THE "FISHING PRESSURE" COMPONENT IN SUPPORT OF THE IOTC ECOSYSTEM REPORT CARD

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SUMMARY

In support of the development of the IOTC ecosystem report card, this paper addresses the "fishing pressure" component and how it cans contribute towards implementing the Ecosystem Approach of Fishery Management (EAFM). At first we illustrate what are main principles of the EAFM and what the fishing pressure component means within the context of the EAFM implementation. We also make a proposal of a conceptual and an operational objective which to be used to measure progress towards management of this component. Then we give briefed information about Current status of Tuna and Tuna like species stocks in IOTC area of competence and propose candidate fishing pressure related indicators that could be estimated to monitor this component. We selected fleet capacity, fishing effort, fishing activity intensity per area and time and other proxies of fishing pressure, as broad indicator types and describe the types of attributes they measure. We also highlight data limitation and current impediments hindering indicator development; on-going projects and efforts that may address some of these challenges. Finally, we prepare a draft work plan to guide our future work with focus on long term strategies. We invite the IOTC contracting parties, none contracting cooperating parties, related communities and the others to contribute towards the development of the IOTC ecosystem report card.

KEYWORDS

Ecosystem approach to fisheries management, EAFM, Fishing pressure component, Fishing pressure indicators, IOTC,

Introduction

For the past twenty five years, approaches to fisheries management have been slowly evolving. It is now widely recognized that for the effective management of a fishery, it is not enough to consider only targeted species in isolation of their environment and other influences. An ecosystem approach to fisheries management (EAFM) offers a far greater chance of developing realistic, equitable and sustainable management plans that cover the broader impacts of fisheries on the ecosystem. This approach pursues sustainability by balancing ecological and human well-being through good governance. (FAO, 2003 and Link, J.S., 2002).

EAFM is a more holistic approach to management that represents a move away from fisheries management systems that focus only on the sustainable harvest of target species, towards systems and decision-making processes that balance ecological well-being with human and societal well-being, within improved governance frameworks i.e. it is a practical way to achieve sustainable development. It addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems. (Garcia *et al*., 2003).

EAFM is a practical way to implement sustainable development principles for the management of fisheries by finding a balance between ecological and human well-being through good governance. On this way sustainable development can be summarized as a balance between ecological well-being and human well-being that does not compromise the needs of future generations.

The main principles of the EAFM can be summarised as follows:

1- *Good Governance:* Is includes mechanisms, processes and institutions through which groups (institution and arrangements) voice their interests, mediate differences, exercise their legal rights and meet their obligations.
2- *Appropriate scale:* It takes into account connections within and across ecosystem and social system (these connections can be place-base; across different environment: land –air –s; and across scales, i.e. district/regional/national/international).
3- *Increased participation:* Cooperation of key stakeholders.
4- *Management multiple objectives:* Balancing societal trade-offs entails working across scales and with different stakeholder objectives; the aim is to develop objectives which address multiple challenges/concerns).
5- *Cooperation and coordination:* Both vertically across different levels of government and society and horizontally across agencies and sectors.
6- *Adaptive management:* Embracing change through learning and adapting. The key is to have flexible system and processes, including feedback loops that allow for learning through doing.
7- *Precautionary approach:* Using the approach when uncertainty exists.

The Indian Ocean Tuna Commission (IOTC), Working Party's on Ecosystem and By-catch (WPEB) Program of Work (2013-2019) includes the development of an indicator-based ecosystem report card and assessments for the IOTC area of competence. The main purpose of the IOTC ecosystem report card is, to improve the link between ecosystem science and fisheries management to support the implementation of the EAFM in the IOTC area of competence. Potentially, the ecosystem report card could be used as a communication tool to increase the awareness and reporting of the main pressures on IOTC species and the state of species and associated ecosystem components to the Commission, since it can be used to synthesize large and often complex amount of information into a succinct and visual product. (Juan-Jordá, M.J., Murua, H. & Andonegi, E. 2018). Ultimately the ecosystem report card aims to report on the relevant pressures affecting the state of the pelagic ecosystem, and report on the ecological state of the pelagic ecosystem interacting with IOTC fisheries.

