9TH MEETING OF THE SPRFMO COMMISSION

Held remotely, 25 January – 3 February 2021

COMM 9 – Obs 03
FAO - GFW Submission to the 9th SPRFMO Annual Meeting

FAO – Global Fishing Watch

In October 2020, FAO and GFW (Global Fishing Watch) presented a paper to the SPRFMO Scientific Committee (SC8-Obs05 FAO GFW 2020) to determine the interest and feasibility in developing a collaborative project between SPRFMO, FAO, and GFW on the use of AIS data technology to improve monitoring of high seas fisheries. The Scientific Committee noted that this seemed a worthwhile initiative and important in relation to the development of management measures that are ongoing in the SPRFMO SC. The SC agreed that the Secretariat would help to determine the required resources and clearer development of the aims of the project (paragraphs 266,267 SC8-Report). This document includes two proposals resulting from subsequent discussions between the three partners.

FAO will lead the project, and will contribute scientific capacities to participate in the analysis or in sharing knowledge for orienting data analysis or interpreting results. If it progresses the project will be based on in-kind resources from FAO, GFW and SPRFMO for the supervision and the provision of data, complemented with the computing infrastructure and the financial resources of the EU H2020 Blue Cloud project to support specific consultancy needs.

COMM9 is invited to:

- Consider the two proposals described
- Add one or both of the proposals to the SC Work Plan 2021 (COMM9-Doc06) so that the project can proceed under the supervision of the Scientific Committee and under SC data confidentiality provisions

Problem statement

Fisheries currently face many issues of sustainability, and enhancing their management requires better evidence-based measures, with timely corrective actions that rely on near-real-time monitoring systems. Automatic Identification System (AIS) data offer opportunities in near-real-time monitoring and higher time-space resolution analyses than vessel monitoring systems (VMS). AIS is well-established on the high seas, with the use of AIS expected to grow in other regions and with coastal fleets (Taconet et al. 2019). AIS and other remote sensing technology offer new opportunities for fisheries data analytics when combined with data services such as vessel registries, fish stock or fishery status registries, fish tags, and environmental monitoring. AIS can transform the way we observe, analyse, interpret and eventually manage and monitor fisheries and the environment.

With such prospects, some research questions of interest are:

- What improvements can be achieved by using AIS data in supporting assessments and fishery management?
- What share of the world's vessels, fisheries, and catch are covered by AIS-systems and how does this evolve over time with improvements in AIS use, AIS reception and algorithm performance?
- With the understanding that many institutions face difficulties to benefit from technological innovations and to analyse an increasing amount of data, what should FAO and other international organizations offer to facilitate access to information processed from such technologies?

Background

In 2019, FAO published the Global Atlas of AIS-based fishing activity in partnership with Global Fishing Watch (GFW), AZTI Tecnalia, and Seychelles Fishing Authority (Taconet et al. 2019). This Atlas investigated the potential and the limitations of using Automatic Identification System (AIS) data to monitor global fishing activity and develop indices of fishing effort using neural network-based algorithms developed by GFW to detect fishing events. AIS use, coverage, and reception were found to be good, and where vessel registries with gear types exist, the algorithm could provide good estimates of fishing effort for several gear types (e.g., trawl, longline).

Several reviewers of the Atlas from RFBs/RFMOs expressed interest in how AIS can improve sustainable fisheries. Specific analyses in the Atlas found that by assembling AIS, vessel registries, VMS, and logbook data, estimates of effort and CPUEs could be noticeably improved in fish stock assessment studies that are currently approximated using VMS data. This is due to the higher frequency of transmissions with AIS (seconds to minutes) versus VMS (one to several hours). Due to this higher transmission frequency, AIS can supplement other sources of management information, providing a broader picture of vessel activity. Using AIS, analyses of vessel activity can be undertaken in and beyond the area of interest, including cross-jurisdictional assessments, as AIS use is often based on IMO legislation and are accessible via satellite companies (Kroodsma et al. 2018). This is in contrast to VMS, where VMS data are highly restricted and accessible via specified mandates within convention areas by regulatory bodies, and generally only available at the national level.

While we note that AIS data can be representative of fleet dynamics and have been shown as a good complement to VMS data, the dataset includes several limitations of note. Though AIS transmission frequency is seconds to minutes (Robards et al. 2016), data can be patchy, with gaps of several hours due to limited coastal ground stations and satellite receivers or a high degree of marine traffic that swamps the signal (Taconet et al. 2019). Furthermore, AIS was originally intended as a ship-to-ship avoidance strategy to prevent collisions, and use outside of port can be variable. Some vessels and even whole fleets can choose to turn off their AIS transmissions upon departure from the port zone (Nieblas et al. 2019). Finally, position information can be manipulated and can be subject to errors, falsifications, and spoofing (Iphar et al. 2016).

