Innovation in fisheries monitoring science

— Fisheries dependent data as a tool for real-time advice

SCAR-Fish, the Strategic Working Group on Fisheries and Aquaculture Research

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Background

Under FP7 and EU H2020, a high number of projects has been funded where technological advances were used in the development of tools for monitoring marine ecosystems and fisheries activities in particular. Funded projects also touched upon many aspects of results-based management, social and economic factors and participatory approaches. Additionally, DG MARE funded several studies dealing with similar aspects. The extent to which such aspects have been covered at the scope of these projects was discussed in the Workshop on Research Gaps in Fisheries Topics, held in Brussels in March 2018, where scientific, economic, industrial and societal gaps, as well as research gaps in support to policies, were highlighted. Research on spatio-temporal dynamics of fisheries as a basis for Marine Spatial Planning (MSP), ecosystem and fisheries management was recommended as a priority, along with stakeholders' involvement in fisheries management and policy development. A main conclusion from this workshop was the need of changing the fisheries management paradigm towards a more flexible one, where a new set of rules is developed, adapted to a more diverse and regional structure in the fishing activities. This new paradigm calls for a bottom-up management, with real-time assessment of fishing activities, requiring active involvement of fishers in data collection and advice.

As a result of the discussions about technological advances in fisheries monitoring science, during the meetings of the Strategic Working Group on Fisheries and Aquaculture Research of the Standing Committee on Agricultural Research (SCAR-Fish), it was agreed that such advances are currently not fully used as a tool in support of fisheries advice. To propose R&I priorities in the EU, and strengthen this topic, an ad-hoc working group was formed in the frame of SCAR-Fish at the 31st SCAR-Fish Meeting on 29 September 2020. This group was tasked to identify gaps and propose research on the use of fisheries-dependent data usually collected during fishing operations (FDD) to support near-realtime advice and management. The focus is on better use of existing data and the further development of tools to improve the data collection and provision of this data for advice and management. In the EU, fisheries data is collected under the DCF (Data Collection Framework), which establishes a set of rules governing the collection of biological, environmental and socio-economic data on the fishing sector. It is important to note that, for the purpose of this group, the term

“fisheries-dependent data” is used under a narrower scope, being defined as data that are already collected during fishing operations by the fishing industry. It does not include data collected through sampling of catches that are either sampled at sea through scientific observers on commercial vessels, or by scientists in harbours, when the fish are landed. Data from the Automatic Identification System (AIS), are also not considered in this document as fisheries-dependent data, despite their usefulness as a complementary source of geo-referenced data for fishing vessels. The group mainly looked at a better usage of already existing technologies rather than the development of new technologies for data collection as well as data use.

Conclusions and recommendations

A set of technological tools are now available to monitor the first link of the fish value chain – from sea to port. However, there is still a long way to go in exploring their potential, including the Vessel Monitoring Systems (VMS) and e-logbooks, transforming the data generated by these systems into useful information complying with the general time frame needed for scientific advice and in particular near-real time advice and management. The main focus of this document is on fishing operations/fish capture. This is the link which needs most attention concerning fisheries governance.

The document “Science in support of the European fisheries and aquaculture policy”, produced by SCAR-Fish in 2013, is a very relevant document, mainly in its conclusions and recommendations regarding the challenges in fisheries management. The importance of a decentralized fisheries management is emphasized, enabling decision making to be made at a more regional level. In that document, the innovation of methods and technology in fisheries which can facilitate sampling and utilization of data from commercial vessels for scientific purposes is pointed out as essential for a transition to the new Common Fisheries Policy (CFP). However, the document does not point out any directions in this line.

With the present document, our objective is to complement this former SCAR-Fish exercise, raising awareness, near the Commission, Member States and Associated Countries, fisheries research organisations and platforms within SCAR-Fish, of the integration and operationalization of technological developments in fisheries monitoring in order to help shaping the toolbox of fisheries management and advice. Our objective is to guide the R&I agenda to the need of new studies addressing

challenges for improving Fisheries Spatial Management in line with the CFP and the Marine Strategy Framework Directive (MSFD).