Developing an indicator-based ecosystem report card requires a long-term strategy to build ecosystem knowledge and increase capacity and collaborations in the IOTC community. As a first step, the WPEB14 drafted a work plan to support the development of an indicator-based ecosystem report card for the IOTC area of competence (IOTC–WPEB14

2018). The work plan included a reporting framework to monitor the full range of interactions between IOTC fisheries and the different components of the pelagic ecosystem, and it also identified a Team of Ecosystem Assessors to be in charge of developing ecosystem indicators and indicator-based assessments to inform the IOTC ecosystem report card.

In support of the development of the IOTC ecosystem report card, this paper addresses the “fishing pressure” component and specifically it contributes towards developing the following elements:

1. It describes what this component means and the potential risks that may arise if this component was not monitored. It also makes a proposal of a conceptual and an operational objective to monitor changes in the spatial-temporal patterns of fishing pressure exerted by IOTC fisheries on several components of the ecosystem and in order to measure progress towards management of these components.
2. It summarizes the current status of tuna and tuna like species stocks in IOTC area of competence.
3. It proposes a candidate list of pressure indicators to better monitor the actual fishing pressure exerted by IOTC fisheries on the ecosystem and its components.
4. It highlights the current challenges and data gaps hind the development of fishing pressure indicators.
5. It drafts a work plan to guide our future work with focus on IOTC long term strategies.

The “Fishing Pressure” Component and Potential Indicators

Indicators are defined as variables, pointers or indices of a phenomenon and are widely used for environmental reporting, research and management support. In the context of an EAF, the ways in which groups of indicators are selected for different purposes can be generalized by considering an ecosystem (or more realistically a spatial management unit) with components and attributes. For reporting and research, indicators are usually chosen to provide good coverage of the components and attributes, where components are defined as functional or species groups and attributes as properties of the components. ‘Good coverage’ is usually achieved by selecting components and attributes that are considered to be representative of the ecosystem, as knowledge and resources will always be too limited to achieve comprehensive coverage. Several indicators may be needed to track the state of one component and attribute or one indicator may track the state of several components and attributes.

In order to implementation an EAFM successfully, it is not only necessary to have suit indicators to describe and monitor the “state” of the various ecosystem components in the IOTC ecosystem report card, but also it is critical to have some indicators to monitor and describe changes in the overall fishing pressure exerted by IOTC fisheries, to address the impact of fishing pressure on the state of the various ecosystem components. Only by adequate covering both types of indicators, pressure and state indicators, we will be able to examine the mechanistic links between "cause" and "effect" to provide the advice required. Therefore, the overall extent of fishing pressure and the associated spatial-temporal patterns of fishing as an anthropogenic activity need to be monitored in order to draw sounds conclusions regarding the impacts of fishing on different components of the ecosystems as well as inform management strategies to minimize and avoid impacts. It is also essential to consider the temporal and spatial extent and patchiness of the fishing activity, as well as to have information about the consistency with which areas are fished in the same regions from year to year. Not taking into account the spatial-temporal patterns of fishing activity limits the potential of informing and defining plans to minimize regional impacts of fishing on main target species, as well as protect vulnerable taxa (e.g. avoid localized depletions).

In order to measure progress towards addressing the "fishing pressure" component within the IOTC ecosystem report card, we proposed the following conceptual and operational objectives.

Conceptual Objectives: "Ensure that IOTC monitors the changes in the spatial-temporal patterns of fishing pressure that affect the state of the different components of the ecosystem from species to communities to food webs".

Operational Objectives: "Determine if overall fishing pressure is increasing over time"

Current Status of Tuna and Tuna like Stocks in IOTC Area of Competence

According to 21st IOTC Scientific Committee report in 2018, current status of Tuna and tuna like species in IOTC area of competence are as below:

1- Albacore (*Thunnus alalunga)*: Albacore catches have increased substantially since 2007 for fleets. The fish catches were marginally below the MSY level in 2017. According to the IOTC reports the amount of Albacore catch has been 38374 t in 2017 while the amount of catch has been 36004 t in average, during 2013-2017 and MSY was calculated about 38.8 t (33.9-43.6t). Based on SS3 model analysis aggregated Indian Ocean assessment Kobe plot, Albacore stock's statues evaluated in green area and the stock status in relation to B_{MSY} and F_{MSY} target reference points indicates that the stocks are not overfished and not subject to overfishing. Albacore tuna are currently caught almost exclusively using drifting long liners, with the remaining catches recorded using purse seines and other gears. Catches from the long line fisheries are split between deep-freezing long liners, and fresh-tuna long liners. The majority of Albacore catches are attributed to vessels flagged to distant water fishing nations (i.e., Taiwan, China and Japan), followed by coastal countries such as Indonesia and Malaysia.

