MARE/2016/22 "Strengthening regional cooperation in the area of fishery data collection"

Annex III "Biological data collection for fisheries on highly migratory species"

Strengthening regional cooperation in the area of large pelagic fishery data collection (acronym: RECOLAPE)

FINAL REPORT

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FRAMEWORK CONTRACT
MARE/2016/22

Strengthening regional cooperation in the area of large pelagic fishery data collection (RECOLAPE)

FINAL REPORT

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LIST OF ACRONYMS

ANABAC- Asociación Nacional de Armadores de Buques Atuneros Congeladores

APE- Average Percentage of Error

ALK- Age Length Key

AZTI- AZTI-Tecnalia Research Institute

BET- Bigeye tuna

BFT- Blue Fin Tuna

CPC - Contracting Party or Cooperating non-Contracting Party, Entity or Fishing Entity

CPUE - Catch per unit effort

CV - Coefficient of Variation

EMP - Electronic Monitoring Program

EMS - Electronic Monitoring System

ERS - Electronic Reporting System

EU - European Union

FAD - Fish Aggregating Device

FOB - Floating object

FSC – Free school set

GFCM-GSA - General Fisheries Commission for the Mediterranean- Geographical Sub Area

ICCAT – The International Commission for the Conservation of Atlantic Tunas

ICES – International Council for the Exploration of the Sea

IOTC – Indian Ocean Tuna Commission

IRD – Institut de Recherche pour le Développement

LP – Large Pelagic

MoU- Memorandum of Understanding

MS – Member State(s)

NC – National Correspondent

OPAGAC- Organización Productores Asociados Grandes Atuneros Congeladores

ORTHONGEL - ORGANISATION DES PRODUCTEURS DE THON CONGELÉ ET SURGELÉ

PA- Percentage of agreement

RCM – Regional coordination meeting

RCG – Regional coordination group

RCG-LP – Regional Coordination Group – Large Pelagic

RDB - Regional Data Base

RDBES - Regional Database and Estimation System

RFMO - Regional Fisheries Management Organization

RSP - Regional sampling plan

SCRS - Standing Committee on Research and Statistics

SDEF format - Standard Data-Exchange format

SKJ – Skipjack tuna

SWO- Swordfish

WCPFC – Western & Central Pacific Fisheries Commission

WP – Work Package

WPDCS - Working Party on Data Collection and Statistics

YFT - Yellowfin tuna

EXECUTIVE SUMMARY

This report refers to the framework contract MARE/2016/22 and, specifically, to the Annex III "Biological data collection for fisheries on highly migratory species". The overall objective of the project is to strengthen the regional cooperation in the area of biological data collection for highly migratory species in the current context where regional cooperation will evolve from a single annual meeting (RCM – Regional coordination meeting) to a continuous process that will have greater responsibilities (RCG – Regional coordination group). The project has been involved in several developments:

- the design of Regional Sampling Plans (RSPs) for large pelagic stocks,
- creation of tools and protocols for collecting new data around FADs (Fish Aggregating Devices),
- testing the alternative onboard data collection methods and
- the design of an appropriate regional framework to assess the data quality.

The objective of this final report is to explain the work undertaken, giving details of the implementation and results of the specific work packages. The final section in each work package report also lists recommendations for the future work to improve the coordination in the collection of data on highly migratory species

<u>WP1</u> made a proposal for the future organisation of the Large Pelagic RCG (RCG-LP). This proposal includes different meetings/subgroups, which are organized in three stages.

- The first stage has the objective of identifying data gaps and data needs, based on the research priorities for data collection identified by the end-users (stock assessment groups within the tuna RFMOs). It is expected that this group will serve to improve the coordination between data collection scientists and stock assessment scientists.
- The second stage is in charge of designing Regional Sampling Plans (RSP) both for the target and bycatch species, by coordinating both dockside and onboard sampling for the different stocks. Ideally, this coordination should be achieved by methodological groups dealing with specific fisheries. The proposal includes four parallel groups based on stocks/gears; tropical tunas (focused on purse seine fleet), longline fisheries outside the Mediterranean Sea, longline fisheries inside the Mediterranean Sea and bluefin tuna fisheries.
- Finally, the third stage would evaluate the results of the two preceding stages, and it would make the final decisions of greater importance and approve the RSPs.

Having been consulted MS that participate in the RCG-LP, RECOLAPE project anticipates a broad consensus on the proposal made in the WP1, where MS agree on the global structure and number of subgroups proposed for the internal functioning of the RCG-LP. However, this proposal will probably demand an increase in human resources. Therefore, although the proposed structure seems appropriate and accepted by the interested parties, it does not seem entirely realistic to expect that all subgroups will be created within a short period To break the impasse and give a decisive impulse to the much-needed work in the different groups, the following actions are recommended:

- First, more people should be involved in the RCG-LP (both scientists and national correspondents); traditionally, the group had a very small number of participants.
- Second, the group should identify the key person(s) that can effectively drive the creation of subgroups.
- Finally, these groups should be as flexible and dynamic as possible. Once a subgroup is operational, it will decide on the frequency of the meetings, coordinate and share its own tasks.

The **WP2** explores all the elements needed for the design of a European Regional Work Plan that may replace the relevant parts of the MS National Work Plans. This WP includes two case studies: one for the Mediterranean swordfish and another for the tropical tunas in the Atlantic Ocean. In both cases, data needs and priorities were defined, current port sampling protocols were reviewed, and specific variations to current sampling design are recommended to increase the sampling efficiency.

For **tropical tunas**, eight priority datasets were defined necessary to conduct a robust stock assessment. These were discards (dead and alive), catch-at-size estimates, support vessel activity data (location and number of days at sea), monthly number of FADs deployed by statistical rectangle (1ºx1º), maturity, ages and local market data (so-called "faux poisson"). Moreover, two changes in the current port sampling protocol are recommended, which should collaborate improving the accuracy of the species composition and size distribution: First, modify the sampling stratification, moving from the current (hierarchically structured by large sampling areas, quarter and school types) to a regular 5-degree grid. Second, reduce the number of individuals to measure per sample and still assess accurately the size distribution of the major tunas.

For the **Mediterranean swordfish**, nine priority datasets were selected. They were discards (dead and alive), catch and fishing effort data, size frequency, catch-at-size estimates, maturity, fecundity and ages[1]. In addition, data available on the size distribution of the landings of four national longline fisheries (Cyprus, Greece, Malta and Italy) exploiting different Mediterranean regions, were analysed to obtain estimates of optimal sampling rates. The results showed that, depending on the size of the exploited area and the season, a sample size of 60–120 individuals per year-quarter would provide sufficient levels of precision. Generally, as a "rule of thumb", it could be suggested that quarterly sampling of 70–100 samples is adequate, at the GFCM/GSA level. However, this estimate is based on size measurements and does not take into account other biological parameters, such as sex ratio and maturity stage. It also ignores the size composition of discards as such information was not made available to the project and neither does it exist in the database in The International Commission for the Conservation of Atlantic Tunas (ICCAT).

WP3 includes two independent pilot studies. **WP3.1** proposes best standards for data collection and data transmission around fish aggregating devices (FADs), which are presented as valid to fulfil minimum requirements in all tuna Regional Fisheries Management Organizations (RFMO). The use of FADs has continuously increased in tropical tuna purse seine fishery, with FAD-associated catches now exceeding those on free schools in the case of the European Fleet. Despite the importance of this fishery, little information is available on FAD use worldwide which is crucial for the understanding, monitoring and management of FADs use and the impacts on pelagic ecosystems. As a result, tuna RFMOs have called for FAD management plans, including data collection and reporting on deployment and use of FADs by purse seiners and support vessels[2].

Although efforts are being made to record and report information on FOBs (which refers to any floating object, including man made FADs equipped with satellite buoys) due to the

[1] These datasets are either not-available or their collection should be improved, that is why the datasets are different for tropical tunas and swordfish. For further information go to the specific WP explanation and related annexes.

[2] Support vessels are those fishing in cooperation with tropical tuna purse seine vessels. They do not fish but devoted to supporting the activities with FADs.

complexity of this fishing strategy and the lack of unified data collection and reporting requirements, there are significant data gaps and the information collected and reported has been of limited utility. The aim of this WP3.1 is to review current requirements and procedures and to propose standards for data collection and reporting on FOBs to RFMOs. The proposals included in this document are the result of a collaborative work between scientists and fishing industry.

- On the one hand, skippers should collect information on FOBs by the use of FOB logbook on board. All interaction with FOBs and buoys if present, should be recorded in the logbook. The record of each activity should provide information on the vessel, trip ID, date and time, position, buoy attached if present (including the ID of the manufacturer and owner-ship), type of activity, specifications on the FOB type, and structure of the FOB allowing the assessment of the dimension, entangling character (given by the mesh size if present and configuration) and nature of the material in the floating and submerged structure, as well as the catch of fishing sets (i.e. target species and bycatch) when applicable. In order to further standardize the data collection on-board, a software is being developed (i.e. ObServe) which will be share by the fishing industry and research institutions.

- On the other hand, during this WP3.1. standards for data submission on FOBs to RFMOs were defined. This WP recommends that the RFMOs templates should be adjusted to the data sources (FOB logbook and data coming from buoys attached to the FADs, which permit their constant tracking):
  - One template dedicated to report activities on FOBs and buoys. The information should be derived from FOB logbooks.
  - A second template dedicated to report information of density of FADs (in this case it only refers to FADs, as FADs are FOBs which are equipped with satellite buoys), which should be derived from buoys transmission information. Information on buoy density should be requested stratified at least by month and 1ºx1º (i.e. average number of operational buoys belonging to the vessels over the month and 1ºx1º, by summing up the total number of operational buoys recorded per day over the entire month in each grid and dividing by the total number of days in the month). This information should be extracted from buoy transmissions provided by buoy manufactures and not from FOB logbooks.

The second pilot study, **WP3.2**, compares the data collected using Electronic Monitoring Systems (EMS) to the data collected by observers and self-reporting programs, to determine if EMS can be used to reliably collect unbiased data onboard longline fleet. This pilot study, which was conducted in the longline fleet targeting large pelagic species around La Reunion Island (Indian Ocean), demonstrates that using the EMS is a viable complement or alternative to collecting the data using human observers, even if there are still some weaknesses. Based on the main findings of this pilot study we conclude, that the implementation of an Electronic Monitoring Program (EMP) means much more than the deployment of cameras on a fishing vessel.

- Before launching it, requirements must be clearly presented by the project coordinator to the fishing industry and the crew of vessels involved.
- The EMS implementation is likely to proceed by respecting a Memorandum of Understanding (MoU).
- To be effective, the EMP will need a collaboration of the crew to enhance the quality of the data collection, particularly to keep clean the lenses of cameras.

- The EMS installation must be vessel-based. However, a rotation sensor installed on the drum as trigger to switch on the system when fishing operations occur is efficient and can be deployed on any types of pelagic longliner.
- The EMS is a viable alternative to collect human observer data, even if some limitations still exist. The congruence between EMS data and human observer, or self-reporting data, was high for the main species kept on board. Conversely the congruence between datasets was low for some discarded species like sharks, that were released by cutting the line (only 40% and 70% of sharks were detected compared to the data collected by observers and self-reporting respectively).

WP4 developed a data collection strategy for some variables not collected under the Data Collection Framework (DCF). These variables should be provided by the fishing industry and buoy providers and will be used, in combination with traditional DCF data, for Catch per unit effort (CPUE) standardisation, as well as in the estimation of alternative abundance indices in tropical tuna fisheries. The introduction of FADs in conjunctions with the satellite linked echo-sounder buoys was one of the most significant innovation introduced in the industrial tropical tuna purse seine fishery. These buoys provide information on the accurate geo-location of the floating object and estimation of fish biomass aggregated underneath the FAD along its trajectory, which increases the efficiency of the fishing operations. Alternative indicators of tuna biomass and fishing effort can be derived from echosounder buoys, which could help to assess natural variations on target species abundance and improved scientific advice for stock assessment. As such, the objectives of the WP4 are:

- to develop a data collection strategy on FADs
- to provide indicators of the total number of operational buoys at sea
- to improve the CPUE standardization procedure,
- to define dedicated algorithms to improve estimates of biomass signal from echo-sounders, and
- to develop alternative abundance indices in tuna fisheries, which requires the efforts from all the stakeholders.

Under specific data-exchange agreement signed between research organisms (i.e. AZTI and IRD) and European Union (EU) tuna purse seiner associations (i.e. ORTHONGEL , ANABAC and OPAGAC) historical information (i.e. 2006-2018 period) on buoys positions and data on acoustic information has been gathered on the Indian and Atlantic Ocean, for buoy density estimation to be used in the CPUE standardization process and the development on alternative indices of abundance derived from acoustic data. Filtering steps for filtering erroneous buoys positions, buoys on land and buoys on-board vessels were defined. Two methods for filtering buoys and quantifying operational buoys at sea were tested. The buoy pre-processing methods showed high matching coefficients (>94%) in all oceans and datasets. In addition, the described method for estimating buoy density is in line with the one adopted by ICCAT, and it refers to average number of operational buoys belonging to the vessels over the month (total number of operational buoys recorded per day over the entire month/ the total number of days).

On the other hand, the WP4 is devoted to developing and test methods for the estimation of reliable estimates of tuna presence and abundance underneath the FADs.

- The algorithm developed for one specific brand of buoys (i.e. Marine Instruments) has shown a very good efficiency in pattern recognition of presence and absence of tuna aggregation under FADs, regardless of the ocean. This procedure is less accurate for estimating the precise range of aggregation sizes (i.e. aggregations of <10t, 10-25t, >25t).
- The method applied on a different buoy brand (Satlink) (based on existing knowledge of the vertical distribution of non-tuna and tuna species at FADs and mixed Target

Strength and weights) improves slightly the biomass estimates provided by the manufacturer. However, the improvement of the biomass estimates was not as large as expected, so it should be further improved.

<u>WP5</u> developed an R package[3], named "dqassess", which could improve the procedures assessing the quality of biological data on large pelagic stocks, at the national and regional levels. The introduction of the R package "dqassess" has to be seen as the first step in a larger dynamic process. Several projects on data quality assessment have been started by different initiatives (e.g. COST[4]); the package needs to be linked to these projects. Furthermore, this kind of quality control and checks have to be tested by the community and all contributions, and feedback experiences should be considered to improve the methodology and, especially, to follow-up the specific user needs. In addition, Mediterranean swordfish age-reading coordination exercise was conducted under WP5, which could be understood as an example of cooperation under the DCF between the institutes from several MS and which could be extended to the rest of the LP species. This cooperation has resulted in common and agreed procedures (age scheme, age criteria) and methods (preparation of the spines) used for swordfish age reading.
Moreover, it is recommended that the coordination on the swordfish ageing should continue, organising new exchange exercise and workshop after three years to assess any improvements that might be ascribed to the agreed-on procedures and common ageing protocol.

Finally, **<u>WP6</u>** has focused on a **consultation process** about the results obtained in the present project among MS involved in LP fisheries. The participation rate exceeded 50% including some of the most relevant countries with large pelagic captures.
There is a broad consensus among MS on:

- the general proposal to structure the RCG-LP in 3 stages,
- the recommendations done for the development of a RSP for tropical tunas and Mediterranean swordfish, and
- for the procedures to assess the biological data quality.

Discrepancies with RECOLAPE proposal, if any, should be solved within the context of the RCGLP. In this context, the results from WP1, WP2 & WP5 were presented and discussed during the RCG-LP 2019 meeting (Madrid, May 2019). Results obtained through the written consultation were confirmed. The proposed structure of the RCG-LP, as well as the number of stages and subgroups was adopted. In addition, the RCG -LP recommended to add a fourth technical subgroup focused on the coordination of the bait boat fisheries. As for WP2 and WP5 results, there were no notable disagreements among the RCG-LP participants. However, it is worth highlighting the doubts that persist in some MS in relation to the need of a Regional Data Base for highly migratory species.

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3 R Packages are the fundamental units of reproducible R code. They include reusable R functions, the documentation that describes how to use them, and sample data. R is a programming language and free software environment for statistical computing and graphics supported by the R Foundation for Statistical Computing, which is commonly used by fisheries researchers.

4 https://wwz.ifremer.fr/cost/content/download/15319/file/COSTcore.pdf

INTRODUCTION

General introduction to the project

This report refers to the framework contract MARE/2016/22 and, specifically, to the Annex III "Biological data collection for fisheries on highly migratory species". The overall objective of the project is to strengthen the regional cooperation in the area of biological data collection for highly migratory species. The regional cooperation should evolve from holding single meetings, Regional Coordination Meetings (RCM), to a continuous process involving a Regional Coordination Group (RCG) with increased responsibilities. The project has been designed to help the Member States (MS) to build up experience in new areas of regional cooperation, to establish the Large Pelagic Regional Coordination Group (RCG-LP). This should improve the coordination of the fishery data collection among the EU MS to support stock assessment and advice to the fisheries. The project seeks solutions to various issues in data collection, identified by the scientists involved in the stock assessment by the tuna RFMOs (Regional Fisheries Management Organisations) and the RCM-LP.

The project has been involved in several developments: the design of Regional Sampling Plans (RSPs) for large pelagic stocks, creation of tools and protocols for collecting new data around FADs (Fish Aggregating Devices), testing the alternative onboard data collection methods and the design of an appropriate regional framework to assess the data quality. The results were disseminated using the regional consultation process; all the MS involved in the large pelagic data collection (irrespective of their participation in the project) identified points of consensus and/or disagreement.

The project addressed the following specific objectives:

- The evolution of the large pelagic RCM towards the large pelagic RCG
- Identification of the requirements for the design of RSPs for large pelagic stocks, to help in the transition from individual national work plans to regional work plans
- Development of tools and protocols for collecting new data around the FADs, as needed by the end-users
- Tests of alternative data collection methods for cases where traditional methods are insufficient
- Cooperation between the MS to improve the procedures assessing the quality of biological data on large pelagic stocks, at the national and regional levels
- Identification of points of consensus and/or disagreement that may arise during the coordination process of large pelagic fishery data collection

The following work packages (WPs) are described here:

WP1- Large Pelagic Regional Coordination Group structure

WP1 made a proposal for the future organisation of the RCG-LP. As described in the Article 25 of the Common Fisheries Policy (CFP), Regulation (EU) No 1380/2013[5], and in the Article 9 of the European Data Collection Regulation (DCF), Regulation 1004/2017[6], the MS shall

[5] REGULATION (EU) No 1380/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC

[6] REGULATION (EU) 2017/1004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008 (Recast)

coordinate their data-collection activities with other MS in the same marine region. To facilitate this regional coordination, the RCGs shall be established, to develop and implement procedures and methods for the collection and processing of the data. Thus, the WP1 defines the future structure of the RCG-LP and proposes the manner of optimal engagement of this group in the various defined RCGs/regions.

WP2-Design of Regional Sampling Plan (RSP) for large pelagic stocks

The development of an RSP is a time- and effort-consuming process that cannot be completed overnight. Its design and implementation will be one of the main tasks for the RCGs in the coming years. The WP2 explores all the elements needed for the design of a European Regional Work Plan, or at least a Regional Sampling Plan, that may replace the relevant parts of the MS National Work Plans. It should improve the coordination between the European Union MS in the use of fishery data for stock assessment and management advice and introduce the concept of an RSP at the RFMO level.

This WP includes two case studies: one for the Mediterranean swordfish (*Xiphias gladius*) and another for the tropical tunas in the Atlantic Ocean; skipjack tuna *(Katsuwonus pelamis)*, yellowfin tuna *(Thunnus albacares)* and bigeye tuna *(Thunnus obesus)*. These regional sampling designs are based on the lessons learned from previous projects[7] dealing with other fisheries.

WP3-Specific pilot studies

This WP addressed some data-collection weaknesses identified by the RCM-LP at its annual meeting in September 2016[8], for which it made specific recommendations.

- *"The RCM LP recommends including number of FADs data under effort variables included in table 4 (Fishing activity variables) from EU MAP annex*."
- *"The RCM LP recommends a feasibility study on Electronic Monitoring System for Long Line, in order to study the possibilities of this tool"*

WP3 consists of two independent sections described below.

WP3.1- Development of tools for FAD data collection/transmission

Recently, one of the major concerns in fishing the tropical tunas has been the worldwide increase in the use of drifting FADs by purse seiners. The use of these floating objects helped to increase tuna catches. However, some negative effects of the increasing use of FADs at sea have been reported. These include alterations in the movements of tunas (Marsac *et al*., 2001; Hallier and Gaertner, 2008), reduction in yield per recruit of yellowfin and bigeye (the small specimens are found in the catches of skipjack), increase of bycatch, the impact on coastal habitat and a potential source of pollution (Dagorn *et al*. 2013, Maufroy *et al*., 2015, Davis *et al*., 2017). Despite the increasing FAD use, and the concerns that this generates, little information is available on the appropriate FAD monitoring and management. The RFMOs have recently called for FAD management plans. They established the guidelines for data collection around FADs to be followed by purse seiners

[7] MARE/2014/19 projects on "strengthening regional cooperation in data collection".

[8] https://datacollection.jrc.ec.europa.eu/documents/10213/1017947/RCM+MED+BS+LP+2016.pdf

and support vessels. These FAD management plans are also designed to increase the CPC (Contracting Party or Cooperating non-Contracting Party, Entity or Fishing Entity) FAD data reporting requirements. They limit FAD usage by regulating[9] the number of active buoys at sea (IOTC: Res. 18-08[10], Res. 17-08[11], Res 15/02[12]; ICCAT: Rec 16-01[13], Rec 13-01[14]). Thus, FAD monitoring has become a priority for all tuna RFMOs, as shown in the current advice given to FAD Working Groups[15]. However, the FAD data are not specifically included in the EU Multi-annual Plan for data collection (EU-MAP) (Commission Implementing Decision (EU) 2016/1251[16]). The 2016 meeting of RCM-LP recommended that the number of FADs should be included under effort variables in Table 4 of the EU-MAP about fishing activity variables. This WP, in collaboration with the fishing industry, developed protocols for FAD data collection and the data storage tools that meet the tuna RFMO requirements. WP3.1 is aligned with the work carried out under the joint tuna RFMO Working Groups on FADs (Hampton et al., 2017). It also takes into account the definitions agreed-on during the CECOFAD (Catch, effort and ecosystem impacts of FAD-fishing) project for the standardisation of definitions of drifting FADs and floating objects (FOB) in general (Gaertner et al., 2016). Moreover, the results obtained by WP3.1 will provide valid input data for CECOFAD II[17] (continuation of the CECOFAD) project currently progressing in close collaboration with RECOLAPE.