These limitations have been mitigated in recent years. The number of coastal ground stations and satellites are increasing in quantity, and allow increased AIS data reception. There is evidence of rapid uptake by fleets of AIS, including artisanal vessels due to pilot studies focusing on safety at sea. Furthermore, by the inclusion of further complementary datasets, including radar and Visible Infrared Imaging Radiometer Suite (VIIRS) (satellite-based light detections), AIS data can be cross-checked to aid in detecting vessels that do not transmit AIS and identify erroneous trajectory information, which can lead to vast improvements in vessel and trajectory detection (Park et al. 2020).

Overall, in areas with good AIS use and reception, AIS data can aid in characterising fishing vessel activity, improve transparency, and support management needs, including estimating fishing effort. Analytical objectives using AIS data can be further facilitated with the complementary use of radar and satellite-based light detections of vessels. However, while the potential for use in fisheries management of these data sets is large, the limitations of these data should be considered relative to which vessels and fishing activities are recorded and observed, and those that are not. The FAO AIS Atlas investigated AIS reception, use, and representation in the SPRFMO region (FAO areas 81 and 87), and found that AIS reception is good and its use is high by Australia, New Zealand, and distant water fleets in the high seas, but poor in most coastal regions. In this region, trawlers, set longliners and squid jiggers are the most important gears and have been found to be well represented by AIS data (Taconet et al. 2019). Finer-scale analyses comparing VMS to AIS data could give an indication of how well AIS data represent fleet dynamics in the region.

The results of the FAO AIS Atlas outlined the potential benefits of using this finer grained and near-real time information for sustainable fisheries, and some strategic considerations arose where it was noted that high seas areas under RFMOs governance offer opportunities for researching how and to which extent, in which fishery context, and with which confidence intervals could AIS, combined with other data sources, improve estimates of fishing effort and CPUE; and from there the potential to provide near-to-real time indications of catches by fisheries.

In October 2020, FAO and GFW presented a paper to the SPRFMO Scientific Committee (SC8-Obs01 FAO GFW 2020) to determine the interest and feasibility in developing a collaborative project between SPRFMO, FAO, and GFW to follow up on these strategic considerations. The

Scientific Committee noted that this seemed a worthwhile initiative and important in relation to the development of management measures that are ongoing in the SPRFMO SC. The SC agreed that the Secretariat would help to determine the required resources and clearer development of the aims of the project.

The following document includes two proposals resulting from subsequent discussions between the three partners and are listed by priority due to perceived impact and data availability. The first proposal that aims to develop fishing effort indices for the squid fishery can be undertaken immediately. The second proposal aims to investigate environmental variability in the squid fishery and requires observer data. It is presented here for information and for consideration in two years' time, when SPRFMO observer data have been reported.

Both short proposals include an objective, background to the problem including a short review of previous work, and an overview of the methods. We also list herein the data that would be ideal to work with, understanding that some of these datasets are sensitive and some data requests may not be accepted by CPs. We therefore also list alternative options that would still enable us to achieve interesting results.

1. Evolution of fleet dynamics and changes to fishing strategy in the SPRFMO squid fishery

Objective :
Describe the evolution and fleet dynamics of the SPRFMO squid jigging fleet and any changes to the fishing strategy over time with implications for harvest control rules based on effort limits and impacts to catchability and CPUE calculations.

Background :
Jumbo squid are a short-lived, fast growing species whose life histories are highly linked to environmental fluctuations. Due to their rapid growth and population turnover, jumbo squid populations have the ability to rebound from unfavorable environmental conditions. These characteristics also make this species less vulnerable to overfishing; however a combined effect of adverse environmental conditions and heavy fishing pressure could crash a population and make recovery difficult (Arkhipkin et al 2015).

The squid jigging fishery in the SPRFMO convention area has rapidly evolved in the past ten years from 68 vessels in 2009 to >500 vessels in 2019 (SPRFMO 2020b), leading to calls to investigate effort-based management measures. Rodhouse (2001) states that one of the best ways to manage short-lived species is via controls on effort. The 2020 SPRFMO Scientific Committee (SPRFMO 2020a) noted that little is known about current fishing effort, but that any limit should apply to fishing power, rather than restrictions on the number of vessels. The group concluded that management measures limiting fishing effort should be investigated.