2-Bigeye tuna (*Thunnus obesus*): The amount of Bigeye catch has been 90050t in 2017 while the amount of its average catch has been 95997t during 2013-2017 and it remains below the estimated MSY about 104(87-121). According to SS3 model analysis aggregated

Indian Ocean assessment Kobe plot, Bigeye stock's statues evaluated in green area and the fish stock status in relation to B_{MSY} and F_{MSY} target reference points indicates that on the weight-of-evidence available in 2018, the stock is determined to be not overfished and is not subject to overfishing. Bigeye tuna currently caught mainly with long line, Purse seine and other artisanal gears and Indonesia, Taiwan, China, European Union, are main attributed countries.

3- Skipjack tuna (*Katsuwonus pelamis*): The amount of Skipjack tuna catch has been 524282t in 2017 while the amount of average catch has been 454103t during 2013-2017. Over the history of the fishery, biomass has been well above and the fishing mortality has been well below the established limit reference points. On the weight-of-evidence available in 2017, the skipjack tuna stock is determined to be not overfished and is not subject to overfishing and the stock statues evaluated in green area. Skipjack tuna currently caught mainly with Purse seine, Gill net, Pole and line fishing gears and Indonesia, European Union, Maldives, Sri Lanka, Seychelles and I.R.Iran are main attributed countries.

4- Yellowfin tuna (*Thunnus albacares*): In 2018 a new stock assessment was carried out for yellowfin tuna in the IOTC area of competence. The amount of yellowfin tuna catch has been 409567t in 2017 while the amount of average catch has been 399830t during 2013-2017, which is remains below the estimated MSY about 403(339-436t). According to the fish stock assessment results, the total catch has remained relatively stable at levels of the estimated MSY since 2012 (between 390,000 t and 410,000 t). However, it is noted that the quantified uncertainty in stock status is likely underestimating the underlying uncertainty of the assessment. On the weight-of-evidence available in 2018, the yellowfin tuna stock is determined to remain overfished and subject to overfishing and the stock statues evaluated in red area. Yellowfin tuna currently caught mainly with Purse seine, Longline and Gill net, fishing gears and European Union, Maldives, I.R.Iran, Seychelles and Sri Lanka, are main attributed countries.

5-Bullet tuna (*Auxis rochei*): No quantitative stock assessment is currently available for bullet tuna in the Indian Ocean, and due to a lack of fishery data for several gears, only preliminary stock status indicators can be used. Stock status in relation to the Commission's B_{MSY} and F_{MSY} reference points remains unknown. Total annual catches for bullet tuna over the past six years have fluctuated but remained around 10,000 t. The amount of catch has been 11094t in 2017 and average catch has been 9959t during 2013-2017. Bullet tuna is mainly caught using gillnets hand lines and trolling. This species is also an important catch for coastal purse seiners. Over 90% of catches have been accounted by fisheries in Sri Lanka, Indonesia and India in the Indian Ocean during 2013-2017.

6-Frigate tuna (*Auxis thazard*): No quantitative stock assessment is currently available for Frigate tuna in the Indian Ocean and due to lack of fishery data for different type of gears; only preliminary stock status indicators can be used. Stock status in relation to the Commission's B_{MSY} and F_{MSY} reference points remains unknown. Total annual catches for frigate tuna have increased substantially in recent years with peak catches taken in 2010

(~100,000 t) which have been maintained at that level until 2014 after which they declined to <80,000 t. The amount of catch has been 74886t in 2017 and average catch has been 86157t during 2013-2017. Frigate tuna is mainly caught by using gillnets, coastal long line and trolling, hand lines and trolling and to a lesser extent coastal purse seiners. The species is also a bycatch for industrial purse seine vessels. Indonesia accounts for around two-thirds of catches, while over 90% of catches are accounted for by four countries Indonesia, India, Sri Lanka and I.R. Iran.