WP3.2- Electronic Monitoring System feasibility study for longlines

Based on the tuna RFMO feedback (IOTC/WCPFC), the observer coverage should be increased for some longline fleets, for which the minimum requirement of 5% coverage is not always achieved (RCM Med&BS -LP, 2016; Clarke et al., 2014). Electronic Monitoring Systems (EMSs) on fishing vessels have been developing rapidly during the last decade. The EMSs are used in some fisheries as an alternative and/or a complement to human observers onboard (McElderry and Meintzer, 2019). An EMS consists of a central computer installed on the vessel and several sensors and cameras that record key aspects of fishing operations (such as vessel location, speed, catch, fishing methods and protected species interactions). This technology is quickly gaining popularity with management agencies. However, before implementing this technology in a fishery, system capabilities should be

[9] This report was first delivered in May 2019 and the regulations mentioned on it were considered for the draft version. After revision of the text, in August, some minor updates are necessary. For example: IOTC Res. 18-08 and ICCAT Rec. 13-01 are no longer active, while a new resolution was adopted in June 2019 (IOTC Resolution 19/02 Procedures on a fish aggregating devices (FADs) management plan)

[10] Resolution 18/08: Procedures on a fish aggregating devices (FADs) management plan, including a limitation on the number of FADs, more detailed specifications of catch reporting from FAD sets, and the development of improved FAD designs to reduce the incidence of entanglement of non-target species

[11] Resolution 17/08: Procedures on a fish aggregating devices (FADs) management plan, including a limitation on the number of FADs, more detailed specifications of catch reporting from FAD sets, and the development of improved FAD designs to reduce the incidence of entanglement of non-target species

[12] Resolution: 15/02 mandatory statistical reporting requirements for IOTC CPCs.

[13] ICCAT Rec [16-01] Recommendation by ICCAT on a multi-annual conservation and management programme for tropical tunas.

[14] ICCAT Rec [13-01] Recommendation by ICCAT amending the recommendation on a multi-annual conservation and management program for bigeye and yellowfin tunas

[15] CHAIR REPORT OF THE 1ST JOINT TUNA RFMO FAD WORKING GROUP MEETING (19-21 April 2017, Madrid, Spain)

[16] COMMISSION IMPLEMENTING DECISION (EU) 2016/1251 of 12 July 2016 adopting a multiannual union programme for the collection, management and use of data in the fisheries and aquaculture sectors for the period 2017-2019.

[17] Specific Contract N° 9 "Catch, Effort, and eCOsystem impacts of FAD-fishing" (CECOFAD 2) which is part of the European Framework Contract EASME/EMFF/2016/008 for the "Provision of scientific advice for fisheries beyond EU waters".

tested, identifying its strengths and weaknesses. EMS trials and pilot studies have been conducted in several fisheries to test their effectiveness as an alternative or complement to traditional human observers. Recently, the EMS has been tested in different pilot studies of tropical tuna purse-seine fishing, and its capabilities have been proven (Ruiz *et al.*, 2015; Ruiz *et al*., 2014; Monteagudo *et al*., 2014; MRAG, 2016; Ruiz *et al*., 2016a; Briand *et al*., 2017). Furthermore, based on experience gained during these trials, minimum standards for EMSs on purse seiners have been defined (Ruiz *et al.*, 2016b) and adopted by ICCAT SCRS (Standing Committee on Research and Statistics). These minimum standards include, among others, a tamper-proof system, customised to vessel level and tested by a third party, sufficient number and quality of cameras, minimum data storage capacity, dedicated software for image reviewing and compatibility with current standardised databases. In a similar way, IOTC SC (Scientific Committee) has also recommended the development of minimum standards for EMS (including, for example, cameras) for IOTC.

Thus, the main objective of this pilot study was to determine if the EMS could be used reliably to collect unbiased data onboard longline vessels, clarifying the strengths and weaknesses of the system.

WP4–Data-collection strategy for standardisation of the catch per unit effort (CPUE) or for alternative abundance indices in tropical tuna fisheries

The overarching objective of this WP is to develop a data-collection strategy for the variables used in the standardisation of tropical tuna purse-seiner CPUE and in the estimates of alternative tropical tuna abundance indices. These variables might reflect a combination of data collected under the Data-Collection Framework (DCF) and the new data, not obtained under the DCF on a routine basis, such as the information of support vessels or the number of crew members.

The relationship between the CPUE and abundance is central to stock assessment models. Alterations in this relationship will ultimately result in changes in scientific diagnostics and the associated management advice. In tuna fisheries, fishery-independent information is scarce. As a result, commercial fishery data are traditionally used to compute the CPUE and to derive indices of abundance for stock assessments. In the absence of direct estimates of abundance, an important number of tuna assessments are conducted based on CPUE from several fleets/countries as access to relevant data differs between countries. This results in partial coverage and associated uncertainty in the interpretation of outcomes. In the particular case of tropical tunas, it is not clear whether the observed trends in CPUE reflect the actual changes in abundance or the changes in catchability due to improved fishing efficiency of the fleets. For example, there are no clear criteria for including the role of support vessels in the calculation of the fishing effort or for the estimates of their contribution to the efficiency improvements of the tropical purse seiners. Similarly, there is no established method to discriminate between the fishing efforts of purse seiners targeting free schools and those operating using floating objects (man-made FADs and other similar objects).

For all these reasons and given the importance of the purse-seine fleet for tropical tuna stocks, both DG MARE and European scientists have attempted to standardise the CPUE of this fleet by organising dedicated workshops[18]. To avoid an overlap with the work carried

[18] Workshop for the development of indices of abundance for the EU tropical tuna purse seine fishery, held in Fuengirola, Spain, on July 2016. EU-funded

out by other groups/projects (such as CECOFAD2 currently working on CPUE standardisation process), WP4 aimed to select the information needed to correct the raw CPUE series. Thus, this WP focused on the recovery and integration of data that could be used later for the analysis, rather than on the exploration of new standardisation models. These data reflect the information obtained from the fleet, such as the use of onboard technology, the number of FADs used or the contribution of support vessels.

Alternatively, non-conventional information[19], such as the output of buoy acoustic signals, may be used directly to estimate the local and regional relative abundance of tunas under the drifting FADs, i.e., the Buoy-derived Abundance Index (BAI). This type of information must be compared for different buoy types and models/brands in the particular temporal and spatial strata and then combined at a larger scale to implement direct indices of abundance. These can be then compared with the conventional CPUE-based indices.

WP5–Procedures to assess the quality of biological data collected at the regional level

The main objective of this WP was to develop data-quality assessment procedures and data-quality improvements agreed at the regional level.

Regional data collection requires a common sampling protocol, raising method, data format and common evaluation of data quality. Even in the absence of regional databases for large pelagic species, RCM-LP has used a common Standard Data Exchange Format (SDEF) for exploratory data analysis, employing the IT tools developed under the COST project (Vigneau, 2006) for the evaluation of data quality aspects. SmartDots[20] is an online platform for sharing and comparing images of age structures, to standardise age determination by different readers. Both COST and SmartDots are good examples of the existing potential to improve data quality. The overall target of this WP is to develop a practical framework for the implementation of the minimum set of data-quality checks that should be conducted at the national and regional levels. Furthermore, an annual calendar for the implementation of these quality checks will be proposed, which should help to fulfil the tuna RFMO data-provision obligations.

WP6–Regional consultation of Member States

WP6 was designed to collect inputs from regional consultations with all the MS dealing with the collection of data on large pelagic fisheries, as well as from end-users (tuna RFMOs and RCG). Furthermore, this WP dealt with dissemination of the results, taking into account that the audience for the different WPs could be different (such as tuna RFMO Working Group meetings or RCG meetings).

To make the project truly successful, it is essential that the results and experience gained in the different WPs be well received, understood and implemented by all organisations

Workshop for the development of Skipjack indices of abundance for the EU tropical tuna purse seine fishery operating in the Indian Ocean, held in the AZTI (Pasaia, Spain) on July 2017. EU-funded

Workshop for the development of Yellowfin indices of abundance for the EU tropical tuna purse seine fishery operating in the Indian Ocean, held in the IRD (Sete, France) on September 2018. EU-funded

[19] The fishing industry is the owner of the information and therefore, first, they should provide it under confidentiality requirements.

[20] http://www.ices.dk/marine-data/tools/Pages/smartdots.aspx

involved in the data collection for highly migratory species. WP6 identified possible impediments that may come to light during this process.

Project scope

In general terms, the geographical scope of the study is the Mediterranean Sea and long-distance fisheries in the Atlantic and Indian Oceans, even though the results might be later applied to other areas and tuna RFMOs. The project consortium is composed of eight partners from the main institutes/agencies involved in the DCF, representing five of the most important MS with large pelagic fisheries (Spain, France, Italy, Greece and Cyprus).

Lack of participation of certain relevant scientific institutes, such as IPMA (Portugal) and IFREMER (France), made it impossible for the project to fulfil some of the tasks proposed in the bid (e.g., consolidating the data for the long-distance longline fleet) or to include bluefin tuna as a case study. However, all the relevant organisations were involved in the consultation process (under WP6) even if they were not project partners.

The main goal of the project was to improve the coordination between MS; thus, the organisations from non-EU countries were not included as partners. However, it is true that most of the LP stocks are also exploited by these countries, so a discussion of the results with their representatives would add considerable value to the proposal. Thus, the project results will be shared in the forums where such organisations are represented.

Objective and structure of the final report

The objective of this final report is to explain the work undertaken, giving details of the implementation and results of the specific work packages. The final section in each work package report also lists recommendations for the future work to improve the coordination in the collection of data on highly migratory species. Moreover, this report describes the difficulties encountered so far, and the ways used by the consortium to address them. The Final Report section reflects the structure of the work packages, from WP1 to WP6.

This report is considered the final Deliverable (D.0.3) out of the 21, planned for May 2019.

WP1– STRUCTURE OF THE LARGE PELAGIC REGIONAL COORDINATION GROUP

Objectives

WP1 deals with the future organisation of the RCG-LP. It proposes a structure for the RCG-LP and explores synergies and mechanisms for coordination of this group with the various defined RCGs/regions.

Methodology

Task 1.1. Propose a structure for the establishment and operation of the RCG-LP

All the documents and reports discussing the organisation of RCGs in general, and RCG-LP, in particular, were reviewed (RCM-LP meetings, other RCM meetings, liaison meeting, DCF regulations, reports of annual meetings of RFMO scientists in Brussels, etc.). Based on this review, and in direct consultation with RCG-LP chair and participants, a series of prerequisites for the correct establishment and operation of the RCG-LP has been proposed. The initial focus was on the number of subgroups, meetings and recommended periods for these meetings, to encourage wide participation of MS. The possible use of the current Regional Database (RDB[21]), within the scope of the Northern RCGs, as the host of the LP data, was also revisited.

Task1.2. Synergies with other RCMs/RCGs-LP

The possible synergies with other RCGs were explored, to establish what would be the optimal engagement of this group in the various defined regions, including mechanisms for coordination between the relevant RCGs.

Main results

As stated in the Article 25 of the CFP (Regulation (EU) No 1380/2013) and in the Article 9 of the DCF (Regulation (EU) 1004/2017), the Member States shall coordinate their data-collection activities with the other Member States in the same marine region. To facilitate this regional coordination, the RCGs shall be established, to develop and implement procedures and methods for collecting and processing data. The RCGs shall draw up plans and agree on its own organisation. The first proposal for the future RCG-LP structure was presented during the RCG-LP 2018 meeting (June 2018, Heraklion, Greece). This proposal was later adapted and modified based on the comments and suggestions made by the RCG-LP participants. A final version of the D.1.1 (*Proposal for the organisational structure of the RCG-LP*) is attached to this report as Annexe 1.

Before proposing a new structure, it is important to know the recent history of the group. Data collection on LP fisheries outside the Mediterranean Sea has been initiated within the scope of RCM Long-Distance Fisheries (LDF), while Mediterranean LP fisheries fell within the scope of the RCM-MED&BS. However, the Liaison Meeting in 2013 decided to create a coordination group for LP, covering the areas of competence of RCM LDF, North Atlantic, the Mediterranean and Black Sea (MED&BS) and dealing with all large pelagic species and fisheries. This group has been initially associated with RCM-MED&BS to limit the number of meetings and allow the Mediterranean experts on LP fisheries and stocks to participate in RCM-LP subgroup while also participating in RCM-MED&BS. Between 2014 and 2017, the RCM-MED&BS-LP was, therefore, a joint RCM with two co-chairs, one for MED&BS and one for LP.

However, as stated in the RCM MED&BS-LP 2016 report[22], from the RCM-LP subgroup perspective, it was particularly unfortunate that the annual meeting of this group took place in September, very close to unavoidable ICCAT scientific activities. As a result, some LP data end-users (ICCAT) and many EU scientists participating in tuna RFMOs could not attend. The RCM-LP believed that these absences should be avoided, as far as possible, to ensure that data requirements from RFMOs are reflected in the national programmes for data collection. Moreover, from the RCM-LP subgroup perspective, the topics common to the two subgroups, RCM-MED&BS and RCM-LP, were very limited. Thus, considering the characteristics of these fisheries, it seemed logical to form a specific thematic group (Large Pelagic Group). In 2017, LP and MED&BS experts held separate meetings, even though the two subgroups were still the members of the same RCG. At that time, it was agreed that the RCG-LP should be an RCG independent from MED&BS, and, ideally, it should hold its meetings in the second quarter of every year to avoid the periods of heavy workload. This idea was presented as an RCM-LP recommendation during the 14th Liaison Meeting. The

[21] The Regional Data Base (RDB) Exchange Format. Hosted by ICES is used by Regional Coordination Groups North Atlantic (RCGNA), North Sea and East Artic (RCGNS&EA), Baltic (RCGB) and Long Distance (RCGLD)

[22] All RCM/RCG reports can be found https://datacollection.jrc.ec.europa.eu/docs/rcm

new group would not be regional, but global, associated with the highly migratory large pelagic species rather than with a specific geographic region. The CFP (Regulation (EU) 1004/2017) refers only to the coordination of activities in marine regions (no reference to species or groups of species); the RCG-LP set its region as "all regions". Thus, during 2018, the RCG-LP acted as an independent group, asking all the MS involved in large pelagic fisheries to participate.

Keeping in mind that the RCG-LP would act as an independent group, the WP1 proposed prerequisites for the correct establishment and operation of the group. It is expected that this proposal will foster the implementation of RCG-LP so it can become fully operational in the near future.

The proposal recommends that two preparatory meetings should be held before the RCG-LP main meeting. Too many meetings (subgroups/stages) can reduce the participation of LP experts. The preparatory meetings are to integrate, if possible, the existing gatherings under the umbrella of the future RCG-LP. The first stage would identify data gaps and prioritise the LP data needs, including tuna RFMO data requirements and data transmission failures. The second stage would be much more gear/stock-specific. This second stage would design RSP by coordinating both dockside and onboard sampling for the different stocks. The main RCG meeting (third stage) would evaluate the results of the two preceding stages, and it would make the final decisions of greater importance and approve the Regional Sampling Plan.

Concerning the first proposed stage, the identification of data requirements, DG MARE organised a yearly meeting with a similar goal, with the participation of DG MARE desk officers dealing with RFMOs and EU scientists involved in RFMO activities (e.g., Ref. Ares (2017)1788775 - 04/04/2017). Thus, considering this meeting as a part of the RCG-LP might be advantageous, in case of organisational problems. The aim of such meeting would be to identify and prioritise the LP data needs and to improve communications between EU scientists (involved in data collection and stock assessment), DG MARE and the rest of the end-users (tuna RFMOs).

Once data gaps are identified, and data requirements/priorities are established, the second stage should coordinate the data collection in the different MS. Ideally, this coordination should be achieved by methodological groups dealing with specific fisheries. For many years, France and Spain have coordinated their tropical tuna purse-seine fisheries in an annual coordination meeting with participation of scientists from both countries, via a data analysis working group (Tropical Tuna Treatment, T3). During such a meeting, sampling methodological issues are discussed; tools and sampling protocols are shared, discussed and eventually revised. Regional sampling coordination and possible bilateral agreements are also discussed. Scientists from non-EU landing countries like Seychelles, Madagascar, Côte d'Ivoire, Senegal and Ghana who participate in the data collection are also invited[23]. Specific or common scientific contributions, as well as data calls to tuna RFMOs (ICCAT/IOTC), are jointly elaborated.

The existing trend in coordination for the tropical tuna purse-seine fisheries can be taken as an example of the regional sampling scheme. For the rest of the species and fleets, such regional coordination does not currently exist. Thus, expanding the scope, and organising

[23] Ghana is one of the main fishing countries in the Atlantic and the provision of accurate Task 1 and Task 2 data of their activity to ICCAT is critical for the assessment of tropical tuna stocks. They are always invited to the T3 restitution meetings, but have not responded since 2015.

similar technical meetings to coordinate data collection for other LP stocks (where data acquisition, sampling methodology, bycatch and sampling coordination issues are discussed) could be beneficial. During the 14th Liaison Meeting, the RCG-LP 2017 made a recommendation to hold a workshop to explore the possibility of launching a permanent group for longline fleets outside Mediterranean waters. This group would complement the existing Tropical Tuna T3 Group. Under this scenario, the longline and purse-seine fisheries outside Mediterranean waters would form specific coordination groups for the design of the RSP. Only the fleets operating in the Mediterranean and fleets targeting temperate tunas (bluefin tuna and albacore) in the North Atlantic would remain outside the sampling coordination network. Thus, it makes sense to create specific groups to coordinate the sampling in these fisheries. This would include the Mediterranean LP fisheries (using longline as its main gear) and a coordination group focused on bluefin tuna sampling (the unique stock found both in the Mediterranean and North Atlantic). The north albacore is outside this coordination framework because the main countries contributing to albacore landings in the North Atlantic (Spain and France) do not share the same gear/métiers and thus, there is not much room for dockside sampling coordination. Even though the coordination of other biological samplings (e.g., maturity, ages) could be beneficial, a specific data analysis subgroup has not been considered necessary.

Figure 1 shows the diagram of the possible meetings and subgroups for the future RCG-LP, including the three stages. The details of the subgroups are provided.

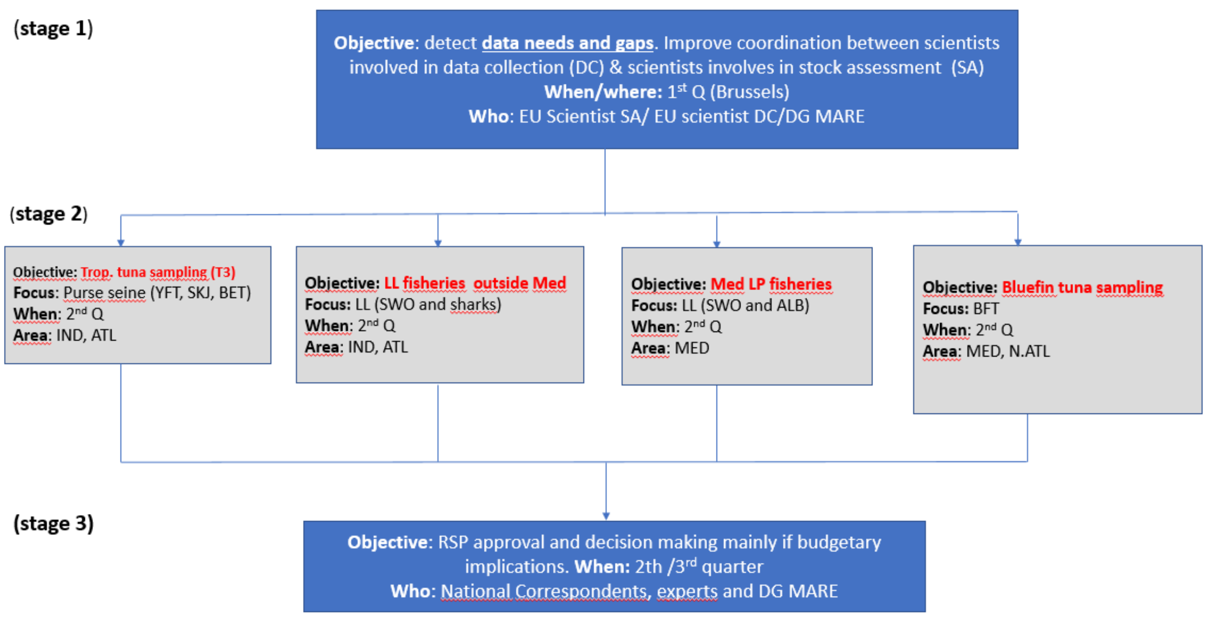


Figure1. Proposal for RCG-LP subgroups.

- *<u>Stage 1: subgroup for data requirements and data gaps</u>*

The objective of this subgroup is to address the data collection issues of common interest to tuna scientists. The research priorities for data collection should be identified based on data gaps and data needs presented by the end-users (stock assessment groups within the tuna RFMOs). The coordination between data collection scientists and stock assessment scientists should be improved.

The group would also be in charge of identifying the needs outside the commercial fishery sampling, such as scientific surveys on highly migratory species or adding new recreational fisheries to Table 3 in the EU-MAP (Commission Implementing Decision (EU) 2016/1251).