For this purpose, SCAR-Fish recommends:

- To extend data collection (i.e. position and catch data) to small vessels involved in local fisheries, by promoting user-friendly technologies and reducing the costs of using these technologies. Small-scale fleets represent around 86% of all vessels in EU waters;

- To enhance the vessel reporting capacity concerning the frequency of transmission of VMS positions;

- To incorporate technology for automatic real-time data collection, including data on starting and ending time of individual hauls. This will allow the estimation of the effective fishing effort and its spatial component; and at the same time, will establish a knowledge base for documentation and traceability;

- To increase the number of existing datasets in fisheries dependent data. Data need to be collected on by-catch species, non-commercial species and discards;

- To implement procedures and quality control for collecting and processing data with a view to using this information in fisheries management and improve the reliability of scientific advice.

- To improve the mechanisms for sharing fisheries dependent data among fisheries management authorities and institutions formally charged with provision of scientific advice.

1. The importance of fisheries-dependent data in support to scientific advice

Within the current CFP, which has become effective from 1 January 2014, fisheries are recognized to be heavily dependent on healthy marine ecosystems and were integrated into other policies related to the broader marine environment, such as the Integrated Maritime Policy (IMP) and the MSFD. The relevance of the implementation of an Ecosystem-Based Fisheries Management (EBFM) was recognized as a central element of fisheries governance under the third CFP reform.

A full implementation of EBFM requires the consideration of the effect of the multitude of human activities and their individual and cumulative effects on the marine environment and the effect of changes of the marine environment, particularly under climate change, on the human activities, specifically fisheries. The EBFM implementation implies a regionalized approach to fisheries management, increasing stakeholders' participation with the establishment of fishery-based plans and mitigation measures to be tailored to specific fisheries. This places heavy demands on data collection, in which fishers already have a central role; and at the same time it requires that the fishing industry should receive more responsibility in implementing conservation and control, advocating participatory management or co-management as a second central element of fisheries governance.

While EBFM was proposed under the last CFP reform, almost ten years ago, discussions on strengthened participation in fisheries governance date back from the second CFP reform in 2002. In the Green Paper on the CFP (Anonymous 2009) a generalized support for decision-making is expressed focusing on core long-term principles and increased regionalization, with mechanisms for monitoring and auditing of policy development and decisions by either the EC and/or at regional level. However, the operationalization of EBFM and participatory management require additional effort.

Fisheries-dependent data (FDD) have been systematically collected since decades through paper logbooks and sales notes, and more recently, through the development of tools such as Vessel Monitoring Systems (VMS) and e-logbooks. Conceived for the purpose of fisheries control, the utility of these FDD sources, providing geo-referenced data from the fishing vessels activity, can be explored to a high extent in support of scientific advice.

VMS is a tool used by Member States (MS) and already accepted by the industry for more than two decades. Since 2012, VMS is used with e-logbooks, in all vessels above 12 metres. The data generated by these systems can give a picture of the spatial distribution of the fishing activity in marine ecosystems, allowing the analysis of the fishers' behaviour and fleets dynamics. When coupled with catch reporting data in logbooks, they can give a proxy of fishing effort distribution and species abundance.

Despite the importance of both VMS and e-logbooks in terms of data collection, their potential is far from being explored to this purpose. There is a need to integrate and operationalize these systems in order to help shaping the toolbox of fisheries advice.

2. Needs on how to use FDD in a meaningful way for management

2.1 Existing data

FDD are retrieved for fisheries management purposes through data calls issued by the end users, such as DGMARE, the International Council for Exploration of the Sea (ICES), regional fisheries management organisations (RFMOs) and regional coordination groups (RCGs), comprising data on vessel activity and commercial catches gathered by the fishing industry and shared with the fisheries control agencies. ICES is the prime source of scientific advice on the marine ecosystem to governments and international regulatory bodies that manage the North Atlantic Ocean and adjacent seas, providing advice on fisheries issues to the EU and maintaining a large database on FDD. These data, containing detailed vessel movements and commercial information about catches for vessels over 12 metres in length, are provided in an anonymized format from national database systems of a high number of countries. As they are considered confidential data, they are used in an aggregate manner and are not publicly accessible under the general ICES Data Policy. DG MARE is responsible for launching the data calls of the Mediterranean and the Black Sea and fisheries dependent information (FDI), among others, for EU Member States.

These systems generate big data streams. To organise this information, a new governance for marine data is required. There is a need to document data gaps by area and vessel type, in order to estimate the likely level of under-reporting of fishing effort. There is also the need to have standardization on how data are collected and harmonisation of procedures across MS, as well as on new methods to handle these

data. The Quality Assurance Framework in Member States' DCF Work Plans and Annual Reports provides relevant information of the work done at national level. ICES implemented procedures and methods for quality control and assurance of data. For VMS data this is the Working Group on Spatial Fisheries Data Governance (WGSFDGOV) and for catch data the Working Group on Governance of the Regional Database & Estimation System (WGRDBESGOV). ICES also explores the development of new tools, e.g. in the Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD) and other groups under the Data Science and Technology Steering Group (DSTSG[1]).