7-kawakawa (*Euthynnus affinis*): A stock assessment was not undertaken for kawakawa in 2017 and the status is determined on the basis of the 2015 assessment, which used catch data from 1950 to 2013. Analysis using an Optimised Catch Only Method (OCOM) approach in 2015 indicates that the stock is near optimal levels of F_{MSY} and stock biomass is near the level that would produce B_{MSY}. Total catch of Kawakawa have been 159881t in 2017, also the average catch have been 157326t during 2013-2017, while MSY has been 152t (125-188t). Based on the weight-of-evidence available, the kawakawa stock is classified as not overfished and not subject to overfishing in the Indian Ocean and the stock statues evaluated in green area. Kawakawa are caught mainly by gillnets, hand lines and trolling, coastal purse seiners, and may also be an important by catch of the industrial purse seiners. Also Indonesia, India, and I.R. Iran account for over two thirds of catches in 2013-02017.

8-longtail tuna (*Thunnus tonggol*): Analysis using the Optimised Catch-Only Method (OCOM) indicates that the stock is being exploited at a rate that exceeded F_{MSY} in recent years and the stock appears to be below B_{MSY} and above F_{MSY} (67% of plausible models runs). Catches were above MSY between 2010 and 2014; however catches have decreased between 2012 and 2016 from ~175,000 to ~128,000t and were below estimated MSY in 2017. The amount of catch has been 135006t in 2017. Also average catch has been 139856t while MSY have been 140t (103-184). Based on the weight-of-evidence currently available, the stock is considered to be both overfished and subject to overfishing and the stock statues evaluated in red area**.** Main fishing gear of Long tail tuna are gillnets and, to a lesser extent, coastal purse seine nets and trolling. Also I.R. Iran, followed by Indonesia and Oman are main fleets which are account for two thirds of the catches in 2013-02017.

9-Indo-Pacific king mackerel (*Scomberomorus guttatus*): A preliminary assessment was undertaken for Indo-Pacific king mackerel using catch-only methods techniques (Catch-MSY and OCOM) in 2016. According to 2017 information the amount of the fish catch has been 49905t while the average catch has been 46814t during 2013-2017. There is no new assessment was undertaken in 2017, but WPNT considered that stock status in relation to the Commission's B_{MSY} and F_{MSY} target reference points remains unknown. Indo-Pacific King mackerel are caught mainly by gillnets, however significant numbers are also caught by trolling. Almost two-thirds of catches are accounted for by fisheries in India and Indonesia; with important catches also reported by I.R. Iran.

10-Narrow-barred Spanish mackerel (*Scomberomorus commerson*): Analysis using the Optimised Catch-Only Method (OCOM) indicates that the stock is being exploited at a rate exceeding F_{MSY} in recent years, and the stock appears to be below B_{MSY}. Based on IOTC report the amount of the fish catch has been 159370t in 2017 with average catch 160812t during 2013-2017 while the MSY has calculated 131t (96-180). Based on the weight-of-evidence available, the stock appears to be overfished and subject to overfishing and the stock statues evaluated in red area. Narrow-barred Spanish mackerel are caught mainly by using gillnet, however significant numbers are also caught using troll lines by artisanal and sports/recreational fisheries. Fisheries in Indonesia, India, and I.R. Iran account for around two-thirds of catches.

11-Swordfish (*Xiphias gladius*): In 2017 a stock synthesis assessment was conducted, with fisheries catch data up to 2015. The assessment uses a spatially disaggregated, sex explicit and age structured model. The SS3 model, used for stock status advice, indicated that MSY-based reference points were not exceeded for the Indian Ocean population. Most other models applied to swordfish also indicated that the stock was above a biomass level that would produce MSY. Based on IOTC report the amount of Swordfish has been 34782t. Also average catch has been 31405t while calculated MSY has been 31590 (26300-45500t) in 2017. On the weight-of-evidence available in 2018, the stock is determined to be not overfished and not subject to overfishing and the stock statues evaluated in green area. Swordfish is caught mainly by using Long liners and Taiwan, China, Sri Lanka, EU, Spain and Indonesia are main fleets which are caught 60% of the fish in Indian Ocean.