Since 2011, DG MARE has been organising meetings with the overarching objective of improving the coordination between DG MARE and EU scientists working in different RFMOs. Such meetings offer a good opportunity for scientists and DG MARE officers to exchange views on the achievements at RFMO level during the preceding years and to provide a response to the challenges of the current year*.* If this existing meeting is used as part of the RCG-LP instead of creating a new group, following the RCG-LP Chair invitation to the national correspondents, each MS should be free to decide which experts should participate. DG MARE is always part of the RCGs and attend the meetings.

- *Stage 2: subgroup on data analysis and regional sampling design*

The aim of this group will be standardisation and coordination of the sampling at the fleet level, both for the target and bycatch species. Thus, the participation of the institutes involved in the monitoring of these specific fleets is expected. These organisations should share tools for data acquisition (including the database), data collection protocols (including codes) and data-quality checks. Additionally, these groups could prepare tuna RFMO participation including data analysis and data calls. The proposal includes four parallel groups based on stocks/gears.

a) Tropical Tuna Treatment (T3): focus on PS fleet and yellowfin tuna (YFT)/skipjack tuna (SKJ)/bigeye tuna (BET)
b) Focus on longline fisheries outside the Mediterranean
c) Mediterranean LP fisheries: focus on Longline
d) Bluefin tuna (BFT) sampling

Number of parallel subgroups in this stage2 and stocks/gears allocation among subgroups has been based on the RCG – LP 2018 participants feedback. However, they should be dynamic and flexible groups, which may vary in the future, and where the group itself must decide on its operational aspects (e.g. inclusion of specific TORs (terms of reference), how often to meet or election of the Chair-person).

- *Stage 3: RCG-LP main meeting*

In addition to the two stages mentioned above, it is necessary to hold a main RCG-LP meeting, where decisions will be made based on the output from the previous stages. It is not necessary for the participants to have the same technical profile as for stage 1 and 2, but they must have the capacity to make decisions.

In the second step, WP1 explores synergies with other RCGs where the contractors identify the fields of common interest to the "regions" (RCGs), and where mechanisms are proposed, if needed, for coordination between relevant RCGs. These synergies among the RCGs will be necessary and beneficial.

The main common fields for the cooperation between the RCGs are related to the design of the Regional Sampling Plans based on statistically sound-sampling methods and data management. These include the archiving of data and the processes of quality assurance and quality control (development of guidelines for evaluation of data quality, development of common software tools in R, etc.).

This does not mean specific involvement in the design the Regional Sampling Plan for Large Pelagic Stocks (this would be designed and coordinated through specific gear/stock related groups). It does mean maintaining contact with other regions to use common tools to design a statistically sound RSP and the tools to evaluate the quality of the data. DCF-related groups convened by other end-users such as ICES (e.g. PGDATA[24]) could be a good example, where issues of common interest, applicable to other areas/fisheries, are discussed. Ensuring appropriate dissemination/communication of the findings of these DCF-related groups would be beneficial.

This requires (a pan-regional) inter-sessional work involving the different RCGs. This work will facilitate cooperation on a supra-regional level and implement the tasks needed to assure general future coordination.

To achieve this, the first step would be the creation of specific pan-regional subgroups for the common fields mentioned above (sound-sampling design and data management subgroups). It is important to mention that running a "subgroup" does not necessarily mean organising a face-to-face meeting. Once the subgroups are created, it will be the responsibility of the RCGs to identify the appropriate regional experts to work on the relevant tasks.

The key requirement for working in these common fields is to have a Regional Database (RDB), with the data stored in common formats, ensuring transparency and consistent standards for data processing and dissemination. This available for the 3 northern RCGs (RCG NA, RCG NS&EA and RCG Baltic). The RCG-LP is working to adopt the same formats and structures to be able to upload and integrate the data into the RDB (more details on this issue are available under WP2, Task 2.5).

Recommendations for future work

Once the proposal for the future RCG-LP functioning is structured, it has been presented in detail to the MS that might participate in the group (i.e., Cyprus, Spain, France, Italy, Portugal, Malta, Croatia, Greece, Ireland and UK) for their approval. The consultation process conducted by WP6 (see details in Annexe 16) anticipates a broad consensus on the proposal made in the WP1, where MS agree on the global structure and number of subgroups proposed for the internal functioning of the RCG-LP. However, this proposal will probably demand an increase in human resources; although some of these subgroups already exist, some new subgroups must be organised. It should be noted that the survey conducted under WP6 identified the lack of human resources as a limitation for some countries. Therefore, although the proposed structure seems appropriate and accepted by the interested parties, it does not seem entirely realistic to expect that all subgroups will be created within a short period. A clear example of this is the subgroup on data analysis focused on longline fisheries outside the Mediterranean; the RCG-LP has recommended several times that the group should be launched. However, this group has not been established yet.

[24] Planning Group of Data Needs for Assessments and Advice

To break the impasse and give a decisive impulse to the much-needed work in the different groups, the following actions are recommended. First, more people should be involved in the RCG-LP (both scientists and national correspondents); traditionally, the group had a very small number of participants. Second, the group should identify the key person(s) that can effectively drive the creation of subgroups. Finally, these groups should be as flexible and dynamic as possible. Once a subgroup is operational, it will decide on the frequency of the meetings, coordinate and share its own tasks. As an example, the Tropical Tuna (T3) coordination meetings are yearly events, established for a long time. However, other subgroups might work differently. Coordination should be a continuous process, but that does not imply frequent face-to-face meetings.

WP2-DESIGN OF RSP FOR 2019

Objectives

WP2 explored all the necessary elements to realise a Regional Work Plan, which might replace the relevant parts of the National Work Plans. These elements include a definition of data requirements and data sharing mechanisms, agreed sampling protocol, common database and optimisation of sampling intensity. This work package focused on the development of RSPs for large pelagic fisheries. It includes two case studies: for Mediterranean swordfish and major Atlantic tropical tunas.

Methodology

The development of the RSPs was focused on two case studies.

The swordfish in the Mediterranean is a stock heavily exploited by several countries. Two types of longline fishing techniques are used: surface drifting longlines and mesopelagic longlines.

The management of Mediterranean swordfish falls within the Convention area of the ICCAT. This stock is considered overexploited, and ICCAT has recently adopted a multi-annual plan (Recommendation 16-05[25]) designed to help in its recovery. Apart from the management measures, the plan introduces several rules for the collection of fishery data and the biological monitoring of the stock. It is not clear if the relevant actions, particularly those referring to scientific information (part V of the Recommendation 16-05) are currently fully implemented, but they should be considered in the development of the RSPs.

The second study case is focused on the main tropical tunas in the Atlantic Ocean (i.e., skipjack, yellowfin tuna and bigeye tuna). The European Union is by far the major contracting party in ICCAT (in terms of catch volume; 38% of the total catches in 2016, nominal catch information from ICCAT statistical databases). Within the EU, the commonly used gear is the purse-seine (49% of the EU catches, nominal catch information from ICCAT statistical databases). Therefore, this study case considered only the purse-seine

[25] ICCAT Rec [16-05]: Recommendation by ICCAT replacing the recommendation [13-04] and establishing a multi-annual recovery plan for Mediterranean swordfish.

fishery, where the main challenge of an RSP is to cover the fishery activities on the spatial and temporal scales (with stratification if needed). To achieve this, the sampling protocol and sampling design (spatial and temporal strata) have been updated. Furthermore, the optimum sample size has been calculated.

WP2 includes the following six tasks for each case study:

Task 2.1 - Definition of data needs and priorities

This task identified the data needs and priorities for RSP design essential for performing robust estimates of the catch levels and size composition of the catches.

Task 2.2 - Definition of data sharing

This task identified the best framework for data sharing between all the MS involved in LP fisheries.

Task 2.3 - Development of a common sampling protocol

A common sampling protocol was developed, accepted and agreed on by all the MS. This included ICCAT sampling requirements, as well as additional information recommended for improving stock assessment studies. In the case of tropical tuna sampling, a standardised and agreed-on sampling protocol is already in use in Spain and France. Thus, this protocol only needed updating following the recommendations made in task 2.4.

Task 2.4 - Simulation of the proposed RSP

This task simulated the RSP to test its feasibility. The simulations considered spatial and temporal stratification on the *métier* scale and used bootstrap techniques and variation measures (coefficient of variation, CV) as selection criteria for the sampling intensity. During the project, the ability of the sampling design to deal with possible sources of bias was examined (for example, a bias introduced when the sampling is not performed in both small and large sets).

A data call was launched in October 2018 to all MS involved in tropical tuna and Mediterranean swordfish fisheries; landing, effort and sampling data were requested for the period of 2015–2017. The SDEF format, used before by the RCG-LP, was requested. This format is a slight adaptation of the format developed under the COST project (AA.VV., 2006).

Task 2.5 - Data storage/management/analysis solutions at the regional level

The aim of the task was to identify the elements of the system that would allow the storage, management and analysis of data at the regional level. It also addressed the question of the roadmap and proposed specific actions needed for establishing such a system.

Task 2.6 - Lessons learned

This task presented a set of rules and recommendations for transferring the lessons learned under WP2 to other relevant large pelagic fisheries exploited by similar means (for example, Mediterranean longline targeting albacore or tropical tunas in the Indian Ocean).

Main results

Task 2.1 - Definition of data needs and priorities

Table 1 shows the list of data requirements and priorities necessary to conduct a robust stock assessment for Mediterranean swordfish and tropical tunas in the Atlantic. The "priority" variables selected here are those needing special attention or improvement during their collection and/or parameter estimation. This means that the data are either not available or is affected by bias or errors and needs to be improved to provide the correct information. However, it is very important to understand that all the data selected (priority or not) need to be collected to make robust estimates of stock parameters and catch levels

For tropical tunas, eight priority datasets were defined. These were discards (dead and alive), catch-at-size estimates, support vessel data, number of FADs deployed, maturity, ages and local market data (so-called "faux poisson").

For the Mediterranean swordfish, nine priority datasets were selected. They were discards (dead and alive), catch and fishing effort data, size frequency, catch-at-size estimates, maturity, fecundity and ages (see Table 1 for more information about the datasets).

The collection of some of these data is mandatory under ICCAT rules. However, obtaining some other variables, not required at the RFMO level, would significantly improve the stock assessment and, thus, the scientific advice. In this case, the RCG should define which are the main biological variables needed and recommend their collection.

More details on data needs are available in Annexe 2 (*D.2.1.- List of data requirements for the development of an RSP for the SWO-Med & TROP tunas*)

Table 1. List of data requirements and priorities[26] for the design of a Regional Sampling Plan for large pelagic fisheries (focusing on 2 study cases: Mediterranean swordfish and major Atlantic tropical tunas). Empty cells indicate that the relevant information is already available. The main difference between task 1 and Task 2 data is that the latter uses precise geographical dimensions (e.g., a statistical square of 1° by 1°). In contrast, Task 1 data are reported on the scale of the ICCAT area.

[26] The data selected need to be collected to make robust estimates of stock parameters and catch levels. When it is considered priority, it means that for that specific stock data are either not available or should be improved.

	Dataset	Description	Atlantic yellowfin tuna	Atlantic bigeye tuna	Atlantic skipjack tuna	Mediterranean swordfish
Mandatory by ICCAT	**Task 1 fleet characteristics** Fishing vessels with positive fishing effort and fishing for any of the ICCAT species in the Convention Area	Vessel and fleet ID, other attributes (gear group, length overall, tonnage and tonnage type), total fishing effort and fishing activity				
	Task 1 nominal catches Yearly total catch (targeted, non-target and by-catch, recreational and sport fisheries) estimates in live weight (kg) by species	Catch quantities landed (dead)				
		Catch quantities discards (dead)	Priority	Priority	Priority	Priority
		Catch quantities discards (alive)	Priority	Priority	Priority	Priority
	Task 2 catch & effort Monthly catch and effort by species and geographical squares (5x5 longline and 1x1 for other gear)	Catch data and fishing effort data				Priority
	Task 2 size sampling Monthly size frequencies (size/weigth classes) with number of fish sampled by sampling area and/or geographic square	Size frequency				Priority
	Task 2 catch-at-size estimations Monthly estimations of size composition of the catch by fleet, gear and area strata (use relation weight-length)	/	Priority	Priority	Priority	Priority
	Support Vessel activity Monthly activity of tropical support vessels authorized to operate in the ICCAT Convention area	Activity of support vessel (location and number of days at sea) and fishing vessel association	Priority	Priority	Priority	Not applicable
	FAD Monthly number of FADs deployed by statistical rectangles (1°x1°)	FAD characteristics (presence/absence of beacon/buoy, type of FAD and beacon/buoy/echo-sounder, average numbers of beacons/buoyes active/deactivated/active lost)				Not applicable
		Number of FADs deployed by support vessels	Priority	Priority	Priority	Not applicable
	National Observer programs	Data collected under national observer programmes (observed by-catch including interactions between fleets with sea turtles and incidental seabird by-catch), data and information collected from sampling programme, meta-data like percent coverage, sample scheme or geographical regions				Priority
Non-mandatory but recommended	**Information about maturity**	For example region-specific size and age at maturity		Priority	Priority	Priority
	Information about reproduction and fecundity	For example estimates of spawner and recruit proporiton in the catches				Priority
	Information about age	Based on fin-rays, otolith, vertebra, etc.	Priority	Priority	Priority	Priority
	Catch data from local market	Proportion of fish sold on the local market	Priority	Priority	Priority	

Task 2.2 - Definition of data sharing

A detailed outline of actions needed to ensure data sharing between the MS is included as Annexe 3 and refers to the Deliverable D.2.2. of this project.

In summary, it was considered that data sharing via a regional database would be the most appropriate mechanism in terms of efficiency, transparency and confidentiality. However, there is no regional database to store the large pelagic stock data. According to the RCG-LP, such tool is urgently needed for efficient use of the data collected under DCF; this has also been recognised by the DG MARE International Directorate (RCG-LP report, 2017). A new Regional Database and Estimation System (RDBES) is under development by ICES, which, when functional, will allow responding to different data calls without extra work. Expanding the scope of the RDBES to the LP stocks would facilitate the data sharing in the RCG-LP framework. However, RDBES data model should be tested on the LP stocks first (more details are provided under Task 2.5). In the meantime, the data sharing could be performed through specific data calls from the RCG-LP or conducted by projects such as RECOLAPE in agreement with the RCG-LP. The exchange of data within this project was supported by the project SharePoint[27] and by the SmartDots[28] online platform. The former was established by AZTI to exchange the information and documents related to project activities; the latter was used for the exchange of samples of hard structures for fish-ageing analysis (foreseen in the Task 5.3.1). The access to the data was granted by the project coordinator to the project participants, other end-users and stakeholders. The project partners agreed and acknowledged that the data shared would be regarded as

[27] https://azti.sharepoint.com/sites/Proyectos/RECOLAPE/default.aspx

[28] See footnote 20

confidential information and will be used only for the purposes of the RECOLAPE project and for the RCG-LP activities. The data provision was made according to the access restrictions stated under the DCF (Regulation (EU) 2017/1004 (recast)). National correspondents (whether they participated in the project or not) were a part of this process during all the stages. They all received a specific invitation to access and upload the data to the SharePoint. The data sharing has been supported through specific data call by the project RECOLAPE. This will represent an example also for the future data sharing and issuing data calls at RCG-LP. Data analyses performed within the RECOLAPE project will be performed in the future by specific working groups of the RCG-LP.

The mechanisms identified and examined in the RECOLAPE project might be an example for similar actions to be undertaken by the RCG-LP.

Task 2.3 - Development of a common sampling protocol

Annexe 4- include the details of the modifications proposed for the current sampling protocol used by Spain and France for the tropical tuna sampling, and the first proposal for a common Mediterranean swordfish sampling protocol. It refers to the project deliverable D.2.3.- *Guidelines and sampling protocols for tropical tuna and Mediterranean swordfish sampling*. A summary by case study is provided below.

Major tropical tunas in the Atlantic Ocean

Spain and France have shared a port sampling protocol for the tropical purse seiner fleet for several years. However, recent studies (Duparc et al. 2018, Fonteneau et al. 2017, Herrera et al. 2018) highlighted the necessity to improve some aspect of the sampling design, to improve the accuracy of the species composition and the specie's size distribution.

Task 2.3 proposed two changes in the protocol, which should collaborate improving the accuracy of the species composition and size distribution:

- Modify the sampling stratification, moving from the current (hierarchically structured by large sampling areas, quarter and school types) to a regular 5-degree grid.
- Reduce the number of individuals to measure per sample and still assess accurately the size distribution of the major tunas.

This proposal was tested, and proved effective, in the following task 2.4.

Swordfish in the Mediterranean

Regarding the Mediterranean swordfish, there are no common sampling protocols shared among Member States. Such protocols should be developed through RCG-LP, considering ICCAT code listing and the particularities of each national fishery. The most important aspects that should be considered refer to the spatiotemporal resolution of the sampled/reported fisheries data, the effort units and the size frequency composition of the catch. Furthermore, a protocol for sampling basic biological parameters, such as gonad maturity stage, should be developed.

Task 2.4 - Simulation of the proposed RSP

Annexe 5 and Annexe 6 include the details of the optimisation of regionalised sampling scheme for the tropical tunas and Mediterranean swordfish, respectively. Both refer to the project deliverables *D.2.4.- Simulation of the regionalised sampling plan.* A summary by case study is provided below.

Major tropical tunas in the Atlantic Ocean

Different analyses were performed to improve the design of sampling currently used by Spain and France. First, the importance of the spatial and temporal dimensions using different scales was investigated, regarding the species composition. Second, the assessment of species composition was simulated according to the sampling intensity. Thus, the theoretical number of sets to be sampled per square of a regular grid was modelled to assess the species composition accurately. We performed the analyses only using a 5-degree grid, as we did not have enough samples to test the sampling effort at a finer resolution (taking into account the actual funds allocated to sampling). Third, at the sample scale (fishing operation sampled), sample size (number of fishes to be measured) was re-evaluated to obtain good representativeness of the size distribution for each species. Finally, the potential bias of the RSP in set size distribution was investigated.

Several results of the analyses should be noted here. First, as expected, the spatial and temporal use of the fishing grounds were highly correlated, confirming that the spatial exploitation of the fishery is seasonal. We also noted that the association between spatial and temporal dimensions was very similar for the free school sets (FSC) and floating object (FOB) sets, irrespective of the spatiotemporal resolution (square size and period from 1 week to 3 months). Second, the finer the resolution of the sampling, the more accurate was the representativeness of species composition in the fishing ground (Figure 2). Finally, the spatial dimension explained a larger part of the variability in species composition of catches than the period. For instance, the effect size of the spatial dimension at 5-degree square resolution is 11 times more informative than a month resolution for FOB, and 5.4 times for FSC. The year effect was always negligible with a mean of around 0.004 and 0.002 for FOB and FSC, respectively.

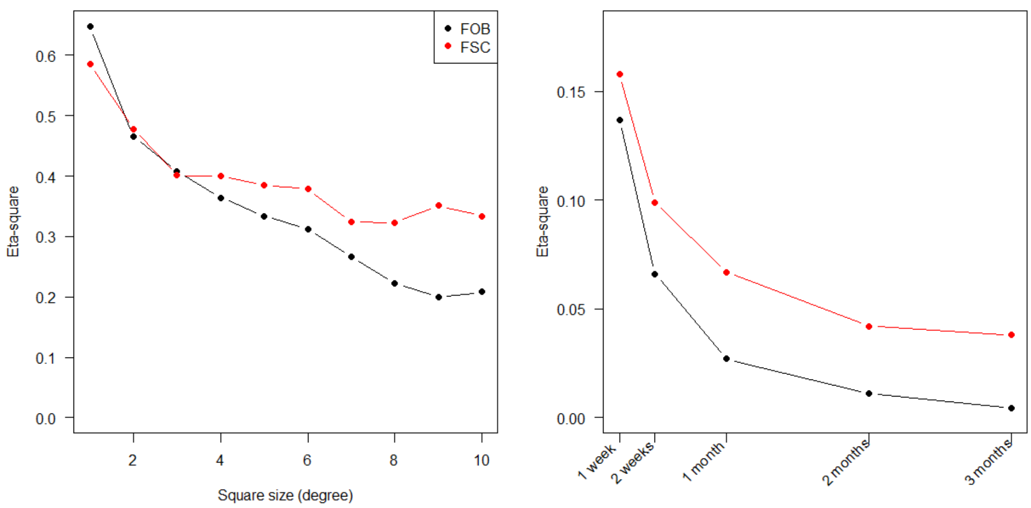
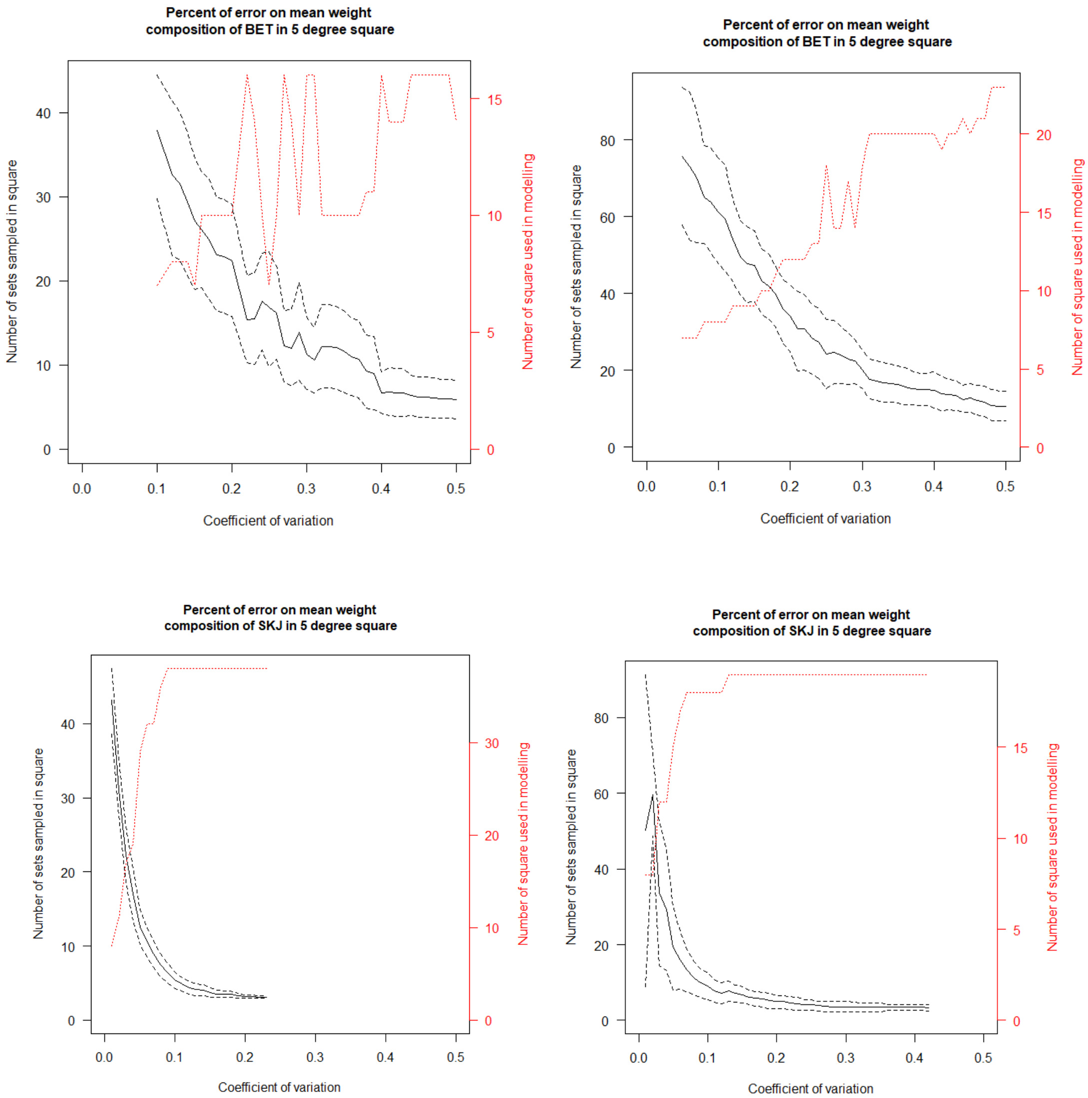


Figure 2: Partial association (Eta-squared) in MANOVA for mean species composition in tropical tuna catches depending on grid square size, with period fixed to 1 week (left), and on the period, with square size fixed to 1° (right), for two school types

Regarding the spatial sampling intensity, the minimum number of samples required to assess species composition increased exponentially with the precision of the estimate of mean proportion in catches (i.e., a decrease in CV, Figure 3). We noted that for the CV <

5% for the bigeye tuna (BET), the number of squares was not sufficient to estimate a threshold for sampling. Moreover, the number of samples required is mainly dependent on the species. Thus, skipjack tuna (SKJ) is the species that needs less sampling effort, whereas the mean proportion of BET is always the most difficult to assess as it needs more samples for the same CV. As an example, considering 5-degree square grid and an error of 10% in the mean, the required mean number of samples per square was 5±1, 33±7 and 38±7 (mean and 95% CI) for SKJ, YFT (yellowfin tuna) and BET catches using FOBs, respectively. Surprisingly, the school type plays a minor role in the sampling effort for the species composition assessment, except for the BET. Assessment of catches using FOBs always needed smaller sampling effort than using FSCs.