2.2 Extra data needs

2.2.1 Small scale vessels data

VMS is currently operating in vessels with overall length of 12 metres or more. However, vessels between 12 and 15 metres may be exempted of this obligation either if they operate exclusively within the territorial seas of the flag MS or never spend more than 24 hours at sea from the time of departure to the return to port. This universe comprises the vast majority of the deep-sea fishing fleets and a significant percentage of the units in the coastal fleets but does not cover small-scale fleets. However, the increased computing power of handheld devices facilitates their expansion to small vessels involved in local fisheries. In some MS, examples of this expansion have been implemented in small vessels from coastal fleets that are now collecting their own data. This is the case of the Portuguese bivalve dredge fleet where high spatio-temporal resolution data are collected through real-time GPS tracking devices installed on fishing vessels. This allows to identify the main bivalve fishing grounds, assess the spatio-temporal distribution of the fishing effort, and contributes to the sustainable management of the fishery.

(https://play.google.com/store/apps/details?id=pt.ipma.bivalvesipma).

2.2.2 Resolution of spatial data to the fishing haul

Although the combination of VMS data, logbooks and landings data is quite insightful and is widely used for fisheries research and fisheries management purposes,

[1] https://www.ices.dk/community/groups/Pages/DSTSG.aspx

including modelling, its usefulness in ecosystem-based fisheries management depends on data quality. In what concerns VMS, data quality depends on the frequency of the registers regarding the vessel position during the fishing activities. Until 2004, VMS data were received with a resolution of one point every 10 minutes; however, due to the high costs of communications, EC regulations set a minimum rate of transmission of only one position every two hours, whenever the monitoring centre has the ability to control the actual vessel position (EC, 2003). The analysis of geo-referenced data from 2 to 2 hours, while allowing the identification of fishing trips, undermines the spatial definition of the fishing events, and thus the estimation of the effective fishing effort and its spatial component. Increase in transmission rate from 2 to 1 hour was proposed by the Commission in the Revision of the EU Fisheries Control System and presently, different VMS rates of transmission are in place, including 30 min in fishing restricted areas (cf. Art 50 (3) Control Regulation. However, independent of the transmission rate, these data can be recorded at a high frequency, allowing their use for a better definition of the fishing operations within each trip. On the other hand, logbook data and sales notes are produced once each fishing trip; e-logbooks, that must be completed and transmitted on a daily basis, are required to provide georeferenced information at haul level regarding setting and hauling operations, soak time, and gear attributes such as gear length, mesh size or hook size, along with catches and main discards, allowing the definition of métiers. However, as they are manually filled, in practice this is not observed in many situations, in particular in mixed fisheries, where many species are captured simultaneously and the same vessel can operate different gears. In order to take the next step towards true EBFM, fisheries data collection will need to innovate and increase its resolution to the fishing haul. Innovative data collection should record the geographical details of the fishing track and the associated composition of the catch. The challenge remains in interconnecting VMS and e- logbooks, making them interoperable, and expand their use in SSF. Several MS are already exploring this interoperability for fisheries control purposes.

2.2.3 Increase the reporting capacity of the CME

The reporting capacity of the VMS Continuous Monitoring Equipment (CME) can be enhanced by developing and testing solutions to enable CME data transmission modules through alternative communications systems to the satellite, lowering transmission costs. Due to the specific requirements of geolocation and data

transmission of the CME, but also, to its supervisory nature and inviolability mechanisms, the CME can also be developed towards an integrated technological system to gather information about fishing operations in real time. It can be developed to be used in combination with remote electronic monitoring, including CCTVs, and with multiple sensors collecting data on human activities and environmental parameters, complementing and communicating with each other, improved with innovative technological solutions such as machine learning and artificial intelligence, transforming fishing boats into platforms for collecting fisheries data as well as data on the observation of the marine environment.

Vistools is a Belgian project where all instruments on board that produce data are connected to a data concentrator that uploads the data real-time to the cloud. As such, detailed fish tracks and landings data at haul level are made available to the fisheries institute to be used in modelling exercises supporting the development of an EBFM. One vessel has been fully operational for over two years, in the summer of 2022 four vessels have been made operational.