As a nighttime light-based fishing strategy, the use of visible light has been investigated as a measure to monitor squid fishing activity. Previous work investigating squid jiggers in FAO Major Fishing Area 41 found that AIS data and Visible Infrared Imaging Radiometer Suite (VIIRS) data (Ruiz et al. 2019) had good coherence. We note that by combining the datasets, these could be used to develop an index of fishing effort based on time spent fishing and luminosity.

This study could also be undertaken by combining GFW's VIIRS dataset to VMS data regularly and frequently provided to SPRFMO. Heuristic squid jigging events could likewise be predicted for VMS datasets. However, we note that the added value that AIS data sets bring of investigating potential interactions with vessels outside of the SPRFMO mandate (e.g. vessels in the tuna fleet). We further note that limits to AIS data coverage and use can be successfully mitigated using complementary datasets (i.e. VIIRS and radar) (e.g. Park et al. 2020), and very fine time scales may improve effort estimates. Furthermore, AIS data may allow for broader scientific value of this study, as effort indices developed using this global dataset can be applied elsewhere.

Methods :

- Describe the fleet evolution over time, including the number of vessels, their gross tonnage, and gear attributes (number of jigs/jiggers and light power) using a combination of SPRFMO vessel registries, vessel information, and effort data and GFW-AIS and VIIRS data. Compare these results to the recent study describing the fleet capacity in the SPRFMO convention area (SPRFMO 2020b).
- Compare AIS trajectories of SPRFMO vessels, and the complementary radar and VIIRS data to their VMS trajectories to validate the use of AIS as representative of fleet dynamics (derive AIS data coverage in the SPRFMO fleet, reception/transmission indicators).
- Describe any changes in fishing strategies over time as identified by light power, similar to Paulino et al. 2017, and using VIIRS (light detection) data, and also including e.g., vessel number, tonnage, type of bait (if data are available). Identify whether there have been shifts in fishing strategy (i.e. increased light power) that could impact catchability, thus CPUE calculations. VIIRS data are daily, global, and 750 m resolution. They cannot currently identify specific vessels but can differentiate the very bright squid vessels from other vessels.
- Develop a nightly index of effort - e.g. hours * lumen of light power using vessel and gear information for the squid fishery to identify an effort-based management measure for the SPRFMO region. Could be applicable to other regions.

Data requested :

SPRFMO:

Ideal:

- Vessel registries,
- vessels' gear information (jig set up, manual or automatic),
- number of jigs per jigger, light power),
- catch and effort data (logbook preferable),
- CPUE,
- VMS tracks.

Alternatively:

- Vessel registries,
- vessels' gear information derived from effort data,
- aggregated catch and effort data,
- CPUE,
- aggregated or anonymised VMS.

GFW :
AIS (2016 - present), VIIRS (2016-present), synthetic aperture radar (SAR from RadarSat-2 and Unseen Laboratories) (2007-present)

- Indices of squid fishing events based on heuristic models using AIS trajectory data (see Taconet et al. 2019).
- Light indices from VIIRS to identify active squid jig fishing events (750 m resolution). Current work at GFW is developing a link between individual AIS tracks and VIIRS data to track the light emissions of individual vessels.
- Detection of vessels via SAR for those not transmitting on AIS

Added value of GFW data

- AIS data (data transmission from min to secs) improves on VMS data transmission (hourly for SPRMO vessels), allowing a more precise detection of fishing events. However, as noted in the Background section, AIS transmission can be patchy, with data gaps of several hours, thus a comparison with regular VMS data can give an indication of how well AIS data represent fleet dynamics in the region. In addition, the complementary datasets provided by GFW, i.e. VIIRS and SAR data can aid in detecting vessel activity for those that do not transmit AIS, as has been successfully done by GFW previously (Park et al. 2020).
- GFW data are available for vessels both within and outside of the convention area, indicating that results derived from this analysis could have broad applicability to e.g., other regions, thus enhancing the scientific value of this work.
- Fishing activity is detected by the GFW neural network algorithm for most gear types, including vessels that do not fall under the SPRFMO mandate, thus enabling a complete picture of vessel activity in the region of interest.
- GFW's VIIRS dataset can be used to identify an evolution in the fishing strategy used by squid fishing vessels, e.g. increased light power over time, which can have impacts on the catchability of the squid (i.e. brighter lights attract more squid, making them more available to be caught). Changes in catchability can have a significant impact on CPUE time series. Light power data are provided to SPRFMO, but reporting may not be regular. Note that light detections are impacted by cloud cover, limiting the VIIRS dataset to some extent, though GFW is working to mitigate the impact of cloud cover by linking VIIRS to AIS tracks and extrapolating likely light emissions.