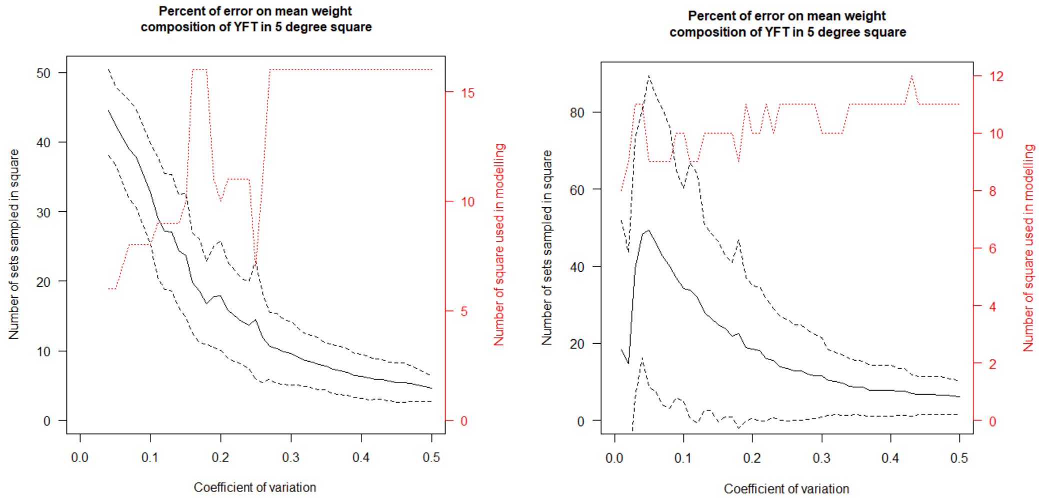
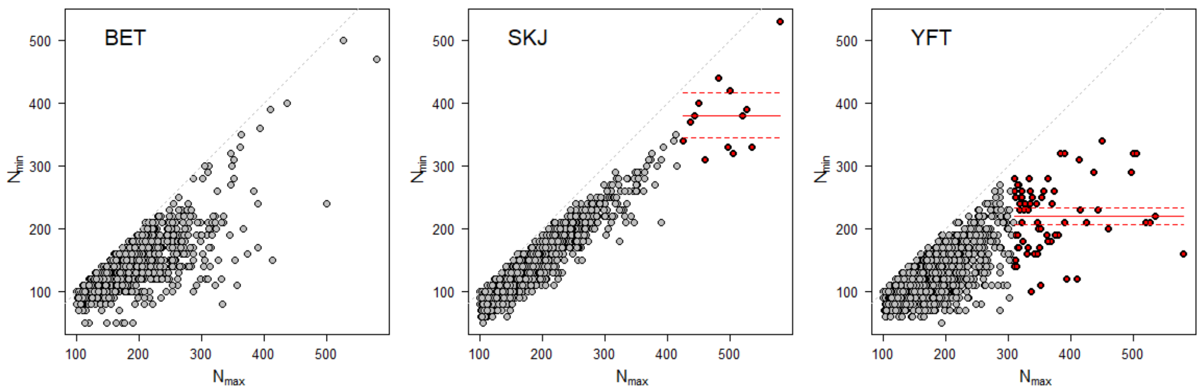


Figure 3: Mean and 95% CI of the number of samples in a 5-degree square according to the CV of the mean in composition per species and per school type: FOB in the left-hand panels (school under floating object) and FSC on the right (free school). Red line corresponds to the number of square years used in the model.

Considering the effort (i.e. number of fish measured) for each sample (using FOB or FSC) we could estimate a minimum number of total fish (N_{min}), on average, to measure to conserve good representativeness of the YFT size distribution (219 ± 13 fish and 228 ± 16 fish for FOB and FSC, respectively). Under such conditions, the number of YFTs to be sampled was on average 107 ± 15 for samples of FOB and 152 ± 12 for samples of FSC set. For the BET, we only could estimate the N_{min} for FSC (343 ± 43 fish), for which the number of BETs was, on an average, 124 ± 42. However, the N_{min} for FOB was always dependent on the total number of fishes measured (N_{max}), meaning that the accurate size distribution was not obtainable (Figure 4).

For the SKJ, surprisingly, we found that the N_{min} was very high for samples from the FOB set (343 ± 37 fish); however, this was based on only 12 samples. Even worse, for FSC, the N_{min} was always dependent on the N_{max}, meaning again that the size distribution was not perfectly known irrespective of the number of fish measured. One reason for these results might be that the threshold of 100 fish measured (the limit under the current protocol) could not be reached for the FSC because the proportion of SKJ was too low.



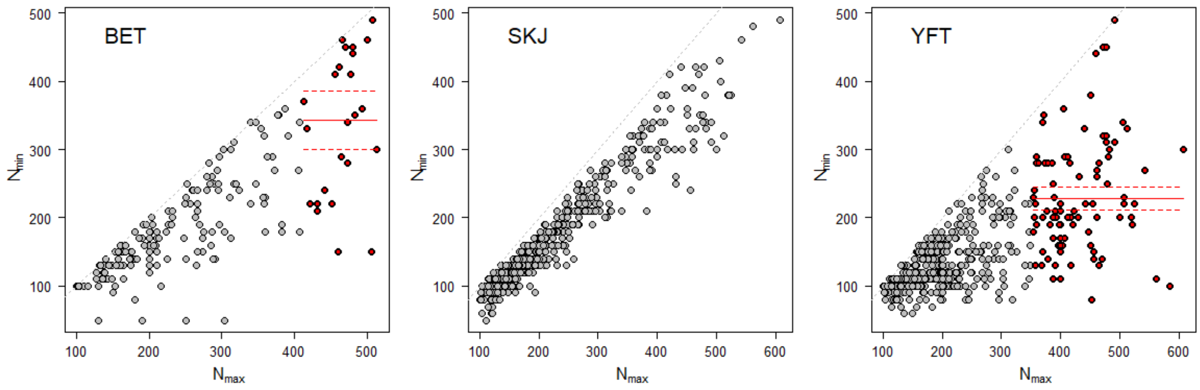


Figure 4: Minimum number of fish to measure (N_{min}) to keep similar size distribution in the samples (R = 0.95) against the total number of fish measured in the sample (N_{max}). The 3 top panels are samples for the catches on FOB, and the 3 bottom panels on FSC. Red points are the samples for which N_{min} and N_{max} are not correlated. Continuous and dashed red lines represent the mean and 95% CI for the N_{min}, respectively.

Finally, the investigation of the set size distribution comparing all sets versus sampled sets revealed only a slight bias due to the sampling design. Indeed, the smallest sets (< 20 tons) were under-sampled whereas medium sets (30 t < size < 140 t) were over-sampled. However, these results have to be mitigated relatively to their values. The over- and underestimates accounted for only about 3% of the discrepancy between the total and sampled sets. The largest catches were not biased because they were almost all sampled (Figure 5).

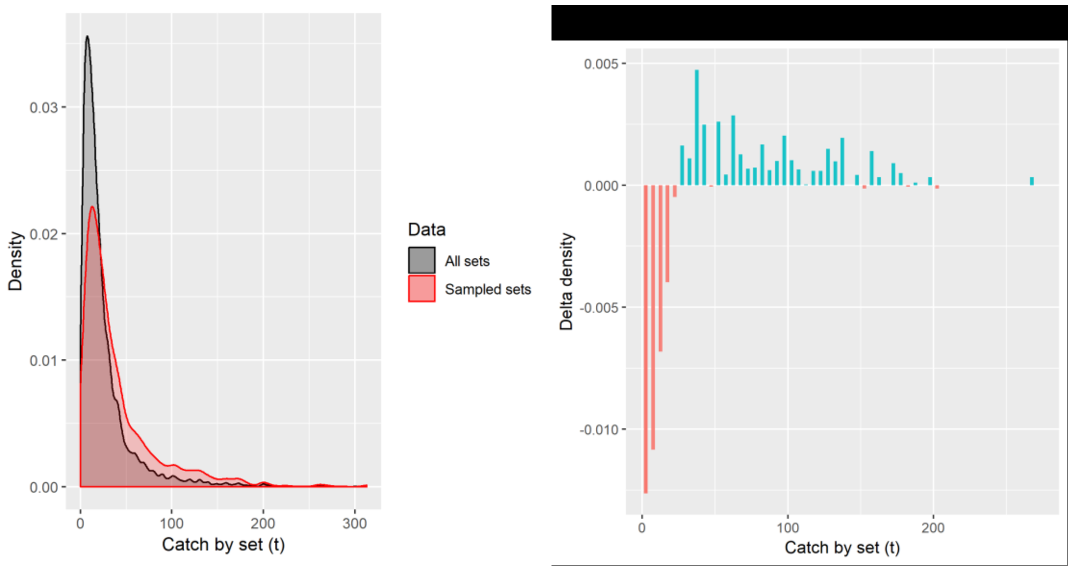


Figure 5: Sampling bias and set size. Left panel: density in catch per set for all sets and sampled sets only from 2015 to 2017. Right panel: differences in density (delta) between the sampled sets and all sets against the catch by set from 2015 to 2017 (red < 0, blue > 0).

Swordfish in the Mediterranean

The data available on the size distribution of the landings of four national longline fisheries (Greece, Italy, Cyprus and Malta) exploiting different Mediterranean regions, were analysed to obtain estimates of optimal sampling rates. This was achieved using a bootstrap simulation approach, which estimates the coefficient of variation (CV) values for different sampling levels. As the CV decreases non-linearly with increasing sample size, the objective was to estimate the trade-off between the number of samples and precision, i.e., the number of samples after which the gains in precision are not important (Figure 6)

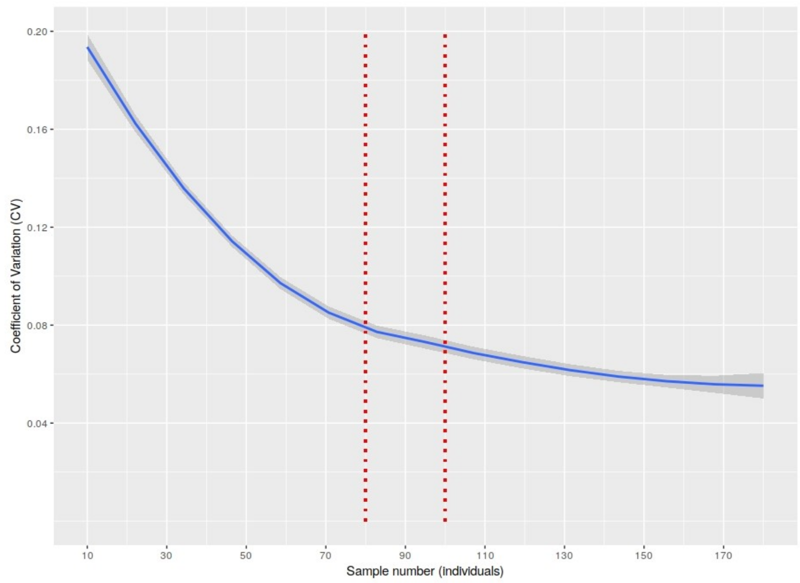


Figure 6. Example of a CV versus sample size plot. Vertical lines indicate optimal sampling levels.

The bootstrapping approach allowed estimating the optimal sampling rates that would meet the requirements identified in Deliverable 2.1. Though the available data did not cover the whole Mediterranean, they included information from several fisheries exploiting different parts of the basin and provided useful information on the sampling frequency requirements by fishery/region. The results showed that, depending on the size of the exploited area and the season, a sample size of 60–120 individuals per year-quarter would provide sufficient level of precision. Generally, as a "rule of thumb", it could be suggested that quarterly sampling of 70–100 samples is adequate[29], at the GFCM/GSA level. However, this estimate is based on size measurements and does not take into account other biological parameters, such as sex ratio and maturity stage. It also ignores the size composition of discards as such information was not made available to the project and it does not also exist in the ICCAT database. In general, the suggested sampling levels are not in agreement with the current schemes that seem to be exclusively based on the volume of landings. As both under and over sampling rates are currently observed, depending on the fishery and season, optimization of the temporal allocation of sampling effort is needed.

Task 2.5 - Propose data storage/management/analysis solutions at the regional level

Deliverable 2.5 – *Guidelines for data storage/management/analysis solution at the regional level* - (included as Annexe 7) propose concrete solutions for storing, at the regional level, the data needed to execute an RSP.

RCG-LP has recommended, several times, expanding the scope of the existing Regional Database and Estimation System (RDBES) to include the Large Pelagic specificities. It addresses fishery management needs related to the European Union Common Fisheries Policy and currently covers fisheries of the RCG North Sea and Eastern Arctic, the RCG North Atlantic and the RCG Baltic Sea. Having a single system hosting the data from

[29] A subsampled of these would be sampled later for other biological variables.

different regions (including LP fisheries) would be the best way of procedure harmonisation and the best from a cost-benefit point of view. RDBES aims to:

- Support the RCGs by supplying harmonised data for coordination.
- Improve data quality by using common quality checks for all the MS data.
- Automatically deliver data for different data calls, including tuna RFMOs.
- Ensure that the estimation methods used are transparent and documented.
- Support document data submissions to the RDBES.

This section summarises the main conclusions reached during the feasibility study of the RDBES as a host for LP-stock sampling data, and, concretely, for the data from the tropical tuna port sampling and Mediterranean swordfish port sampling programmes. The RDBES Core Group was contacted, and both the RCG-LP and the Core Group will look at the results of this exercise and respond to specific questions or adapt the data model and documentation as required. Some issues were identified and documented. However, none of the issues raised is believed to be serious impediments to moving forward with the RDBES data model. Nevertheless, this process does not end here. Sampling programs of highly migratory species are diverse, as diverse as the difficulties that some of them might face in the process of uploading data to the RDBES. It is likely that sampling bluefin tuna cages will have little in common with tropical tuna or swordfish sampling. Moreover, the RDBES is relatively new and many of its aspects, such as the implementation of raising procedures, will certainly change in the future. A regional database is one of the main prerequisites for the development of Regional Sampling Plans, for data standardisation and for quality assurance. For the incorporation of the LP data in the RDBES to succeed, active involvement of RCG-LP is needed.

The first objective was to find out which RDBES model hierarchy fits best the two case studies. Mediterranean swordfish sampling matches well, without major issues: onboard sampling matches Hierarchy 1 and onshore sampling matches Hierarchy 6. For tropical tuna onshore sampling, the best fit seems to be Hierarchy 5. However, even after discussing this with the RDBES Core Group, it is not entirely clear whether the sampling design can fit within the existing hierarchies (i.e., Hierarchy 5) or a new hierarchy is needed to accommodate a selection level for the wells. Once the correct hierarchy is identified, there will be no major problems with populating the different tables. However, some new codes should be included in the master tables for both, Mediterranean swordfish and tropical tunas. Such codes are needed for: the tropical tuna sampling areas, ICCAT 1-degree and 5-degree statistical squares, new *métiers* to distinguish free school sets from sets using floating objects, as well as provision for allowing hook size in the gear characteristics based on ICCAT principles.

Task 2.6 - Lessons learned

Drifting longlines of various types are widely used in the Mediterranean for fishing large pelagic species, such as swordfish and tunas, and various national fleets are involved in those fisheries. By far the most important longline fisheries are those targeting swordfish; other longline fisheries target bluefin tuna and albacore. The albacore fisheries share some characteristics with the swordfish fisheries in terms of the distribution of fishing activities and the numerous national fleets involved. Hence, the approach followed in Task 2.4 (Annex 6) could be used for monitoring catches and collecting data on their size composition. For the development of a biological sampling plan for the Mediterranean albacore fisheries, the following steps are suggested:

- Identification of exploitation patterns for the national fleets involved in the albacore fisheries
- The CV estimates for different sample sizes by appropriate region and season, based on the approach shown in Deliverable 2.4 (Annex 6)
- Determination of optimal sample sizes using the CV versus sample size curves
- In case of spatial overlaps between different national fleet segments, the required sample size for the given region should be split among fleets, based on their catch volume

Furthermore, the already developed R-scripts, with slight modifications, would facilitate the realisation of the above goals.

Similarly, in the case of tropical tunas, one could transfer the proposed RSP to the purse-seine fishery in the Indian Ocean. The current protocol shared between France and Spain has been already applied in both oceans (Atlantic and Indian). Thus, any recommendation made to improve the sampling design and protocol will apply to both oceans. As proposed for the Atlantic, the current (extremely large) sampling areas used in the Indian Ocean could be replaced by a 5-degree grid, which would probably improve the accuracy in terms of species composition and size frequencies (Figure 7).

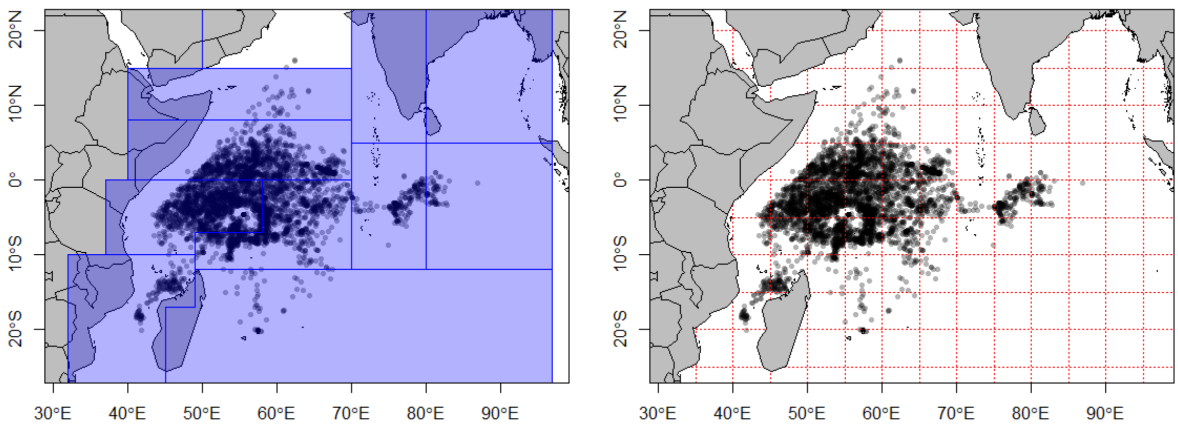


Figure 7: Sampling zones used for free schools in the current protocol for the Indian Ocean (left panel) and an example of a regular grid of 5°-squares (right panel). Black points represent catch locations of the French fleet in 2017.

To establish the minimum number of samples required per square, further analyses are needed before adopting the current proposal in the Indian Ocean. However, the method and scripts used for the estimation of the optimum sampling effort in the Atlantic are valid for any ocean. Similarly, all the data requirements and priorities defined in Task 2.1, as well as the hierarchies of the Regional Database and Estimation System tested under Task 2.5, are valid for any tropical tuna purse-seine fishery.