Considering, on the one hand, the effort currently expended in on-board sampling, both in human and financial terms, and the limitations to have observers in smaller vessels, for instance in the multi-gear coastal fleet, it is of great interest to invest in the development of new technologies, including remote electronic monitoring, aimed at automatic monitoring of fishing activities.

2.2.4 Increase the number of fisheries- dependent datasets

In addition to the landings data as recorded today, discards of commercial and non-commercial species need to be recorded as well. As such, mortality and fisheries impact can be allocated to habitats and marine communities in high resolution. The technology to obtain these data, including remote electronic monitoring, is available or is being developed and should be also considered as a priority. Fishing tracks are recorded routinely and for the analysis of fisheries catches, self-sampling and image analysis technology is innovating in a way to be applicable in the near future. As these data, however, are quite sensitive in the fishing industry, sufficient attention should be given to stakeholders involvement and potential benefits for the fishery of this data collection.

2.2.5 Alternative applications of fisheries-dependent data – Development of software tools in support of spatial fisheries management

Several tools have been developed for the exploration and visualization of spatial information on fisheries, including maps of fishing intensity, landings, catch rates and environmental characterization. They use vessel position, speed and course data from VMS/AIS, combined with catch data (sales and logbook records), to estimate and map fishing effort and catch rates. Fishing Trips and Trawl Hauls identification routines are also developed and the identification procedure automated through the inclusion of artificial intelligent algorithms. Fishing trip landings and logbook catch records are used as a proxy of catch, and when crossed with fishing effort allow the calculation of catch rates (catch per unit effort, CPUE), by region or fishing ground.

GeoCrust software, a pioneering application developed to map fishing effort and CPUE information for the Portuguese crustacean trawl fleet, operating off the Portuguese coast. The data available for this study included GPS vessels' geographical positions and speed, transmitted via satellite to the Portuguese fisheries inspection authorities, and their catch reported to the Portuguese Directorate-General of Fisheries. The application includes several modules allowing to map and edit the original VMS data for a single vessel or group of vessels, for different periods of time; to define fishing grounds; to identify and define the trawl hauls; to issue maps of fishing effort and CPUE; to recreate the activity of a single vessel, group of vessels or the total fleet, for a fixed period of time, among others.

VMStools is a package of open-source software, built using the freeware environment R, specifically developed for the processing, analysis and visualisation of landings (logbooks) and vessel location data (VMS) from commercial fisheries. Embedded functionality handles erroneous data point detection and removal, métier identification through the use of clustering techniques, linking logbook and VMS data together in order to distinguish fishing from other activities, provide high-resolution maps of both fishing effort and landings.

VMSbase is an R package devised to manage, process and visualize information about fishing vessels' activity provided by the VMS, and catches/landings, as reported in the logbooks. *VMSbase* is primarily conceived to be user-friendly; to this end, a suite

of state-of-the-art analyses is accessible via a graphical interface. In addition, the package uses a database platform allowing large datasets to be stored, managed and processed very efficiently. Methodologies include data cleaning, and data enhancing, that is interpolation and merging with external data sources. Standard analyses comprise: 1) métier identification; 2) linkage between VMS and Logbook records, with the former organized into fishing trips; 3) discrimination between steaming and fishing points; 4) computation of spatial effort with respect to user-selected grids; 5) calculation of standard fishing effort indicators.

3. From real-time monitoring to (near) real-time advice

ICES advice provides catch limits (TACs and quotas) for a high number of stocks shared between ICES countries. However, the general time frame of scientific advice and resulting management actions does not generally comply with management needs of real-time advice. This has generally been a lengthy process and typically there is a two-year time lag between fisheries observations and management actions. This is problematic, particularly for short-lived species.

Today, it is possible to integrate these fishery-dependent data sources, in the generation of real-time advice. With increasing capacity for “big data” storage, sharing, and analysis, the conditions are now being created to implement dynamic, decentralized advice, adaptive, operating at a much finer spatial and temporal scale; increasing participatory decision-making.

Presently, real-time advice is already used to avoid regions of high juvenile or sensitive species bycatch, e.g., in the North Atlantic region (Iceland, Norway, EU), through real-time closures. A further step has been taken with “Real-time incentives” (RTI), a novel management concept capable of responding to species distributions, and biological and ecological knowledge. RTI can operate at a much finer spatial and temporal scale than traditional management approaches, and can be updated in close to real-time (e.g. weekly), through harnessing modern satellite and digital technology. This system, under development, can in the future partially replace or complement traditional management measures such as catch/landing quotas and effort limitations.

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