FAO
FAO will provide legacy data and any relevant databases available through the EU H2020 iMarine-BlueCloud platform and the computing infrastructure and financial resources of the EU H2020 Blue Cloud project, including:

- The Global Record of Stocks and Fisheries (GRSF) in the SPRFMO context;

- The FIRMS tuna atlas;
- FIGIS's geospatial database including FAO species distribution maps, FAO statistical areas, RFBs competence areas, etc.;
- Other databases available through the iMarine-BlueCloud, such as OBIS, AquaMaps, EMODnet bathymetry and biology, Copernicus Marine Environment Monitoring Service, Copernicus Climate Change Service (C3S) projections of Essential Ocean Variables, national jurisdiction boundaries, etc.

Data sharing and clauses
Any envisaged project will include a data sharing agreement with relevant clauses for the secure and confidential use of shared data.

Note: in this project and in general, FAO will not promote AIS for MCS purposes.

Proposed capacity contributions :
The project will be based on in-kind resources from FAO, GFW and SPRFMO for the supervision and the provision of data, complemented with the computing infrastructure and the financial resources of the EU H2020 Blue Cloud project (and any additional project) to support specific consultancy needs. FAO will lead the project, and will contribute scientific capacities (staff time) to participate in the analysis or in sharing knowledge for orienting data analysis or interpreting results.

The current proposal requests contributions of capacity by SPRFMO in the form of data provision, and scientific capacities (staff time) to participate in the analysis or in sharing knowledge for orienting data analysis or interpreting results. This could come via the Secretariat, or through interested national researchers (e.g. an SC committee member).

GFW will contribute their datasets, as well as scientific capacities (staff time) to participate in the analysis or in sharing knowledge for orienting data analysis or interpreting results.

All members will contribute to reports and/or publications.

SPRFMO : Data provision and support, contribution to report and/or publication
GFW : Data provision and support, 15 days data analyst, contribution to report and/or publication
FAO : 30 days data analyst, 10 days data manager, provision of legacy data, computing infrastructure and any relevant database in i-Marine BlueCloud platform, contribution to report and/or publication

Provisional planning :

2021	J	F	M	A	M	J	J	A	S	O	N	D
Commission meeting												
Project approval												
SPRFMO data provision												
GFW data provision												
Analysis - GFW												
Analysis - FAO												
Report writing												
Presentation of results										SC9		
Final report delivered												

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2. Squid habitat monitoring improved with AIS/VIIRS data : climate change impacts and dynamic time-area closures

Objective:
Improve habitat monitoring for squid fisheries using GFW AIS, VIIRS, and radar datasets as proxies for fish distribution. Identification of temporal and spatial extents of potential spawning habitat towards a dynamic time-area closure and of overall distribution towards investigating climate change impacts on squid distribution.

Please note that this proposal could easily be separated into two separate topics (i.e. climate change impacts and time-area closures) that could be investigated independently of one another.

Background:
Jumbo squid are a short-lived, fast growing species whose life histories are highly linked to environmental fluctuations, and strongly by El Nino-Southern Oscillation (ENSO) events (Arkhipkin et al 2015, Liu et al. 2015). During ENSO events, jumbo squid populations are known to contract to more coastal ranges and produce smaller individuals that mature earlier. Quantitatively describing the relationship with past range contractions of squid and the environmental conditions that characterise them can enable predictions of future change and variability in squid distribution (e.g., Waluda and Rodhouse 2006, Yu et al. 2019).

Spawning can occur within 20°N-25°S in coastal and inshore regions (50-150m from shore) and the major spawning area in the SPRFMO convention area is off the coast of Peru (Tafur et al. 2001). Offshore spawning may occur in lower latitudes. The primary spawning peak is in the austral spring and summer (September-November) with a secondary peak in July and August. China recently declared a self-imposed time-area closure in the East Pacific (5°N - 5°S, 95°W - 110°W), and they note that further work is required on squid resource monitoring to inform a management measure that would enable a dynamic time area closure.

Methods:
Identify environmental characteristics of squid distribution and spawning regions using GFW-developed fishing activity as a proxy of squid distribution

- Validate AIS/VIIRS/Radar data against VMS for fleet coverage, distribution.
- Validate fishing activity as calculated from AIS/VIIRS/Radar data with survey data to ensure these can represent a proxy for fish distribution
- Relate changes in “squid distribution” using the AIS/VIIRS/Radar proxy to environmental variations (e.g. ENSO, SST, Chl, fronts, etc).
    - Define environmental habitat envelopes using e.g. habitat suitability indices and/or cluster analysis
    - Investigate changes in habitat envelopes with climate change using ocean model predictions.
- Use previous studies to identify the environmental characteristics of potential spawning regions, couple with any biological data available (e.g. Hu et al. 2018, or squid samples from

Chinese Taipei from which they derive their maturity scale (SC8,2020)) and the squid distribution proxy.