More details of the lessons learned are included in the Deliverable *D.2.6 - Set of rules and recommendations that would allow transferring the proposed Regional Sampling Plan (RSP) to other large pelagic fisheries with similar characteristics*, which is included as Annex 8 in this report.

Recommendations for future work

Based on the WP2 results, this section provides some recommendations for the MS involved in both tropical tuna purse-seine and Mediterranean swordfish fisheries. This should help them to build effective RSPs and facilitate the progress of the RCG-LP in various key aspects of the same process.

Major tropical tunas in the Atlantic Ocean

In the case of the tropical tunas, sampling (including sampling protocol) is already shared between Spain and France. However, based on simulation results, some changes are proposed to the current protocol and sampling design (strata). During the study period (2015–2017), the yearly number of samples (wells sampled) was around 1200 (approximately 750 for FOB and 450 for FSC) for the French and Spanish fleets. Considering the consistency in costs and human resources allocated to the sampling and knowing the number of squares fished depending on the grid size, the yearly sampling effort should tend towards the sampling of 17 of wells by square in a 5-degree grid. The simulations show that it is difficult to assess the mean species composition with less than 5%-error because it involves big effort in terms of sample numbers by square (using the 5-degree square scale). Obviously, this number is an indication, which should be adjusted over the year based on fishing activities. Indeed, the spatiotemporal aspect of fishing should be considered. Not all squares could be sampled during each period because not all of them were fished during the whole year (see the spatiotemporal correlation of fishing). Not even the "optimal" number of samples can be reached in a square infrequently fished. Thus, sampling effort should be adjusted dynamically according to the vessel landings and its well plan (stowage plan) characteristics throughout the year.

Regarding the number of individuals to be measured in each sampled well, the total number of fish measured by following the current protocol seems to be suitable. Even though for the YFT, the size distribution is well estimated by measuring relatively few fish, more effort is needed to obtain the size distribution for BET. YFT and BET (all individuals are measured in the current protocol) required more than 150 individuals to maintain accurate representativeness of their size distribution in the samples for the FSC and FOB.

For the SKJ, increasing the number of fish measured in the FSC samples should not change the accuracy of the size distribution because they are not abundant enough to supply 100 individuals (current threshold) or more in their samples. However, an increase in the number of SKJ measured in FOB catches should be considered.

The under-sampling of the smallest sets (< 20 t) identified as bias cannot be solved for the port sampling (small sets are normally mixed in the same well onboard). However, this sampling bias is an issue only if the species composition and the size distribution change depending on the set size. In that case, this size effect should be integrated into the model that assesses the catch data. Further analyses should be performed to improve the procedure.

Finally, one of the major constraints in sampling is a mixture of sets in the wells, when the sets belong to different strata (FSC and FOB, different areas, etc.). Indeed, such wells are not suitable for assessments of species composition and size distribution. In these cases, the measured fish cannot be associated with a particular set and so cannot be used to reconstruct species composition and size distribution of heterogeneous catch sources. Therefore, an increase in the number of sampled wells improves the RSP accuracy only until all wells suitable for sampling are examined.

Thus, based on the simulation results, we could make some recommendations, in order of priority, for the RSP improvements.

- Reduce the size of sampling areas (currently, they are too large) and try to work on a grid with the finest possible resolution, taking into account the allocated sampling effort and cost implications.
- It is more informative to sample a new square (a new part of the fishing ground) than to take many samples from a small number of squares.
- If more than one well is adequate to be sampled in the same day, always sample the well coming from the stratum that has been less sampled in that specific year.

- It is also important to sample each square several times during its exploitation period. This should be done at least once per quarter but could be done monthly for the densest catch areas.
- According to the well plan supplied by vessel crews, the BET (and YFT using FOB) catches are preferred if there is a choice between several suitable wells.
- At least 500 fish should be measured during each sample
- For BET and YFT, try to measure 150 individuals whenever possible.

Swordfish in the Mediterranean

In general, the identified optimal sampling levels are not the same as those in the current schemes, which seem to be exclusively based on the volume of landings. As both under- and over-sampling have been observed, depending on the fishery and season, optimisation of the temporal allocation of sampling effort is needed. Relatively high over-sampling rates were found in the Italian fisheries operating in the central part of the Mediterranean. The results might have been different if the procedure had considered sub-regions of the large area examined. Because of the ecological differences between different Mediterranean areas, ICCAT has proposed the collection of biological data on a regional scale; however, this recommendation has not been clarified. Apart from data reporting discrepancies, there are no spatial overlaps in the exploitation patterns of the examined national fisheries. This effectively prevented the development of regional sampling schemes jointly coordinated by different Member States. It should be noted that harmonised data reporting in standard formats is crucial for the future development of coordinated sampling schemes in jointly exploited regions, as well as for stock assessment purposes.

Although several MS accomplish various sampling programs, sampling protocols have not been yet standardized and discussed in the relevant RCG. However, based on the above findings, it is suggested that rationalisation of the sampling schemes should primarily consider:

- Information on the spatiotemporal exploitation patterns of the various fleets involved in the fisheries
- Determination of optimal sample sizes by region and year-quarter
- Harmonised sampling protocols for the different fisheries
- Sampling not only on landings but also on catches, to identify discard levels

Finally, in addition to these specific recommendations for the analysed case studies, some recommendations are provided for the RCG-LP to help them in various key aspects of creating an effective RSP. If the RCG-LP becomes structured in the manner described in WP1 of this report, design of the RSP will fall to the specific subgroups on data analysis and regional sampling design (stage 2). These groups would be responsible for identifying and prioritising data requirements specific to each fishery, launching data calls and conducting simulations. The same methodology can be used for similar case studies, e.g., longline fisheries targeting albacore in the Mediterranean or purse-seine fisheries in the Indian Ocean. Until the RDBES becomes available for LP data, the SDEF seems to be the best data exchange format and RCG SharePoint, the best solution to share the data. However, it is important to stress the need to move towards a real Regional Database; expanding the scope of the current RDBES is the most cost-effective solution. The following points should be taken into account:

- Considering that the RDBES road map has been already announced by the RDBES Steering Committee, it is certain that any new requirements depicted for LP will not be included in the first releases of the platform. The funds and time (dedicated representatives or projects; this complicated task cannot rely on volunteer work)

must also be provided for distinct LP developments. To succeed, this requires the involvement of the RCG-LP, RDB Steering Committee and the Development Core Group.
- An important landmark is the estimation procedure to be unveiled and developed in detail after the WKRDBES-EST (estimation process for selected stocks) in October 2019. The aim of this workshop is to produce estimation scripts where inconsistencies, issues or extra requirements for hierarchies might emerge. The WKRDBES-EST should test complete datasets of large pelagics sampling (using the current scheme and proposed Regional Sampling Plan).
- Saving time is one of the important benefits of the system, apart from the obvious improvements in data checks, quality assurance, uniformity, etc. The system will help the MS to report to the end-users (tuna RFMOs, EU etc.) in a fast and accurate manner; the centrally developed (and peer-reviewed) scripts will be able to extract and prepare the data in the requested formats.

However, for the success of this undertaking, the active involvement of RCG-LP in these steps is essential.

WP3-SPECIFIC PILOT STUDIES

WP3 includes two independent sections:

WP3.1: DEVELOPMENT OF DATA COLLECTION PROTOCOLS AND TOOLS FOR FAD MANAGEMENT PLANS

Objectives

The work described in this section is closely linked to work packages 2 and 4. It is designed to develop the tools that can provide quality data to the different tuna RFMOs and produce standardised indices for purse-seine associated fisheries. This WP presents a proposal for harmonising terminology for FADs and defining best standards and minimum requirements for data transmission and submission to tuna RFMOs.

Methodology

Task 3.1.1. - Revision of data requirements for the different tuna RFMOs

The current data requirements of tuna RFMOs were reviewed:

- IOTC: Res. 15/01; Res. 15/02; Res. 18/08, also provides a specific form for reporting of FAD statistics, form 3FA;
- ICCAT: Rec. 16-01, para 21, Annex 2 FAD logbook form, Annex 3 on the nomenclature of FADs and activities; and Rec. 16-01, paragraph 22, Annex 4 form [list of deployed FADs and buoys], and developed and updated ST08-FadsDep form for CPCs for data submission to the RFMO on activities with buoys and FADs (ST08A) and buoy density (ST08B);
- IATTC: Resolution C-18-05 (Article 2 and Annex I) and C-17-02 has established data collection and reporting requirements for purse-seine vessels operating with

FADs, developed and updated the FAD Form 09/2018 for skippers and requested information on operational buoys through the INF1 and INF2;
- WCPFC: Collects information on FOB activities using the fishing logbooks and the Regional Observer Programmes.

Data availability for the institutes (IRD and IEO) in charge of the provision of this information was also reviewed. Thus, the current FAD data requirements, gaps and potential data sources were described, to define a minimum data field set that can serve all the tuna RFMOs.

Task 3.1.2. - Standardisation and harmonisation of the FOB/FAD terminology and definitions

In response to the increasing use of FADs in the purse-seiner tropical tuna fishing, legally binding measures have been implemented by RFMOs to limit the number of FADs used and to strengthen the data collection. Broad terminology referring to buoys and FAD use is included in different management measures. This should be standardised among the RFMOs and precisely defined to avoid subjective interpretation and to harmonise the data collection and verification system. Although the standardisation and homogenisation of the terminology used to describe FOB/FAD and buoy activities have been attempted in previous projects (i.e., CECOFAD), there is still some room for improvement (e.g., the definition of terms related to the buoy life cycle). Thus, this task benefited from the input from CECOFAD project, which helped, among others, to define the minimum data requirements and harmonise the different FOB-related areas, including FAD and buoy activities.

Task 3.1.3. - Coordination workshop

A workshop to coordinate the development of new templates for data collection around FADs/FOBs, with agreed data fields and definitions, was organised during 24th and 25th of May in AZTI (Sukarrieta, Spain). The workshop attempted to clarify some data requirements, which could not be provided at the time due to inadequate data sources (e.g., the average number of FADs followed per strata in ICCAT could not be supplied, due to the lack of information from buoy tracking). The discussion benefited from the participation of the Spanish and French ship-owner associations (OPAGAC, ANABAC and ORTHONGEL). Tuna RFMO requirements and other procedures already in place were reviewed, and the best standards on FOB/FAD data collection and submission were proposed. The basis for the development of FAD and other floating object data collection tools was established (Task 3.1.4)

This task also received inputs from WP4, on the identification of additional data fields required for CPUE standardisation.

Task 3.1.4. - Development of data collection and data storage tools

There are some issues with the forms[30] proposed by the tuna RFMOs for FAD data transmission and with the FAD logbooks, developed by the CPCs, for data collection for the FAD management plans. The main problem was the lack of adequate formats for data acquisition (Ramos *et al*., 2017). For example, initially the Spanish FAD logbook (Excel format), was not user friendly; the skippers found it extremely time-consuming and error-prone; no quality checks had been performed. This hampered reaching the objectives for

[30] Some examples: ICCAT: Rec. 16-01 (para. 21) Annex 2 form [activities with FADs], Rec. 16-01 (para. 22) - Annex 4 form [list of deployed FADs and buoys]; IATTC: FAD Form 9/2016).

which the information was collected, such us tracking individual FADs or estimating FAD densities. The first review of the Spanish FAD Management Plan (Ramos et al., 2017) identified some ways to improve the onboard FAD data collection. However, the template is still an Excel file, a format that does not lend itself easily to data sharing and analysis.

A better solution would be to use a relational database powered by an onboard acquisition software with a user-friendly interface. By introducing acquisition checks stronger than those offered by an Excel file, the software should improve the data quality. The ability to consolidate data from different trips and vessels in a common repository would also be beneficial.

Moreover, even though scientific organisms collect FAD usage data for statistical analysis, they have to acquire the data again. If the industry and scientific organisations could use the same software and database (or an affiliated system), scientific researchers would utilise directly the data acquired onboard; this would reduce the overall workload.

Since 2010, the IRD has been developing an open-source information system (ObServe), initially dedicated to purse-seine onboard scientific observations. It consists of client software for the onboard and office computers of the users, a server-side database and a web service to communicate with the central database. As the software installations embed the standalone database, users can work on- and off-line. After off-line sessions, e.g., at sea, the local data can be stored to be uploaded to the central database. The system was later extended to longline fishery observations, and it is currently used at sea by the observers onboard purse seiners and longliners.

The ObServe system has been developed in collaboration with a third-party company involved in open-source projects, working under contract with IRD. This software is currently shared with AZTI (Spain), IEO (Spain), SFA (Seychelles) and other entities. The ObServe includes a server-oriented database; thus, each of the organisations can manage its own data, sharing the same database data model. This facilitates data sharing and allows the development of data exchange tools for future activities (e.g., CPUE standardisation).

The FAD and other floating object data[31] could be acquired using the same system; the scientific and industrial information could be merged easily. As a result, it would be easy to perform cross-checking and cross-analysis of the industrial and scientific data. The system would also facilitate sharing the code-list and data by scientific organisms and would decrease the maintenance costs.

The ObServe seems to be a good open-source technology platform to build a FAD management tool, to be utilised by both the industry and the scientists. The version used by the onboard observers should be adapted to serve this purpose.

Main results

The results from the Task 3.1.1., Task.3.1.2 and Task 3.1.3. were used for analysing the different steps of the actual scenario for FAD and other floating object data collection, from the data collection at sea to the data submission. A proposal was made for the best standards for FOB data collection at sea and the best standards for data reporting. This is

[31] The data should be collected by skippers as not all the FOB activity data can be derived from buoy tracking. The two data sources are complementary, but both are needed to assess the use of FADs.

the result of the collaboration between scientists and the fishing industry (for detailed information, see Grande et al., 2018a or Deliverable *D.3.1.1- Best standards for FAD data collection*, included as Annexe 9 in this report):

Best standards for FOB data collection by skippers

Skippers should collect information on FOBs, using the onboard FOB logbook. All interactions with FOBs (FADs and other floating objects) and buoys should be recorded in the logbook. The records should provide information for the vessel: trip ID, date and time (GMT), position and buoy attached if any (including the ID of the manufacturer and ownership). It should also include the type of activity, the FOB type (for the classification of activities and FOB types into CECOFAD categories) and structure (for the assessment of dimensions). Other information to be recorded is the entangling character (given by the mesh size, if any, and configuration), the nature of the material in the floating and submerged structure, as well as the catch of fishing sets (i.e., target species and bycatch) when applicable. Some purse-seine vessels work in collaboration with other purse seiners and/or with support vessels. In such cases, every vessel should register its own activities, even when they are just supporting other vessels (Ramos et al., 2017). If the collaborating vessels are of different flag states, the details of their activities should be shared with the corresponding CPC or tuna RFMOs.

If Excel files are used for onboard data collection, we recommend using one form to record all FOB activities (i.e. activities with FADs and other floating objects), as proposed by Ramos et al. (2017). This means discarding the second form or FOB inventory form. The FOB inventory form has been previously used in the Spanish FAD Management Plan and is currently utilised in the IATTC area; it is of limited utility. This form is not a practical tool onboard as it requires daily updates, and rarely provides good-quality data (Ramos et al., 2017). The information on the FOB dynamics (including activities and materials used in the construction) can be deduced from the FOB activity form (if detailed information is given in each record). In the case of purse seiners with Electronic Reporting System (ERS), the FOB logbook and fishing logbook should be linked to minimise the errors caused by double recording.

Best standards for data reporting requirements to RFMOs

Based on previous experiences (Báez et al., 2017a; Báez et al., 2017b; Ramos et al., 2017) and data sources, the group recommends using two specific templates adjusted to the data collections sources (FOB logbook vs buoy tracks):

- One dedicated form to report the FOB and buoy activities. The information should be derived from FOB logbooks. The activities and FOB types should be compatible with CECOFAD categories. As we are aware of the difficulties of logbook analysis, we recommend reducing the requests to certain activities, such as deployment, tagging and loss (CECOFAD categories), until the development and implementation of a standardised data collection tool are completed.
- A second template dedicated to reports on FAD density, which should be derived from the buoy transmission information. The information on buoy density should be stratified by month and 1º x 1º square, i.e., the average number of operational buoys belonging to the vessel over the month and 1º x 1º square. This should be done by summing up the total number of operational buoys recorded per day over the entire month, in each grid, and dividing by the number of days in the month. This information should be extracted from buoy transmissions provided by the manufactures and not from FOB logbooks.

The buoy dynamic was described, and detailed definition of the terms to be used by the RFMOs was supplied to facilitate the monitoring of the number of FADs used by a vessel (for further details see Annexe 10). These terms should be considered by RFMOs, not just for compliance but also to follow the good reporting principles, which should help to achieve good-quality data collection. To monitor all FADs at sea properly, (i) the prohibition of FAD deployments without active satellite buoys should be considered; (ii) the activation of the buoys should be done always onboard to avoid remote activation/reactivation of deactivated drifting buoys; (iii) for the verification of the FAD limitations, clear definitions and guidelines should be established.

One of the objectives of the workshop (Task 3.1.3) was to set the standards for the development of the data collection tool. It was decided to implement the FAD management software as an extension of the ObServe platform. Then, the same data format could be used by the industry and scientists, and the data acquired onboard by the captains would be easy to merge with scientific data. Moreover, scientific organisations would be able to provide feedback on the information acquired by the industry.

ObServe is open-source software under *GNU Public Licence.* The software development performed within the framework of this project was also published under this licence. This means that everyone, every entity, can both use the binary files produced by this project, and/or edit the source code to make new versions of the system.

Based on the coordination workshop outputs agreed on by the scientists and industry, a specification document (in French[32]) was written. It described the potential technical implementation of the requirements provided by the workshop as a new ObServe feature.

The IRD published a Call for Tenders for the software development based on the existing ObServe project. This process lasted for 6 months, and the company *Ultreia.io* was finally selected in March 2019.

Three utilities of the ObServe v5[33] were then updated and released in ObServe 7.

<u>a) Redesign the existing FAD data management model</u>

ObServe v5 already had a data model and graphical interface to manage the acquisition of FAD-related information from the point of view of the observer. However, the module could not be used with the collection parameters requested by the tuna RFMOs. It could only process the object type and did not allow design changes by the crew.

The data model and interface for FADs were redesigned to a more generic mechanism, so the new design should satisfy the appropriate requirements, i.e., it should become:

- suitable for both scientific FAD observations (acquired by observers) and FAD logbook data (acquired by crews)
- compliant with the CECOFAD-recommended hierarchy and with both FAD and non-FAD objects
- compliant with the requirements issued by the D.3.1.1
- suitable for all scientific partner organisms

[32] Available on request.
[33] ObServe version used by the at sea observers prior to RECOLAPE project.

- able to model the structure changes introduced to existing FADs by the crew
- able to acquire emitting beacon brands, models and identifiers
- sustainable and resilient, for the future FAD designs and requirements

b) Adaptation of new FAD design to observation and logbook data[34]

The data model and the graphical interface have to be reorganised so that two distinct sections appear in the navigation tree: a section dedicated to observations and a new section suited for logbook data, including catches and FADs. The latter will be the part used by the crew.

Moreover:

- FAD material list and properties are simplified for the items proposed for the observers. The properties for the logbook part will satisfy the t-RFMOs requirements summarised by the coordination workshop.
- A few buttons are created for commonly used FAD schemes. These buttons are freely configurable by the ObServe administrators, to adjust to the future FAD designs.

c) Create a simplified mode dedicated to crew members[35]

1. Create a new start-up mechanism so the software can run in one of the two different modes:
    a. Simplified mode, showing only the features useful to purse-seiner crews, i.e., logbook data (catches and FAD activities). This is a simplified version in comparison with the functionality used by the observers, but the two modes are compatible.
    b. Complete mode, showing all the features: observation data and logbook data (including catches and FAD activities), for both purse-seine and longline fishing.

Considering that the call for tenders launched by IRD was granted in March 2019, it only has been possible to complete the first phase (release of ObServe v7); the other two stages will be completed in July and September 2019, respectively.

Recommendations for future work

Harmonised terminology and best standards for data collection on FOBs

The best standards for data collection and terminology proposed in this study have been already presented in ICCAT and IOTC. New forms for FAD and buoy data reporting, to replace the currently used form, were also proposed and adopted by the ICCAT SCRS (Standing Committee on Research and Statistics). They proposed that the best standards for data collection included in WP3.1 be considered a minimum standard for data collection within the ICCAT framework. However, some work still needs to be done as the standardisation should be applied to all RFMOs. The same results were presented during the joint tuna RFMO working group (May 2019, La Joya), where it was proposed to use these standards as the working basis for all the tuna RFMOs. In addition, the terminology was reviewed intersessional by the joint RFMO Technical working group on FADs which is

[34] This is currently under development and will be released in July 2019.
[35] This is currently under development and will be released in September 2019.

working on-line, and a document was presented in the joint tuna RFMO Working Group[36]. Some of the terminology proposed has been recently adopted in the IOTC in Res. 19/02[37].

The link between ERS and ObServe

The software development conducted under this project offers an up-to-date solution for the management of FAD statistical data to:

- Crews that do not currently have electronic FAD logbooks
- Scientific organisms whose national vessels acquire FAD data onboard using the software and want to review and edit the data
- Scientific organisms whose national vessels acquire FAD data on paper, using Excel or in any other format, and want to secure them in a safe, generic format and accessible database

The Electronic Reporting System (ERS) is available on European purse seiners; however, it does not support the detailed FAD and buoy data. Once the ERS format and onboard client software fit the new FAD requirements, the ERS could replace the onboard ObServe software. However, the ERS does not provide any graphical interface that would permit data management and review. Thus, a link should be developed, so that the scientific organisms can still integrate FAD data coming from ERS into their ObServe information system.

However, if, for any reason, the ERS is not updated to include FAD requirements, it might be useful to set-up a link from ObServe to ERS (or any European data repository). This would ensure that scientific organisms collecting accurate FAD data (on their own or with the help of the crews) could contribute to the creation of a complete European repository of statistical fishery data.

