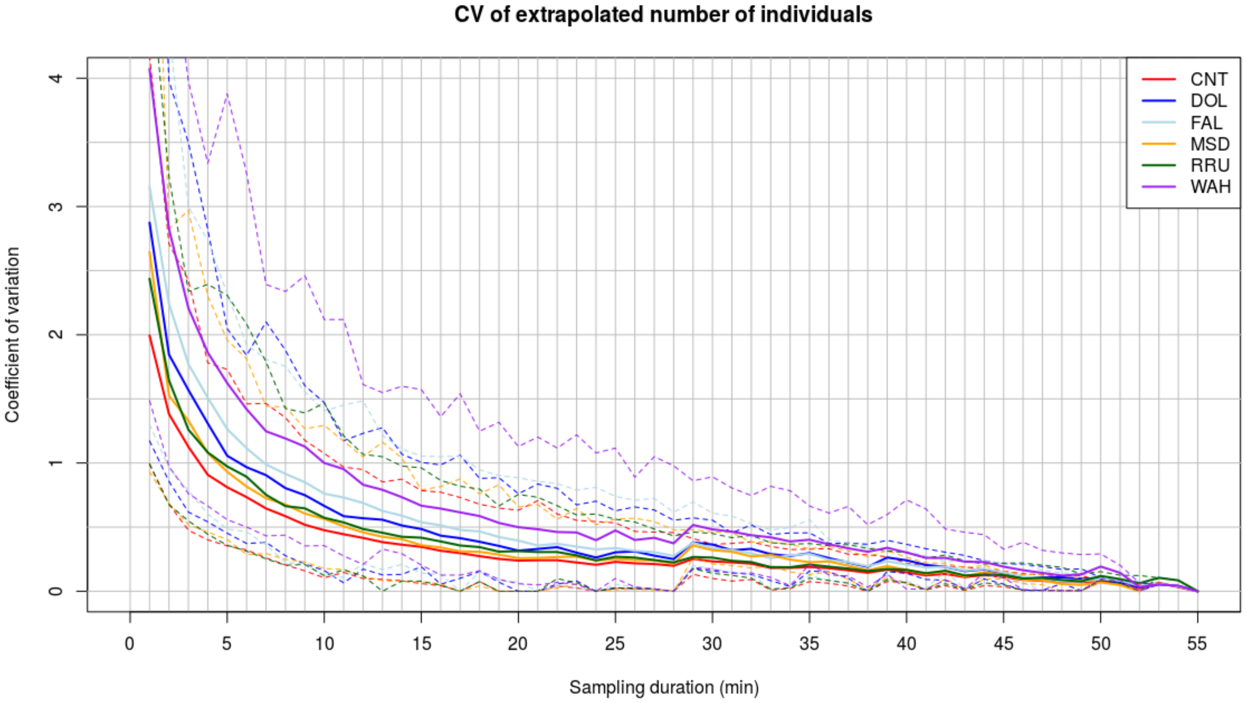

Figure S3. Coefficient of variation (CV) of the extrapolated number of CNT, DOL, FAL, MSD, RRU and WAH as a function of sampling duration.