12- Black marlin (*Makaira indica*): A stock assessment based on JABBA was conducted in 2018 for black marlin. This assessment suggests that the point estimate for the stock in 2017 is in the green zone in the Kobe plot. The Kobe plot from the JABBA model indicated that the stock is not subject to overfishing and is currently not overfished. However these status estimates are subject to a high degree of uncertainty. The recent sharp increases are seen from 15,000 t in 2014 to over 20,000t since 2016. According to IOTC report around 21250t of Black Marlin is caught in 2017. Also average catch has been 18673t during 2013-2017, while MSY is calculated 12930t (9440-18200t). In conclusion, the result of the Black Marlin assessment is unclear and should be interpreted with caution. The fish is caught mainly as a non-target species in industrial and artisanal. Black Marlin is largely considered to be a non-target species of industrial and artisanal fisheries. Gillnets, followed by long lines account for around two third of total catches in the Indian Ocean, with remaining catches recorded under troll and hand lines. According to average catch 2013-2017 I.R.Iran, Sri Lanka and Indonesia are main fleets in catch of Black Marlin.

13- Blue marlin (*Makaira nigricans*): Based on stock assessment results which carried out in 2016, the fish stock status is located close to MSY in orange zoon. According to IOTC report, the amount of Blue Marlin catch recorded 12155t in 2017. Average catch has been 11635t during 2013-2017, while MSY is calculated 11930t (9230-16150t) during the years. The results of the assessment in 2016 indicated that the stock was subject to overfishing but not overfished in 2015 and the stock statues evaluated in orange area. Blue Marlin is largely considered to be none target species of industrial and artisanal fisheries. Long line catches account for more than two third of total catches in the Indian Ocean, followed by gillnets, with remaining catches recorded under troll and hand lines. Taiwan, China long line, Pakistan, I.R. Iran and Sri Lanka gillnets and Indonesia long line considered as a main fleet for Blue Marin catch.

14-Striped marlin (*Tetrapturus audax*): A new stock assessment for striped marlin was carried out in 2018. The results indicate that the stock is subject to overfishing ($F>F_{MSY}$) and overfished. Also the biomass have been below the level which would produce MSY ($B<B_{MSY}$) for at least the past ten years. Based on IOTC report the amount of striped Marlin catch has been 3082t in 2017. The average catch has been 3587t during 2013-2017, while the MSY has been 4730t (4270-5180) during the years. On the weight-of-evidence available in 2018, the stock status of striped marlin is determined to be overfished and subject to overfishing stock's statues evaluated in red area. Striped marlin is largely considered to be a non-target species of industrial fisheries. Loglines are account for around two third of total catches in the Indian Ocean with remaining catches recorded gillnets and troll and hand lines. Taiwan, China and Indonesia drifting long lines and I.R Iran and Pakistan gillnet are main fleets for Blue Marlin Catch.

15- Indo-Pacific sailfish (*Istiophorus platypterus*): The stock status is determined on the basis of the 2015 assessment and other indicators presented in 2018. In 2015, data poor methods for stock assessment using Stock Reduction Analysis (SRA) techniques indicated that the stock is not yet overfished, but is subject to overfishing. The stock appears to show a continued increase catches which is a cause of concern, indicating that fishing mortality levels may be becoming too high. Based on IOTC report the amount of Indo Pacific sailfish catch has been 33280t. Also the average catch has been 29873t during 2013-2017, while the MSY is calculated 25000t (16180-35170t) during years. On the weight-of-evidence available in 2018, the stock is determined to be still not overfished but subject to overfishing and the stock statues evaluated in orange area. Gillnets account for around two third of total catches in the Indian Ocean, followed by troll and hand lines , with remaining catches recorded as long lines and other gears catch's. Three quarters of the Indo-Pacific sailfish total catches, are accounted for by four countries including I.R. Iran (gillnets); India (gillnets and trolling), Pakistan (gillnets) and Sri Lanka (gillnets and fresh long line).

In conclusion according to latest IOTC stock assessment results five species stock's are determined to be not overfished and not subject to overfishing and stay in green zoon, four species assessment results are unclear with high degree of uncertainty and stay in grey zoon, so they should be interpreted with caution, two species stocks are determined to be still not overfished but subject to overfishing and stay in orange zoon and four species are determined to be overfished and subject to overfishing (Table 1).