Enhancement of ObServe for other logbook data

Historically, sampling data and logbook data of the European tropical tuna fisheries have been managed by scientific organisms in separate databases, even though they refer to the same fishing trips. This made the cross-checking and cross-analysis rather difficult. As now the ObServe system can manage observation data, FAD logbooks and logbook (catches) data, it would be beneficial if the system could manage other types of data from the same trips (i.e., landings, in-port size samplings and local market statistics). Thus, all data related to the same trip would be stored under a single technical identifier and cross-checking, cross-analysis and data sharing between partner institutes would become much easier.

WP3.2 ELECTRONIC MONITORING SYSTEM (EMS) FEASIBILITY STUDY IN LONGLINE FISHERIES

Objectives

The main objective of this pilot study of two pelagic longliners (fleet based in Réunion Island, France, Indian Ocean) is to compare the datasets collected using different sampling

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[36] https://www.iattc.org/Meetings/Meetings2019/JWGFAD-02/Docs/_English/KeyNotesDocs/JWGFAD-02-22_Definitions.pdf

[37] IOTC, Res. 19/02. Procedures on a Fish Aggegating Devices (FADS) management Plan

methods, i.e., EMS versus human observer and expanded self-reported[38] data. The datasets contain the information on the fishing activity (characteristics of the mainline, branchline, floatline, buoy, hook and bait and deployment of devices to mitigate negative impacts) and the information for quantifying catches kept onboard and discarded by species or group of species. This comparative approach will determine if the deployed EMS can be used reliably to collect unbiased data onboard (first on fishing boats and second, on pelagic longline vessels in general). Finally, this pilot study will examine the strengths and weaknesses of the EMS implemented, to define an autonomous electronic system as an alternative or a complement to a human observer.

Methodology

Table 2 presents the time schedule for this pilot study.

Table 2. The time schedule of the main operations realised within the frame of the EMS pilot study.

Period	Description of completed tasks
March 2018	Presentation of the project to the fishing industry in La Réunion and the selection of four longliners to be involved in the pilot study
April 2018	Sending fishing-vessel construction plans to the EMS provider
May 2018	Installation of the EM system on two vessels
July 2018	Installation of a complement to the EMS on one longliner
August to October 2018	Recruitment of two observers for at-sea data collection and desk-based image analysis
December 2018	The first at-sea observations; EMS problems with recording information on one vessel. Statement of maritime security service prohibiting boarding of a human observer on a vessel equipped with EMS
January to March 2019	Data collection from observer at-sea, self-reporting and EMS. Image analysis using the Marine Instrument Beluga software
April 2019	Data analysis of all datasets (human observer, self-reporting data and EMS data)

Selection of longliners

Two pelagic longliners belonging to the fleet based in La Réunion were involved in a pilot study to assess the feasibility, i.e., the strengths and weaknesses of the electronic monitoring deployment onboard small vessels. Two longliners, belonging to the ENEZ DU fishing company, were equipped with EMS. These two vessels, "Le Grand Morne" and "Le Bigouden" had an overall length of 15.8 m and 20.9 m, respectively.

Electronic monitoring system deployed onboard

The two vessels were equipped with the Electronic Eye (eEYE™) system, v6.2, provided by Marine Instruments. The eEye v6.2 is a system with three cameras recording images at a frequency of 0.5 frames per second, a V6 antenna with GPS connection and network-attached storage (NAS), installed in the wheelhouse to speed up image retrieval. A rotation

[38] IRD launched in 2011, a self-reporting programme (where the vessel staff was trained to collect and transmit data in the absence of an expert observer) of exhaustive catch and effort data for the pelagic longline fishery based in Reunion Island (Bach et al., 2013). Same approach has been used during this pilot study.

sensor was installed on the side of the drum where the mainline is stored, to identify the fishing activities (setting and hauling) and trigger the collection of images. This design avoided any interference in the hydraulic circuit of the boat.

Data collection from images

The method of data collection from images was similar to that used in the longline observer programme employed in La Réunion, in which the observer data came from an onboard human observer and self-reporting information, from a volunteer captain. After each fishing trip, the images were analysed using the Beluga software developed by Marine Instruments. Images from the EM (for 36 fishing operations targeting swordfish) were analysed by two trained desk-based observers. Onboard data were collected by human observers (15 fishing operations) and a captain volunteer through self-reporting (26 fishing operations) filling a dedicated logbook.

Main results

The 36 longline fishing operations were performed around La Réunion and in the Mauritius EEZ (Figure 8).

The time necessary for image analysis

The two phases of a longline fishing operation, namely setting and hauling, lasted on average 5.2 hours and 8.2 hours, respectively, adding up to 13.4 hours. The average time necessary to analyse images of setting and hauling[39] took, respectively, 16% and 45% of the real time of each operation (Figure 9). For the two fishing operations, an average of 4.5 hours (33% of the total real time) was necessary for the image analysis (Figure 9).

[39] The variable measure was setting and hauling time in real time, which can be directly link with the line length and or number of hooks.

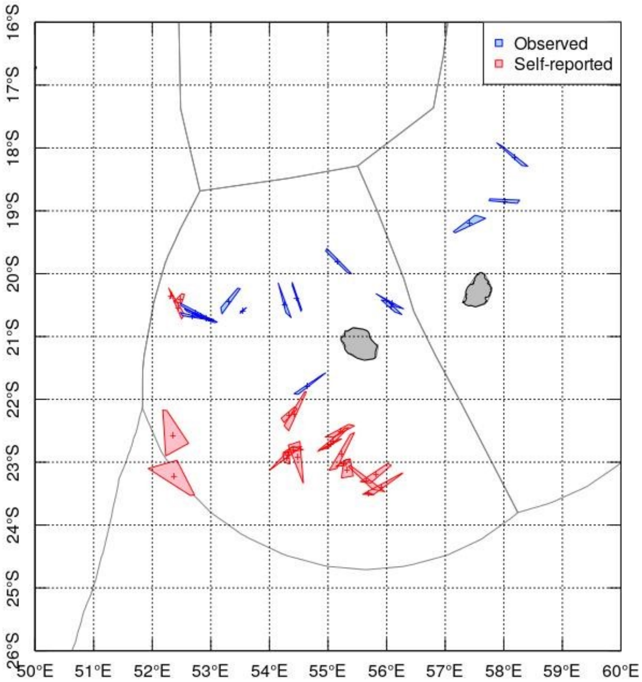

Figure 8. Positions of longline fishing operations with an electronic monitoring data collection carried out from December to February 2019**.**

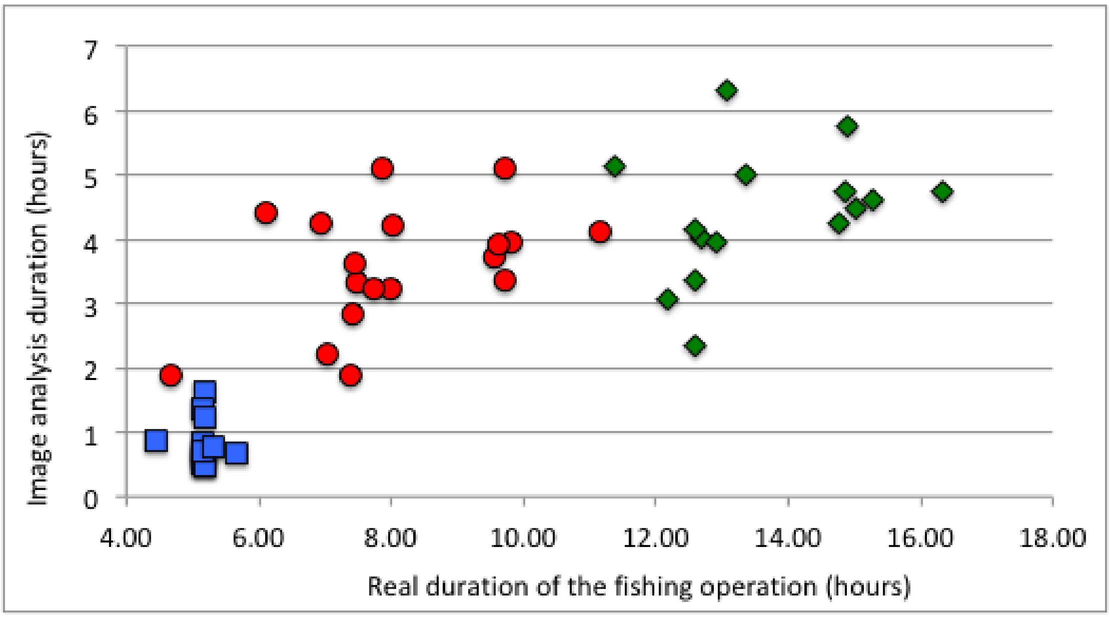

Figure 9. Comparison of the duration of fishing operations (setting in blue, hauling in red, sum of the two in green) with the time necessary to analyse the recorded images.

The value of 33% corresponds to the maximum percentage of time to be allocated to image analysis. Some improvements are expected in the analysis strategy, the frequency of image capture (1 image per 2 seconds used in here is not very suitable for the fishing practice of interest) and the ergonomics of the software interface.

Comparative analysis of the longline characteristics

The EMS data obtained from image analysis were compared with data collected by an onboard observer and self-reporting data collected by the captain. For the EMS and the other two data series, the coordinates of the longline in time and space showed a strong similarity. The EMS completes all the fields, while some of them may be forgotten by an observer (the captain in this study). Moreover, the similarity between EMS data and observer data sources was very strong for the horizontal shape of the mainline.

The data fields for the description of the gear (material and size of mainline, floatline and branchline) cannot be collected through EMS. However, such information is, in general, vessel/captain-dependent, and it can be found in the logbook or in an observer report. Other fields describing the fishing strategy (use of electrolume, weight on branchline) could be filled by recording the images at the designed frequency (0.5 frames per second). However, the deployment of the sensor, the hook type and the bait type could not be identified.

Correlation between the fishing effort estimates from the two types of data sources was significant (with a high level of accuracy for EMS estimates). This was irrespective of the method used to calculate the number of hooks. Method 1 is based on the number of sections, the number of baskets per section and the number of hooks between floats. Method 2 utilises the estimate of the number of baskets by using the time of the setting divided by the average time to deploy a basket and the number of hooks between floats.

Finally, some fields (using shooter to set the line and deployment of tori lines to avoid seabird interactions) were not shown in the table because such operations or events were not observed during the fishing period considered in this pilot study.

Table 3. Comparison of information for the longline deployment characteristics collected by EMS and human observers. The numbers reflect the similarity between the two compared data sources (range from 0 to 1). Letters Y (yes) or N (no) show if the collection was possible or the correlation was significant.

Variables	EMS versus Observer	Comments	EMS versus Self-Reporting	Comments
Date, time of setting	**1**		**1**	
Position of setting	**1**		**1**	
Date, time of hauling	**1**		**1**	
Date, time of hauling	**1**		**1**	
Horizontal shape of the longline	**1**		**0.86**	Due to incomplete image records
Mainline material	**0**	Impossible to be collected with EMS. Can be found in the logbook. Dependent on the vessel/captain	**0**	Impossible to be collected with EMS. Can be in the logbook. Dependent on the vessel/captain
Mainline diameter	**0**		**0**	
Branchline material	**0**		**0**	
Branchline length	**0**		**0**	
Floatline material	**0**		**0**	
Floatline length	**0**		**0**	
Weight on the branchline	**0**		**0**	

N. sections	**0.8**	Image frequency too low	**0.95**	Fishing effort data not declared by the captain for one set. Difference less than 1% for method 1. Overestimate of ~3% by EMS for method 2.
N. baskets/section	**1**		**0.95**	
N. hooks (1)	**Y**	Difference less than 1%.	**Y**	
N. hooks (2)	**Y**	Overestimate of ~3% by EMS	**Y**	
Hook type	**1**		**1**	
Hook size	**N**		N	
Bait type	**1**		**1**	
Bait size, status	**N**		N	
Electrolume deployment	**Y**		**Y**	
Type of electrolume	**Y**		**Y**	
Frequency of electrolume deployment	**0**	Image frequency too low to estimate the number of electrolumes	0	Image frequency too low to estimate the number of electrolumes
Deployment of sensors on the mainline	**Y**		**Y**	

Electronic monitoring versus human-observer data (comparative analysis of the catch data)

For the 15 fishing operations with the two data sources, the number of total catches recorded by the electronic monitoring and the human observer was 419 and 425, respectively. Numbers of catches per fishing set recorded by the two methods are highly correlated and can be considered similar; the slope of the regression line was 0.987, not very different from the slope (1) of the identity line (Figure 10).

However, the comparison of catches by group of species pointed out two major differences between the methods. The EMS overestimates, by 100%, the records of undetermined individuals, which do not exist in observer records (Table 4). In contrast, it under-estimates, by -154.5%, the number of catches of sharks; certainly, some undetermined individuals are likely to be sharks. For the swordfish as the main target species of the fishery, the congruence between the two methods is rather satisfactory, with an underestimation by the EMS of around 10% (Table 4).

Regarding the fate of individuals (Table 4), the records of individuals kept onboard are similar; however, in comparison with human-observer records, the EMS under-estimates the level of discards, a result likely linked to its underestimation of shark numbers.

Electronic monitoring versus extended self-reporting data (comparative analysis of the catch data)

For the 21 fishing operations with the two data sources, the number of total catches recorded by the EMS and the self-reporting method was 580 and 600, respectively. This similarity must be noted as it highlights the quality of the data self-reported by the captain. Except for one outlier, the numbers of catches per fishing set recorded by the two methods are well correlated and can be considered similar; the slope of the regression line (0.956) was not very different from the identity line slope of 1 (Figure 11).

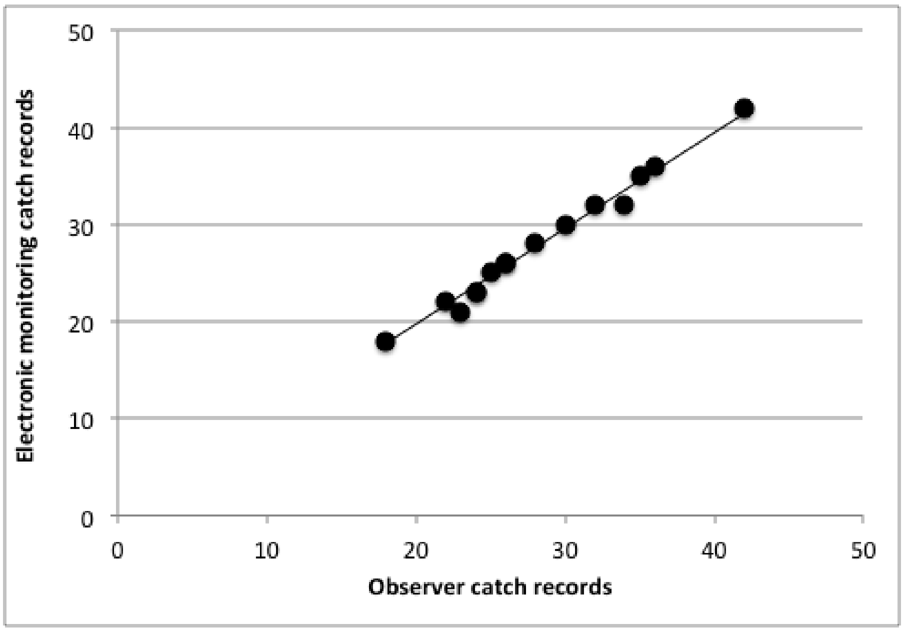

Figure 10. Relationship between the records of catches per set obtained from a human observer (horizontal axis) and EMS (vertical axis).

Table 4. Comparison of records of catches by species group obtained by human observer (OBS) and EMS (UND = undetermined, BILL = epipelagic billfish, FINF = other finfish, RAYS = rays; SHARK = sharks, SWO = swordfish, TUNA = tunas). SWO as target species is considered as one group and not included in the BILL group which are epipelagic billfishes caught as bycatch.

	OBS	EMS	Diff (%)
UND	0	52	100
BILL	8	8	0
FINF	86	83	-3.6
RAYS	11	9	-22.2
SHARK	56	22	-154.5
SWO	177	160	-10.6
TUNA	87	85	-2.4
TOTAL	425	419	-1.4

Table 5. Comparison of the fate of catches of all species aggregated obtained by a human observer (OBS) and EMS.

FATE	OBS	EMS
DISCARDED	214	189
ESCAPED	7	1
KEPT	204	205
UNKNOWN		24
TOTAL	425	419

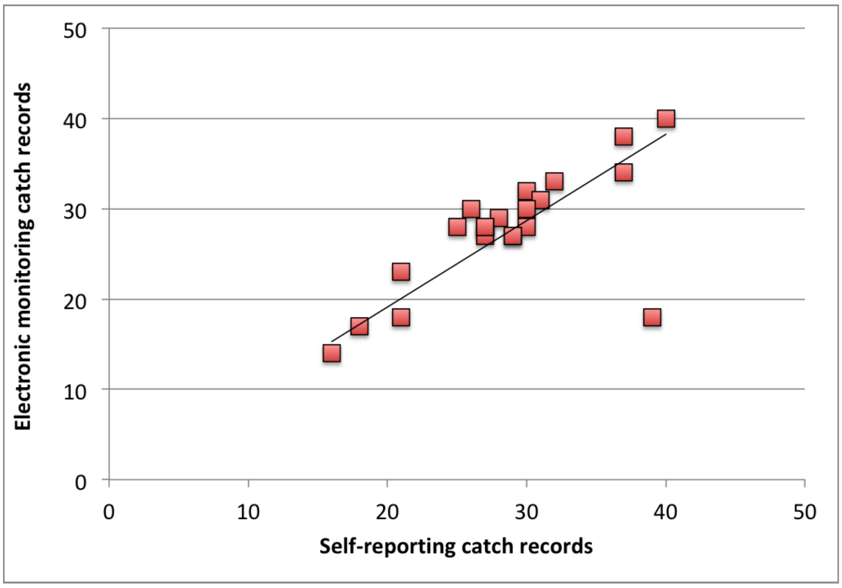

Figure 11. Relationship between the records of catches per set obtained from self-reporting data (horizontal axis) and EMS (vertical axis).

However, as mentioned previously, the comparison of catches by group of species pointed out two important differences between the two methods for discarded groups, finfish and sharks. The underestimation of catches by EMS reached about 60% and 40%, respectively (Table 6). For the target species group, swordfish and tuna, the estimates of catches are rather similar, in contrast to the overestimate for the group of undetermined catches by the EMS (corresponding to some extent to the level of under-estimates described for the finfish and shark).

Table 6. Comparison of records of catches by species group obtained by the self-reporting (SR) and EMS (UND = undetermined, BILL = billfish, FINF = finfish, RAYS = rays; SHARK = sharks, SWO = swordfish, TUNA = tunas, SEA TURTLE = sea turtle, MAM = marine mammal).

	SR	EMS	Diff (%)
BILL	25	25	0
FINF	112	71	-57.7
RAYS	49	47	-4.3
SHARK	111	79	-40.5
SWO	221	210	-5.2
SEA TURTLE	1	1	0
TUNA	81	77	-5.2
UND	0	69	100
MAM	1	1	0
TOTAL	601	580	-3.4

Recommendations for future work

In similarity to other fleets/*métiers*, for which the EMS has already been tested, this pilot study demonstrates that using the EMS is a viable alternative to collecting the data using human observers.

Considering that 33% of the real fishing time is needed to analyse the EMS data of longline fishing operations, we can estimate that the time necessary for image analysis for a trip of

10 days with 7 fishing operations will be on average 31.5 hours for well-trained desk-based observers.

For both sources of human data collection, the congruence with the EMS estimates for the main species group kept on board (swordfish, tunas and marlins) was high. However, the congruence with the EM estimates for the species discarded was low, particularly for sharks, which are not hauled onboard for safety reasons. Counting of some discarded individuals of sensitive species groups, like sharks, proves to be a serious issue with the EMS in pelagic longlining. An underwater wide-lens camera installed next to the hauling door of the freeboard deck might be an appropriate design to satisfy this data collection requirement[40].

Our dataset in this pilot study was rather limited due to the short time dedicated to the data collection and difficulties in embarking an observer on one of the boats after the installation of the EM. However, one of the positive findings was the congruence between our results and those from already published EM studies conducted to collect fishery-dependent data at-sea for scientific and control purposes (Emery *et al*., 2018a and Emery *et al*., 2018b).

This pilot study demonstrates that the implementation of an EM programme means much more than the deployment of cameras on a fishing vessel. Before its implementation, the coordinator of the programme must present clearly its requirements to the fishing industry and the crew of vessels involved. Then, the implementation is likely to proceed by respecting a Memorandum of Understanding (MoU). To be effective, the EM programme will need a collaboration of the crew to enhance the quality of the data collection, particularly to keep clean the lenses of cameras.

The dynamics of fishing with a longline (at setting or hauling) implies using a frequency of image recording higher than 0.5 frames per second, to analyse the images properly. Moreover, the deployment of the EMS must be vessel-based, taking into account the installation of all the materials on the deck, particularly at setting and hauling sites. The rotation sensor used as trigger to switch on the system implemented in this study has proven its efficiency and did not interfere with crucial onboard devices, such as the hydraulic circuit.

Due to calibration issues of the eEye v6.2, the collection of size data could not be tested. However, we showed that it was possible to implement; on "The Grand Morne", the camera for monitoring the hauling operation was working and tallied properly to get the electronic size data.

Further details of this pilot study are available in Deliverable D.3.2.1- *EMS capabilities and functionalities to monitor longline fisheries targeting swordfish* (included as Annexe 10 in this report). The results of this study will be drafted in a working document to be presented at the next Working Party of Data Collection and Statistics of the Indian Ocean Tuna Commission in November 2019.

[40] Other approaches, such as "external protruding cameras", have been considered. Although all proposed structures were found to interfere with the fishing manoeuvre, this option could be consider for future work.

WP4. DATA COLLECTION STRATEGY FOR STANDARDISATION OF CPUE OR FOR ALTERNATIVE ABUNDANCE INDICES IN TROPICAL TUNA FISHERIES.