- Describe spatial-temporal variability of potential spawning habitat and implications to time-area closures

Data requested:
SPRFMO:
Ideal:

- Vessel registries,
- catch and effort (logbook preferable),
- CP biological data preferably with maturity information (e.g., Hu et al. 2018),
- survey data (any in SPRFMO area, otherwise from willing CPs),
- VMS trajectories.

The project could begin with the observer data already available (e.g. if contributed from CPs). Further observer data are being collected in mid 2021, with first reporting in September 2022. This project is thus listed here for information to the Commission for consideration by the Commission in 2022 e.g., Table 2.

Alternatively:

- aggregated catch and effort,
- anonymised VMS trajectories,
- any biological data,
- any survey data.

GFW:
AIS (2016 - present), VIIRS (2016-present), synthetic aperture radar (SAR from RadarSat-2 and Unseen Laboratories) (2007-present)

- Fishing activity derived from AIS,
- VIIRS, and
- SAR data (Radarsat 2, Unseen Laboratories) for squid fishery

Added value of GFW data

- Within season metrics of fishing activity/fish distribution useful for dynamic time-area closures. Temporal resolution of AIS data (minutes to seconds) improves on the resolution of VMS data (hourly for SPRFMO), though it should be noted that there are often gaps of many hours in AIS. Thus, AIS transmission is more frequent, but more irregular than VMS.
- VIIRS data may give a better indicator of fishing activity/distribution than trajectory data.
- Radar data can supplement the AIS datasets by indicating vessels that may not be transmitting in AIS.

FAO:
FAO will provide legacy data, environmental data and ocean model outputs via Fisheries Atlas and BlueCloud partners, and any relevant databases available through the EU H2020 iMarine-BlueCloud platform and the computing infrastructure and financial resources of the EU H2020 Blue Cloud project, including:

- The Global Record of Stocks and Fisheries (GRSF) in the SPRFMO context;
- The FIRMS tuna atlas;
- FIGIS's geospatial database including FAO species distribution maps, FAO statistical areas, RFBs competence areas, etc.;
- Other databases available through the iMarine-BlueCloud, such as OBIS, AquaMaps, EMODnet bathymetry and biology, Copernicus Marine Environment Monitoring Service, Copernicus Climate Change Service (C3S) projections of Essential Ocean Variables, national jurisdiction boundaries, etc.

Data sharing and clauses
Any envisaged project will include a data sharing agreement with relevant clauses for the secure and confidential use of shared data.

Note: in this project and in general, FAO will not promote AIS for MCS purposes.

Proposed capacity contributions:
The project will be based on in-kind resources from FAO, GFW and SPRFMO for the supervision and the provision of data, complemented with the computing infrastructure and the financial resources of the EU H2020 Blue Cloud project (and any additional project) to support specific consultancy needs. FAO will lead the project, and will contribute scientific capacities (staff time) to participate in the analysis or in sharing knowledge for orienting data analysis or interpreting results.

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GFW will contribute their datasets, as well as scientific capacities (staff time) to participate in the analysis or in sharing knowledge for orienting data analysis or interpreting results.

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GFW : Data provision and support, 15 days data analyst, contribution to report and/or publication
FAO : Data provision and support, 30 days data analyst, 10 days data manager, provision of legacy data, computing infrastructure and any relevant database in i-Marine BlueCloud platform, contribution to report and/or publication.

Provisional planning:
Planning for projects requiring observer data can be envisaged in 2 stages - 1) analyses and reporting using any existing observer data during year 1, and 2) updated/refined analyses during year 2 (see planning in Table 2).

Table 2. Proposed planning for project proposal 2: Squid habitat monitoring improved with AIS/VIIRS data : climate change impacts and dynamic time-area closures.

	2022												2023												2024											
2. Habitat monitoring	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Commission meeting																																				
Project approval																																				
SPRFMO data provision									catch, effort, surveys, existing observer												update															
GFW data provision									AIS, VIIRS												update															
FAO data provision									ocean model												update															
Analysis - GFW																																				
Analysis - FAO																																				
Report writing																																				
Presentation of results																						SC10												SC11		
Report delivery																																				

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