Objectives

The objective of this WP was to develop a data collection strategy for the variables not collected under the DCF (e.g., the technology onboard, purse seiner–support vessel relationship, historical buoy data). These variables should be provided by the fishing industry and buoy providers and will be used, in combination with traditional DCF data, for CPUE standardisation, as well as in the estimation of alternative abundance indices in tropical tuna fisheries. Outputs from WP4 will become direct inputs to the future EU PS CPUE standardisation workshops as well as for other EU research projects, such as CECOFAD2[41].

CECOFAD2 and RECOLAPE projects are complementary; RECOLAPE WP4 data and algorithms can provide valid data input for performing data analysis during CECOFAD2 (or future projects working on FADs). This implies that RECOLAPE should produce:

1. Algorithms to estimate the number of active buoys transmitting a satellite signal while drifting at sea (D.4.3 in RECOLAPE)
2. Algorithms to process the echo-sounder data, cleaning erroneous data and improving precision and accuracy of the biomass estimates (D.4.2 in RECOLAPE)

Then, the outputs of such algorithms would be used in CECOFAD2 for data analysis:

1. Studying the dynamics of the biomass on the scale of a buoy and an array of FADs (D.2.2 in CECOFAD2)
2. Using models to estimate a tuna abundance index (D.2.3 in CECOFAD2)

Methodology

Task 4.1 – Cross-checking the selection of variables to be collected

This WP was focused on the variable selection procedures and quality protocols needed to correct the raw CPUE series. Consequently, the data provided by the fishing industry (e.g., echo-sounder data) and traditional data (collected on a routine basis under DCF, such as the catch per set or catch per searching time) were evaluated as potential explanatory variables for the generalized linear model (GLM) "Lasso" method recommended by the EU PS CPUE standardisation workshop (Gaertner, 2017). Thus, the WP focused on the selection of candidate variables and quality protocols needed for the correction of tropical tuna purse-seiner CPUE series, and specifically for FAD-fishing activities.

Task 4.2 – Alternative indices of abundance

The scientists involved in the tropical purse-seine fishery have been trying for some time to estimate alternative indices of abundance by using the echo-sounders attached to the FAD buoys. However, these echo-sounders have been originally designed for commercial activities. Thus, some validation of the collected data is needed before using them for scientific purposes.

[41] EASME specific contract No. 9 Catch, effort, and ecosystem impacts of tropical tuna fisheries

This task compared the current methods (algorithms) used by Spanish and French scientists to filter-out erroneous and non-valid echo-sounder data (e.g., wrong positions or wrong biomass estimation), such as the methods suggested by Lopez et al., 2016; Baidai et al., 2017; and Santiago et al., 2017.

However, it is important to mention that there are several different buoy brands and models used by the fleet, each with its own echo-sounder model. The technology and algorithms used by these devices may vary. Thus, this task also provided indicators to compare different echo-sounder models, so that their functioning can be assessed independently of the buoy/echo-sounder brand and model.

The IRD and AZTI institutes closely collaborated in the following specific tasks.

- Definition of the acoustic data-filtering criteria
- Development and description of algorithms for converting acoustic data into biomass data
- Definition of common indicators of uncertainty in biomass estimates and estimation of uncertainty

Task 4.3- Developing dedicated algorithms to provide the total number of operational beaconed FADs at a spatial and temporal stratum

This task was devoted to developing dedicated algorithms to provide the total number of operational beaconed FADs (active buoys) at a spatial and temporal stratum. Data used for this task were provided directly by the French and Spanish fishing industry under a confidentiality agreement.

AZTI and IRD have worked in close collaboration following the steps shown below.

- Specification of the buoy position and acoustic metadata (i.e., format and description of each column in the database)
- Description of the database of buoy positions and acoustics (i.e., for each ocean and year: number or proportion of buoys, brand/type of buoy)
- Description of the data-filtering protocol currently used by AZTI and IRD
- Running algorithms using a common database (French + Spanish) and comparison of outputs (e.g., number of onboard/at-sea positions, number of wrong positions filtered)
- Adoption of a common protocol for operational beaconed FAD density estimates that will be used to provide data for CECOFAD2 and for tuna RFMOs

Main results

Buoy density, information on buoy models, number of followed buoys, purse seiner–support vessel relationship and list of activities using floating objects were selected as candidates for explanatory variables for CPUE standardisation. For each variable, data source was identified, and data collection templates were proposed. More details on the selected variables are provided in Deliverable *D.4.1-List of explanatory factors for standardising CPUE series* (included as Annexe 11 in this report).

For the development of algorithms providing the number of operational beaconed FADs at a spatial and temporal stratum (Task 4.3), information on three buoy brands (i.e. Zunibal, Satlink and Marine Instrument) was gathered in the Atlantic and the Indian Ocean, covering periods 2006–2018 and 2010–2018 for the French and Spanish fleets, respectively. Then, a common (Spanish and French) database was defined, and different correction filters (F) were applied (table 7).

Table 7. Filters defined for the pre-processing of raw position data.

FILTER	Description
F1. Isolated	Isolated Position (> 48 hours from another position or estimated speed above 35 knots relative to next/previous position)
F2. Duplicated	Duplicated data (all fields are the same)
F3. Land and stationary	Data on land with speed < 0.01 knots
F4. Land	Data on land with speed > 0.01 knots
F5. Ubiquity	Data entry from the same date/time, different positions
F6. Not classified	Position not on the land and not classified by at-sea/onboard algorithm
F7. Onboard	Buoys on board
F8. Water	Buoys at sea. Operational buoys: Active buoy that is transmitting a signal and is drifting in the sea (definition from RECOLAPE)

For applying the F1, F2 and F5 filters, the two organisations agreed on the data processing protocol. For the F3, low-resolution shoreline from GSHHG[42] buffered with 0.05° shapefile was used by IRD and high-resolution shoreline from GSHHG buffered with 0.05° shapefile, by AZTI. To filter the data onboard (F7), IRD applied the kinetic algorithm described in Baidai et al. (2017), which is based on the analysis of buoy speed, variations in buoy speed and acceleration along the buoy trajectory. The validation of these classification algorithms was performed by comparing the classification outputs with the observer data. However, AZTI applied a random forest classification approach to classify the buoys at-sea/onboard. They used the information from the Zunibal buoys, which can identify true positions at sea, employing a conductivity sensor (Orue et al., 2019). The predictor variables used in the RF analysis were distance between two points (km), velocity (km/h), change in velocity (km/h), acceleration (km/h^2), azimuth (degree), change in azimuth (degree) and time since the first and last observation of the corresponding buoy trajectory (days). For the classification algorithms that leave a subset of positions unclassified, it was agreed that the unclassified position should not be eliminated from the dataset and included in the buoy density estimates as buoy "at water". The final comparisons of the performance of the algorithms for classifying the buoys at water were carried out by calculating a simple matching coefficient (Sokal and Michener, 1958), estimated from confusion matrices derived from the outputs of the two classification methods.

Overall, the two methods for pre-processing buoy data showed strongly matching coefficients (> 94%) in all oceans and datasets. In the Atlantic Ocean, the performances of the classification protocol by IRD and AZTI to classify the buoys at water were > 96%. A weaker agreement (94%) was observed in the Indian Ocean in the Spanish data set, possibly due to the characteristics of this data set, with shorter tracks and smaller temporal resolution (i.e., a position per day). The results of the comparison of the performance in

[42] Wessel, P., and W. H. F. Smith (1996), A global, self-consistent, hierarchical, high-resolution shoreline database, J. Geophys. Res., 101(B4), 8741–8743, doi:10.1029/96JB00104.

data processing can be found in the Deliverable *D.4.3- Developing dedicated algorithms to provide the total number of operational beaconed FADs* (included as Annex 13 in this report).

Finally, regarding alternative indices of abundance (Task 4.2), and to process the acoustic information obtained from buoy echo-sounders, the first step was to apply the filtering criteria defined in Task 4.3 (filtering out erroneous GPS positions, and buoys on land and onboard that can give false positives). Additional filters were applied to the acoustic data (besides those applied for filtering position data described in the Deliverable 4.3) associated with the bathymetry of the buoy and the battery level. The following filters were applied:

- Bathymetry: Using high-resolution bathymetry data (British Oceanographic Data Centre, UK, www.gebco.net, resolution of 15 arc-second intervals), acoustic records from buoys in areas with a depth smaller than 150 m (in case of IRD, Marine Instruments buoys) or 200 m (in case of AZTI, Marine Instruments and Satlink buoys) were excluded. This prevents including false-positive echoes coming from the sea floor and allows the exclusion of acoustic records of FADs that have drifted to coastal areas, where tunas are less likely to be found.
- Battery Voltage: According to the buoy manufacturer (Marine Instruments), data obtained with a voltage of 11.5 V have poor reliability (in terms of location and acoustic measurements).
- Vertical boundaries: According to the buoy technical specifications, buoys have a blind area of 3 (Satlink) to 6 meters (Marine Instruments). These data were therefore filtered out.

Depending on the algorithm used to estimate the presence of tuna or tuna biomass, additional filters were used to eliminate noise and obtain a representative signal of tuna biomass. The following filters apply to the approach developed by AZTI:

- Vertical boundaries: acoustic information from the shallower layersis used as the vertical boundary between non-tuna species (living in the first 25 m) and tunas, from 25 m and deeper (Lopez, 2016). Therefore, depending on the algorithm used, this vertical boundary could be applied to eliminate the noise from the non-tuna species associated with the FAD.
- Time of the day: Samples obtained around sunrise, (4 – 8) a.m., are supposed to capture the echo-sounder biomass signals that better represents the presence and abundance of fish under the FADs. This is the time when tuna is closely aggregated around the FADs (Brill et al., 1999; Josse et al., 2000; Moreno et al., 2007; Harley et al., 2009; Baidai et al., 2018); it can vary depending on the ocean (Baidai et al., 2018). For the specific case of comparing the acoustic data with abundance, it is important that the echo-sounder measurements are received when the signal is more representative of the biomass around the FAD (Orue *et al*., 2019).

To obtain reliable indicators of the acoustic signal, IRD developed a procedure for estimating the presence/absence of tuna and the size class of the tuna aggregation based on the acoustic data obtained from M3I buoys[43]. A supervised learning algorithm (random forest classification algorithm) is applied, for each ocean, to translate the raw outputs provided by the buoys into metrics of tuna presence and abundance. The training datasets

[43] Satellite buoy manufactured by Marine Instruments, with 50 kHz echo sounder especially designed for tuna fishing with fish aggregating devices.

for each ocean were constructed by cross-matching the observer data and the daily acoustic matrices corresponding to the same buoy ID, selecting the acoustic sounding of the day before the set. The algorithm considers the acoustic information contained in the whole sampled water column (3–150 m) during 24 h. It selects the most important depth layers and periods to assess tuna presence (or size of the tuna aggregation), which can vary between oceans, using machine learning (Baidai et al. 2018). This approach has shown a very good efficiency for pattern recognition of presence and absence of tuna aggregation under FADs regardless of the ocean (accuracy 0.75 and 0.85 in the Atlantic and Indian Oceans, respectively). The procedure is less accurate for estimating the precise range of aggregation sizes (accuracy 0.5 and 0.45 in the Atlantic and Indian Oceans, respectively).

AZTI developed a procedure to be applied for Satlink buoys, based on the model developed by Lopez et al., 2016. The model is based on the best available knowledge of the vertical behaviour of species and sizes at FADs, their corresponding target strength (TS) and weight values by group of species for the corrected biomass estimations. An echo-integration procedure was conducted repeatedly by applying all possible combinations of depth limits between small and large tuna in the entire depth range. The selected depth limit was the one that had the best coefficients of correlation (r) and determination (r^2) between predicted biomass and the real catch. Finally, to correct the predicted biomass, the error (in tonnes) of the uncorrected predicted biomass was modelled using different regression models (polynomials of order 2 (POL2) and 3 (POL3), GLMs and generalised additive models (GAM) (Hastie and Tibshirani, 1990), as a function of the uncorrected predicted biomass. Functions obtained by regression models were used to adjust biomass estimates and obtain the final corrected biomass values. The polynomial of order 3 was selected as the main model. The results showed that the model used in this study (based on existing knowledge of the vertical distribution of non-tuna and tuna species at FADs and mixed TS and weights) improves the biomass estimates provided by the manufacturer. The improvement is not as large as expected, which could indicate that the large variability in these data is not easily reflected by a single model.

Finally, common indicators for assessing the quality and uncertainty level of the biomass estimates were established. The detailed description of these indicators can be found in the Deliverable *D.4.2- Documented algorithms for cleaning the acoustic signal by type of buoy* (included as Annex 12 in this report).

Recommendations for future work

The collaborative work conducted by the fishing industry, buoy providers and research institutions has allowed recovering historical information on buoy positions and acoustic information to be used for scientific purposes in the development of indicators for evaluating tropical tuna stocks. The access to the data has been obtained thanks to specific agreements with the data owners (fishing industry). Thus, access to this data was dependent on the voluntary collaboration agreements. In the future, it would be desirable to have permanent agreements or obligations of submission of this valuable information to make it available for scientific use.

Some buoy providers faced difficulties when exporting historical data. Therefore, in the future, to advance the recovery of information on buoys, monthly deliveries would be a good solution.

In this specific exercise, for the analysis of data-filtering protocols and the agreement on a common protocol for buoy data pre-processing, a set of filters was defined and tested using a common database. Filters run in each research institute were identical except for the shapefile for land and onboard filtering, for which a specific algorithm was developed by each institute. The inspection of the outputs of the filtering run by IRD and AZTI demonstrated a high level of agreement between the two methods, validating both methods for data pre-processing. The main differences occurred in the classification of buoys on land. The shapefile resolution and the size of the buffer could affect the filtering of buoys on land, and thus an increase in the available resolution and further sensitivity analyses relative to the choice of the buffer are recommended. In addition, minor differences between the two methods were found in the number of buoys classified as onboard. These differences were larger for the Spanish dataset in the Indian Ocean since the performances of the algorithms are affected by the characteristics of the databases (i.e., lower performance on shorter tracks and smaller temporal resolution). To minimise the misclassification, the use of high-resolution data is recommended, if available.

In addition, some factors were identified as valuable for further improvement of the filtering and for the evaluation of the number of buoys followed by each vessel, i.e., water temperature and IMO (International Maritime Organisation number) of the vessels, respectively. This information could be requested from the buoy providers.

Concerning the analysis of the acoustic information, the supervised learning algorithm developed for buoys of the Marine Instruments brand showed very good efficiency in pattern recognition of presence and absence of tuna aggregations under FADs, regardless of the ocean. This procedure is less accurate for estimating the precise range of aggregation sizes. The method used for buoys of the Satlink brand, based on existing knowledge of the vertical distribution of non-tuna and tuna species at FADs and mixed TS and weights, improves the biomass estimates provided by the manufacturer. However, the improvement of the biomass estimates was not as large as expected, so it should be further improved.

To make further advances in the detection of tuna and the estimation of biomass aggregated underneath the FADs:

- Some work is needed to tune the algorithms for biomass estimation in the aggregations underneath the FADs, including the effect of other factors on the acoustic signal. Spatiotemporal factor or environmental factors could be explored.
- New TS values should be considered in future assessments, and new experiments should be conducted for the estimation of new TS (e.g., yellowfin TS).
- Accounting for the spatiotemporal variation in the species and size distribution could help in the estimation of the corrected biomass.
- Further electronic-tagging studies should be conducted to assess the associative behaviour of fish for different FAD densities and environmental characteristics since this behaviour affects the amount of associated biomass and, thus, the abundance index.
- To assess differences between buoy models, further studies should be conducted, attaching different buoy models to the same FAD.

WP5-PROCEDURES TO ASSESS THE QUALITY OF BIOLOGICAL DATA COLLECTED AT THE REGIONAL LEVEL

Objectives

The main objective of this WP is the development of data-quality assessment procedures, to be commonly agreed, both at the national and regional levels.

Within the regional framework, where the data are shared, common quality assessment procedures are needed.

As a minimum, we should check the data quality at two important steps in the data flow:

- At the national scale, before the transmission to the RCG
- At the regional scale, after building the regional dataset and before the transmission to the end-users.

Methodology

This WP is divided into four tasks.

Task 5.1 - National data-quality assessment

The aim of this task was to ensure the compatibility of the produced dataset with the format required at the national level. The important step towards achieving this goal is to check the data structure. Thus, controls at this level should primarily focus on format issues. This format definition includes, for example, controls of the data structure and the code lists used.

Task 5.2 - Regional data quality

The main objective of this task was to establish a regional control, which will ensure that all the measurements produced by the different parties are compatible. Such control should verify that the sampling protocol, as well as the data handling and database, are implemented correctly. This task will also explore the variance of the measurements at the national and regional levels. The results of this regional quality evaluation will help to improve the regional data collection by highlighting any gaps in the coverage. It could also reveal some issues to explore when the variability differs significantly between the data sets, which might indicate inconsistencies in data collection or processing.

Task 5.3 - Regional data-quality improvement

This task focuses on improvements in the quality of collected data with an emphasis on 2 sub-tasks.

- *5.3.1 - Comparison of age-length keys (ALK) in different Member States and exploratory analysis.* The objectives are to identify the main drivers affecting the variability of the age data (through the analysis of ALKs) and to estimate the uncertainty associated with the sampling strategy.
- *5.3.2 - Tools to coordinate age-reading in the different Member States*. The idea here is to identify areas for improvement and harmonise the approaches and protocols. The exchange approach based on supporting tools (SmarDots, Eltink sheet, small-scale exchange and full-scale exchange) were utilised after a calibration of the large pelagic stocks to the geographical scale. The exchange should be focused mostly on the above aspects, to obtain ageing schemes and ageing criteria to be accepted and shared.

Task 5.4 - Proposals for a detailed annual calendar for the national and regional quality checking process

This task proposes an annual calendar for the implementation of the minimum quality checks described in WP5, consistent with the tuna RFMO data-provision requirements.

Main results

An R package, named "dqassess", was developed under tasks 5.1 and 5.2. It uses a simple approach: the quality and associated processes have to be continuously improved. The package is designed to maximise compatibility with the future updates and to facilitate the incorporation of new controls. Furthermore, it must be seen as a bridge to more transversal systems and remain interconnected, like the new RDBES under development by ICES. Moreover, several projects have similar guidelines and goals, e.g., the FishPi2[44] project or the evolution of the COST R package[45]. These projects were not available at the time, but it could be very interesting to develop some common processes.

For now, the package source is stored in a public repository located on GitHub[46]. This is a web-based hosting service for the version control system or tracking changes. In addition to storage and tracking changes, this platform allows a system to track things "to do", bugs or feature requests. To do that, one can use the "Issues" menu, through the following link. All contributions and feedback experiences increase the relevance and the robustness of this package and serve the interests of the large pelagic fishing community.

Several documents for this package are available under R:

- Documentation for each principal function, with examples and help to use the different arguments
- 3 R vignettes to explain the methodology
- Several examples (available through the vignettes and built according to the RECOLAPE data call) with outputs and methodology explanations

All control and, more generally, verification processes are focused on a definition of data format (an Excel file). This element contains metadata and all the information necessary to define data. For example, it can answer many questions, such as, "What is the structure of the data? How many tables are there? What are the relationships among data?"

Otherwise, all the global methodology and the different processes are summarised in Figure 12:

[44] MARE 2016/22. Strengthening Regional Cooperation in the Area of Fishery Data Collection (ICES area).
[45] https://wwz.ifremer.fr/cost/content/download/15319/file/COSTcore.pdf
[46] https://github.com/OB7-IRD/dqassess

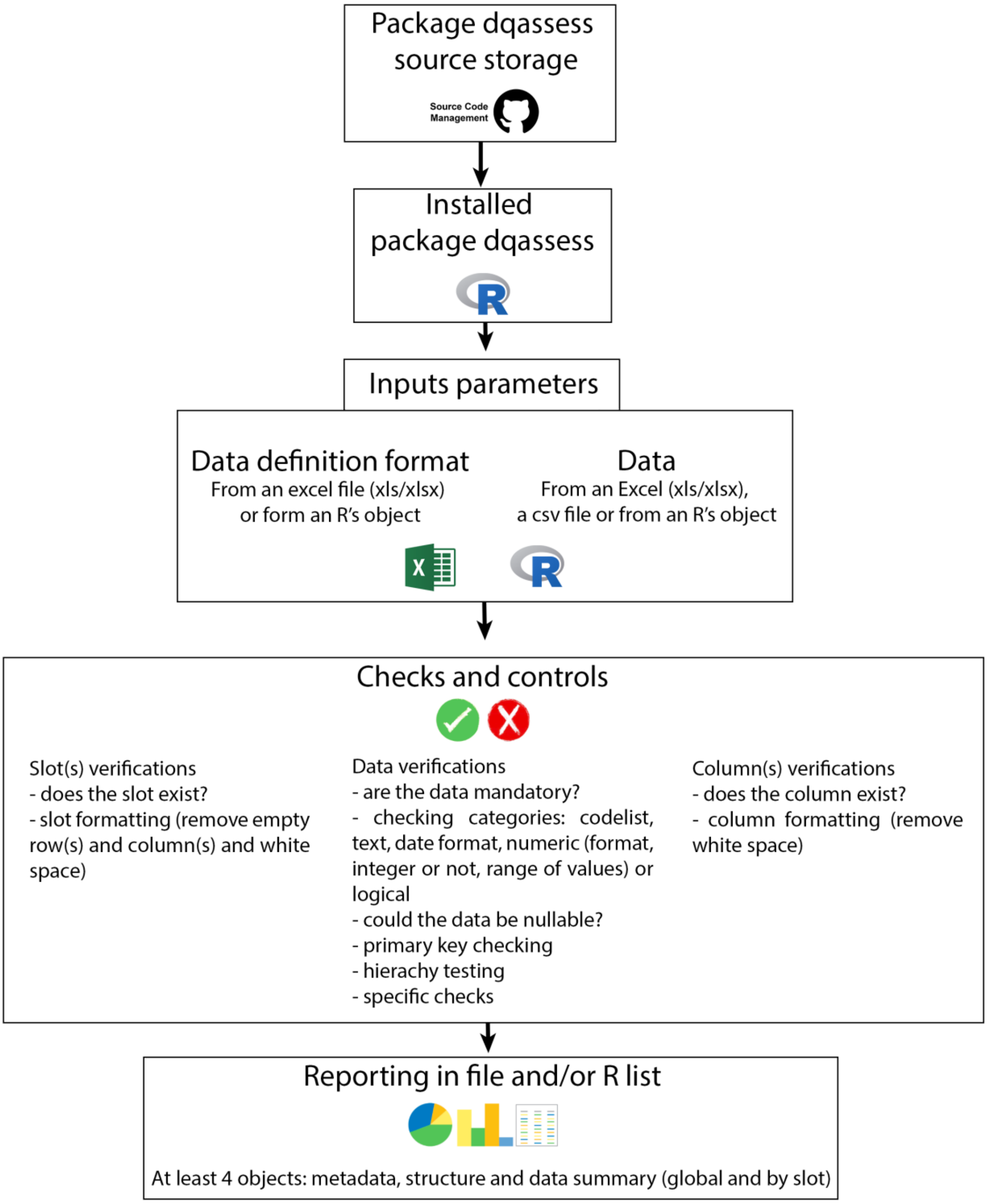

Figure 12. Global methodology of the package dqassess

Further details of the data-quality improvements at the national and regional levels are available in the Deliverable *D.5.1.1 & 5.2.1 – National and regional data-quality improvement* (included as Annexe 14 in this report).

Swordfish age-reading coordination

To analyse the swordfish age-reading coordination, the following tasks were performed. The precision of the data on the swordfish age-sampling strategy in Italy, Greece and Cyprus was evaluated. The precision of the ALKs expressed in terms of coefficient of variation (CV) was estimated for each age group according to the method proposed by Baird (1983).

The sampling strategies in these countries are as follows:

- in two cases, the sample is stratified by length class: two hard structures (HS) by length class (5 cm)

- in one case, the sampling is opportunistic: the HS samples are chosen from those available without any kind of stratification

The stratified sampling strategy, in general, gave better results in terms of precision and coverage of the length frequency distribution. The actual level of age-sampling cannot ensure adequate coverage of the length frequency distribution, mostly for the larger lengths, where it is more difficult to do the sampling (e.g., cost of the sample). Thus, stratification by length and sex might be more adequate, as might be increasing the number of samples by strata to a minimum of 3 spines for each length class (5 cm).

Poor quality of the ageing data has contributed, in certain cases, to a misleading evaluation of the population status, sometimes resulting in the stock collapse (Beamish and McFarlane 1995; Liao *et al*. 2013). For these reasons, an increasing effort has been devoted to improving the age data quality (ICES, 2011; 2013), especially in the context of the European Union Data Collection Framework (DCF). The DCF has been organising exchange exercises, workshops and meetings discussing the ageing of the most important species in the European fisheries (ICES, 2018). These actions are supported by DCF and realized mostly in the ICES context.

A common ageing protocol could be an important tool to decrease the relative/absolute bias and improve the precision (reduce CV and increase the percentage of agreement) in age determination, as well as increase the reproducibility of age-reading in different laboratories (PGCCDBS, 2011). To reach this goal, it might be useful to assess the effect of specific factors (i.e., theoretical birthdate, ageing criteria, age scheme, reader experience) affecting the variability of swordfish age-reading, by using a multiparameter approach, Principal Component Analysis. This analysis could be a first step in the standardisation of reading protocols, to obtain unbiased ALKs for swordfish.

The results of this work confirm those reported by the studies of high variability in the ageing and growth of swordfish (Arocha *et al*., 2003; Quelle *et al*., 2014; Abid *et a*l., 2014). This variability can be affected by several factors, such as sampling methodologies (Coggins *et al*., 2013), geographical differences (Abid *et al*., 2014), age estimation criteria, age estimation scheme, skeletal structures used (otolith or spines) (Farley et al., 2016), methodology (direct age estimation or Length Frequency Distribution Analysis) and the level of experience of the readers.

The geographical location was found to be the most important feature, affecting the age variability significantly, with longitude being the most significant factor.

The experience of readers has been identified as an important aspect affecting the precision of the age data for many species, in both marine and freshwater environments. Here, this factor was also found to be important in ageing variability, especially when we compared the results of readers with long and short experience. Reader experience emerged as a key issue in estimating the age: mostly in the first-year group and the oldest age group (4 years). Therefore, special attention should be devoted when age data from new readers is included within the stock assessment. Indeed, those data are considered acceptable when the Percent of Agreement (PA) and Coefficient of Variation (CV) between new and expert readers reach ≥90% and ≤ 15 % respectively (ICES, 2011).

The results of the present analysis demonstrate the need of a handbook clarifying and standardising the ageing schemes (e.g., birth date), ageing criteria (e.g., number of false rings before the first winter growth increment) and preparation methods. Having such documentation at hand could help to overcome the bias in age data. As the reader experience seems the most important factor explaining the huge variability in the age data in the Mediterranean basin, workshops, age exercises and exchanges should become fundamental tools for improving the precision of age analysis (ICES, 2011)(. These should be conducted preferably at the RFMO level. They might offer an important contribution to overcoming the ageing uncertainties, thus providing accurate and robust input data for stock assessments.

The exchange exercise held for the RECOLAPE project was based on 79 fish samples collected between 2003 and 2017 in the Mediterranean (the Ligurian Sea and the Alboran Sea). The pictures of spine sections (anal fin) were prepared (Quelle *et al*., 2014; Lanteri and Garibaldi, 2019). The overall precision was 64.4%, 30.8% and 23%, for PA, CV and Average Percentage of Error (APE), respectively. These are indeed very low percentages meaning that the exchange exercise needs to be reinforce, although they are, respectively, lower and higher than 80% PA and 20% CV considered acceptable (ICES, 2011). Moreover, they were not significantly different when they were stratified by reader experience, so this did not explain fully the low PA and high CV obtained in this exchange exercise. The analysis of the precision indices by age groups showed a negative trend from the first age group to the oldest one. In addition, the bias analysis of all the data highlighted an underestimate for the older age group and an overestimate for the first age group (0–1 year). These results could be explained by the difficulty in recognising the first growth increment and most growth increments (overlapping of the rings) in the older fish (age > 5 years). The comparison of age readings by different readers showed that this group of readers followed the same ageing criteria. These results were also confirmed by the mean length-at-age estimated by each reader. In the first 6 age groups (age 0 to 5 years), the mean length-at-age values were comparable for most of the readers. All these results were later discussed during a workshop organised under this project.

The Workshop on Swordfish Age-Reading was held in Olhão (Portugal) from the 2nd to the 4th April 2019, under the umbrella of the RECOLAPE project. The meeting was hosted by IPMA Institute. Eight age readers from 4 countries and 5 laboratories (IPMA, IEO-Santander, Genoa University, Unimar and IRD) participated in this workshop. The following Terms of References (ToRs) were covered: *ToR a*: preparation method; *ToR b*: age scheme and age criteria; *ToR c:* analysis of the exchange exercise; *ToR d*: development of a reference collection of spines.

Pros and cons of all the laboratory preparation protocols were first discussed. Then, one protocol was chosen for the preparation of the structure (second ray of the anal fin), conservation and thin-section procedures. This last aspect seems to be fundamental to providing the unbiased age data (Quelle et al., 2014). For the age definition, two schemes were chosen, one based on the 1st January and one on 1st July as a birthday. The suitability of each adjustment scheme was also discussed. To obtain an ALK, the adjustment to the 1st of January was considered best, while for growth curves the adjustment to the 1st of July was regarded more suitable as it considers the biology of the species. In the Mediterranean area, birthdate conventions have been adopted mainly following the biological reasoning, and for most of the stocks the birthdate convention is set on 1st July or 1st June. However, stock assessments are currently run on annual basis, going from January to December. This may cause some problems in the generation of annual catches-at-age coherently grouping year classes (defined for assessment purposes as the fish born from January to December). For this reason, when transforming length sampling into ages (through the ALK), it can be convenient to use an adjustment to the 1st of January. While in the case the growth parameters, it will be convenient using the adjustment to the 1st of July to obtain a more precise estimation of the growth parameters (Panfili et al., 2002). Moreover, a reference collection of swordfish spines was prepared. A reference set of 11 spines was selected using the spines with a PA ≥ 80%.

This work, conducted within Task 5.3, is an example of cooperation under the DCF between the institutes from several MS. It is important to underline that some laboratories (IPMA, IEO-Santander) were involved in this exercise even though they did not belong to the project consortium. Throughout the task execution, from the analysis of the precision of swordfish ageing (sampling strategy and explorative analysis), followed by the exchange exercise and the workshop to solve the uncertainties, the same procedures, proposed by the ICES, were used (ICES, 2011; 2013). At the end of the process, common procedures (age scheme, age criteria) and methods (preparation of the spines) were agreed on. It is recommended that the working group on the swordfish ageing should continue, organising a new exchange exercise and workshop after three years to assess any improvements that might be ascribed to the agreed-on procedures and common ageing protocol.

More details on the swordfish age-reading coordination are available in Deliverable *D.5.3.1-Analysis, report and guidelines on age issues including full documentation of used methods* (included as Annexe 15 in this document).

Calendar for national and regional data quality checking

Finally, the WP5 proposed a calendar for data quality checking, considering all the meetings, working groups, report deadlines or any events where the LP data calls might be launched (included as Annexe 16 in this report).. The data and script used here are available in the GitHub[47]:.

Naturally, it is not enough to focus on the two study cases of the RECOLAPE project (swordfish in the Mediterranean targeted by longline fisheries and major tropical tunas in the Atlantic Ocean targeted by purse-seiner fishery). The idea is to analyse global trends and provide advice to the MS and all fisheries associated with large pelagic stocks. It is important to keep in mind that this advice will just give a global overview, which should be adapted to the specificities of each country.

To make sure that the results and their implications are understood, and the conclusions can be adapted to different countries, number of meetings where the data were requested is presented in Figure 13:

- by tuna RFMOs
- by Tropical Tuna Treatment (T3) group
- by EU data calls (such as the Fisheries Dependent Information (FDI) data call).

[47] https://github.com/OB7-IRD/RECOLAPE/tree/master/WP5/T5.4

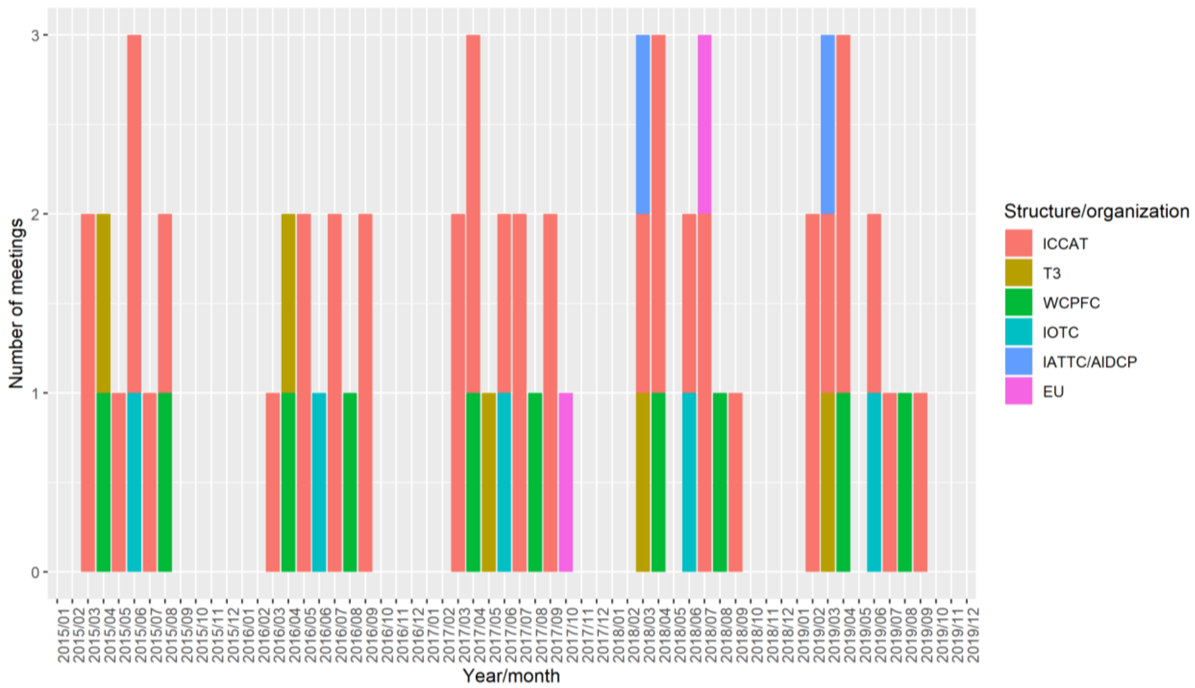

Figure 13: Number of meetings by month, year and end-user, where the data were requested. Only regular data calls are included. Other, non-regular events (e.g., for research projects) should be added to this calendar case by case.

In a perfect world with no resource limitations (human and material), data quality checks should be run for all new data entering the national database. Nevertheless, maintaining this kind of activity stretches the available human resources and, in most cases, it was not possible to achieve this target. An acceptable compromise might be to run national data-quality checks (scripts) at least two months before the regular annual RFMO data calls (June–July).

Recommendations for future work

The introduction of the R package "dqassess" has to be seen as the first step in a larger dynamic process. Several projects on data quality assessment have been started by different initiatives (ICES, IFREMER, IRD); the package needs to be linked to these projects. Furthermore, this kind of quality control and checks have to be tested by the community and all contributions, and feedback experiences should be considered to improve the methodology and, especially, to follow-up the specific user needs.

Based on the age-reading coordination exercise for swordfish, it is recommended:

- To conduct a statistical evaluation of the age-sampling strategy in all MS
- To extend this type of exercise to all the LP species under assessment, to standardise the reading protocols to obtain unbiased ALKs
- The working group on swordfish ageing should continue with a new exchange and workshop after three years to see if any improvements are achieved as a result of introducing established, agreed-on procedures and the common ageing protocol.

WP6–REGIONAL CONSULTATION

Objectives

The purpose of this WP was to collect inputs from regional consultations from all Member States participating in the large pelagic data collection and from the end-users (such as tuna RFMOs or the RCG-LP). The results were also discussed with the tuna industry, mainly concerning WP3.1 and WP4.

The main activity under this WP was a regional consultation process involving the Member States taking part in the large pelagic data collection (irrespective of their participation in the project). The results of the project were discussed to identify points of consensus and/or disagreement.

Methodology

All Member States dealing with large pelagic fisheries were consulted and invited to discuss the project results. This consultation was initially conducted in writing and results were presented during the RCG-LP 2019 meeting, which coincided with the end of the project (May 13, Madrid). The written consultation (survey) was conducted through the national correspondents. This survey only refers to the WPs of common interest (WP1, WP2 & WP5) that concern all the countries, irrespective of the fisheries in which they are involved. The survey was conducted by e-mail using the SurveyMonkey online tool (https://es.surveymonkey.com/). It could also be answered in Word format; the questionnaire included in Annexe 16 was attached. The survey consists of 21 questions in three blocks (i.e., WP1, WP2 and WP5). In most of the cases, it presented a choice of a number in the range from 1 (completely disagree) to 6 (completely agree). This type of answer choice increases participation and facilitates the later analysis. The scale of 1 to 6 does not allow choosing the middle number; every answer has to be at least slightly agreeing or disagreeing. The consultation drew up a list of qualitative and quantitative outputs, where points of consensus and/or disagreement were identified.

Additionally, WP6 dealt with the dissemination of the results. There is no doubt that the meeting of the RCG-LP is the main forum, where these results must be presented and discussed as there is a clear and direct interest. Thus, the results were partially presented during the annual RCG-LP meeting in 2018 (June 26–28, Heraklion), and the final results, during the 2019 meeting (May 13-14, Madrid). There is also no doubt that the feedback and views of the different tuna RFMOs are of paramount importance, as they constitute the end-users of the collected fishery data. Therefore, in cases of those WPs for which the participation and feedback of the RFMOs are essential (such as WP3 and WP4), the results were presented at the RFMO level (in specifically selected working groups).

Main results

Survey results

Detailed results of the survey launched under WP6 are included in Deliverable *D.6.1- List of qualitative and quantitative consultation outputs* (included as Annexe 17 in this report). The survey had been sent to 10 national correspondents representing MS with LP fisheries included in their National Work Programmes (Spain, France, Portugal, Greece, Malta, Cyprus, UK, Italy, Ireland and Croatia). The current Chair of the RCG-LP had also been included as a survey recipient. Seven responses were obtained, from France, Cyprus, Spain (partially), Portugal (partially), Malta, Greece and from the Chair of the RCG-LP. The participation rate exceeded 50% and included some of the most relevant countries with large pelagic captures.

The main points of agreement and disagreement concerning WP1, WP2 and WP5 are listed below.

WP1 – Proposal for a future RCG-LP structure

- There seems to be a broad consensus on the need for RCG-LP to be autonomous.
- The general proposal to structure the RCG-LP in 3 stages, as well as the number of subgroups and meetings, achieved a strong consensus. All MS showed their interest in participating in the subgroups associated with stage 1 (data needs), stage 3 (RCG-LP main meeting), and stage 2 (data analysis) for the fisheries in which they are involved.
- Some MS identified the shortage of human resources as a limiting factor that might hamper their participation in certain subgroups.
- Pan-regional subgroups: The priority subgroups for the MS coincide with those proposed by the contractors ("data management" and "Regional Sampling Plans"). However, most MS consider that the RCG-LP should be somehow represented in all subgroups, including "end user", "governance" and "implication of landing obligation for data collection".
- It seems that there is no clear consensus on the need for a regional database to host the LP data (RDBES or any other). However, this requirement is explicitly mentioned in point 8 of Article 9 of the recast regulation.

WP2 – Development of Regional Sampling Plans

- Neither Spain nor Portugal has responded to this section of the survey. Lack of response could reduce the robustness of the results.
- There are no notable disagreements among the participants: All MS agree with the data requirements and priorities proposed by the WP2 to design an RSP for Mediterranean swordfish and tropical tunas. All MS concur that the sampling protocol should be unique and agreed-on at the RCG level. Finally, all (except for Greece) support the idea of uploading LP data to the current RDBES (Regional Database and Estimation System currently used by the northern RCGs).

WP5 – Procedures to assess the quality of biological data

- Neither Spain nor Portugal has responded to this survey section, which might reduce the robustness of the results.
- There are no notable disagreements among the participants: it seems that the scripts in the R language for checking the data quality are a valid option, favoured by the participants. They also agree on the focus on data checks. Finally, the participants confirm the need to standardise age-reading protocols and agree on the benefits of establishing a working group with this aim. The current Chair of the RCG-LP proposes to expand this standardisation to maturity scales.

RFMO feedback on WP3.1 (ICCAT & IOTC)

The general scope of the project has been already presented in several ICCAT and IOTC data-collection working groups. The results from WP3.1 were presented during the ICCAT species group (Madrid, September 2018) and discussed with the ICCAT Standing Committee on Research and Statistics (SCRS). The Committee reviewed results from

WP3.1 (presented as *docs. SCRS 2018/159*[48] *& SCRS 2018/158*[49]), which proposed the Best Standards for Data Collection and Reporting Requirement on FADs as a response to Annex 8 of ICCAT Recommendation 16-01. These documents also proposed new forms (ST08a and ST08b) for data reporting on FADs and buoys, to replace the form currently used by ICCAT. The SCRS adopted the new proposed ST08a and ST08b forms[50]. They proposed that the Best Standards for Data Collection included in WP3.1 should be considered a minimum standard for data collection in the ICCAT framework.

The same results were presented during the IOTC WPDCS (Working Party on Data Collection and Statistics) (Seychelles, December 2018). This IOTC working group acknowledged the effort put into the harmonisation of terminology and data collection and reporting requirements for FOB. However, due to the differences in classification and reporting requirements between this proposal and the existing IOTC classifications, IOTC suggested the joint tuna RFMOs FAD working group (May 2019, La Joya) as the appropriate forum for harmonising FAD classifications across RFMOs. Thus, the main outputs from WP3.1 and WP4 were presented again during the joint tuna RFMO FAD Working Group. This last meeting coincided with the end of the project so that the feedback from this group has not been included in this report. However, the output from this working group will need to be considered and further discussed by the IOTC/ICCAT Secretariat and the scientific community.

Finally, although the project ended in May 2019, there are plans to present the results of some WPs in later ICCAT / IOTC working groups. The main outputs from WP3.2– "EMS feasibility study in longline fisheries"–will be presented at the next IOTC WPDCS (November 2019, Seychelles).

RCG 2019 feedback

The results from WP1, WP2 & WP5 were presented and discussed during the RCG-LP 2019 meeting (Madrid, May 2019). At the time of writing this report, the report and final list of recommendations done by the RCG – LP 2019 was not available. However, many of the results obtained through the written consultation were confirmed. The proposed structure of the RCG-LP, as well as the number of stages and subgroups was adopted. In addition, the RCG -LP recommended to add a fourth technical subgroup focused on the coordination of the bait boat fisheries. As for WP2 and WP5 results, there were no notable disagreements among the RCG-LP participants. However, it is worth highlighting the doubts that persist in some MS in relation to the RDBES. In this sense, the RCG-LP raised the possibility to organize a practical session on the RDBES, where the RDBES Steering Committee could clarify any doubt.

[48] Best standards for data collection and reporting requirements on FOBs: towards a science-based FOB fishery management. Collect. Vol. Sci. Pap. ICCAT, 75(7): 2259-2282 (2019).

[49] The Use of Instrumented Buoys to Monitor the Activity of the Purse Seine Fleet on FAD.

[50] The number of FADs actually deployed on a monthly basis per 1°x1° statistical rectangles, by FAD type, etc.

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