Table 1- The statues of different species stock's in IOTC area of competence

Color Key	Stock overfished ($B_{year}/B_{MSY} < 1$)	Stock not overfished ($B_{year}/B_{MSY} \geq 1$)
Stock subject to over fishing ($F_{year}/F_{MSY} > 1$)	- yellowfin tuna (*Thunnus albacares*) - longtail tuna (*Thunnus tonggol*) - Narrow-barred Spanish mackerel (*Scomberomorus commerson*) - Striped marlin (*Tetrapturus audax*)	- Blue marlin (*Makaira nigricans*): - Indo-Pacific sailfish (*Istiophorus platypterus*)
Stock not subject to overfishing ($F_{year}/F_{MSY} \leq 1$)		- Albacore (*Thunnus alalunga)* - Bigeye tuna (*Thunnus obesus*) -Skipjack tuna (*Katsuwonus pelamis*) - kawakawa (*Euthynnus affinis*) - Swordfish (*Xiphias gladius*)
Not assessed/Uncertain	- Bullet tuna (*Auxis rochei*) - Frigate tuna (*Auxis thazard*) - Indo-Pacific king mackerel (*Scomberomorus guttatus*) - Black marlin (*Makaira indica*)	

Candidate indicators to monitor "fishing pressure" component, data availability and challenges

Indicators are needed to support the implementation of an ecosystem approach to fisheries (EAF), by providing information on the pressures on and the state of the ecosystem, including the monitoring of the, extent and intensity of effort or mortality and the progress of management in relation to objectives. This paper reviews recent work on the development, selection and application of fishing pressure indicators and consider how these indicators might support an EAFM implementations. Indicators should guide the management of fishing activities that have led to, or are most likely to lead to, unsustainable impacts on ecosystem components or attributes. The numbers and types of indicators used to support an EAF will vary among management regions, depending on resources available for monitoring and enforcement and actual and potential fishing impacts. State indicators provide feedback on the state of ecosystem components or attributes and the extent to which management objectives, which usually relate to state, are met. State can only be managed if the relationships with fishing (pressure) and management (response) are known. Predicting such relationships is fundamental to developing a management system that supports the achievement of objectives. In a management framework supported by pressure, state and response indicators, the relationship between the value of an indicator and a target or limit reference point, reference trajectory or direction provides guidance on the management action to take. Values of pressure, state and response indicators may be affected by measurement, process, model and estimation error and thus different indicators and the same indicators measured at different scales and in different ways, will detect true trends on different timescales. Managers can use several methods to estimate the effects of error on the probability of detecting true trends and/or to account for error when setting reference points, trajectories and directions. Given the high noise to signal ratio in many state indicators, pressure and response indicators would often guide short-term management decision making more effectively, with state indicators providing longer-term policy-focused feedback on the effects of management actions. (Simon Jennings, 2005).

Examples of pressure indicators are fleet size, fishing mortality, fishing effort, catch rates or discard rates. Pressure is influenced by a range of factors including those that are the subject of social and economic objectives. Examples of state indicators are species abundance and mean body size. Most indicator development has mostly focused on state (ICES 2003; Fulton et al. 2004a; Rogers and Greenaway 2005). This focus probably reflects the important link between objectives and indicators of state. However, pressure and response indicators are also essential to manage state and often have the desirable properties of ease of measurement and rapid response times. Examples of response indicators include most pressure indicators, expressed as rate of change, plus indicators of the capacity to support a response (e.g. capacity for decision support). The response indicator might measure management actions that mitigate, reduce, eliminate or compensate for the change in state. A response would usually affect the pressure (mitigation, regulation) but could directly modify state (rehabilitation) (Garcia et al. 2000).

In developing a management system it is essential that societal/political aspirations can be translated into operational objectives to achieve sustainability (often termed strategic goals) (Sainsbury et al. 2000). Setting management objectives for an EAF precedes and informs the selection of indicators. For example, to manage fishing impacts on fish populations requires that the relationship between fishing mortality (pressure) and fishing effort (pressure) is known, as well as the link between fishing mortality and abundance (state). It can also be difficult to define separate pressure and response indicators. Thus the proportion of an area impacted by trawling per unit time shows the pressure on a habitat, but also measures the response of management.

Multiple types of fishing pressure indicators have been identified developed and tested to better improving the estimation of the actual fishing pressure exerted on the ecosystem and its components. It is widely acknowledged that fishing mortality derived from fishery stock assessments is the most accurate measure and the preferred type of fishing pressure indicator, to describe fishing impact on a particular species, set of species or at the ecosystem level. However, fishing mortality derived from fishery stock assessments are only available for some IOTC species and ecosystem models have not been developed in the IOTC convention area in order to be able estimate overall or aggregated fishing mortality rates exerted by IOTC fisheries. Therefore the data limitations and shortage of stock assessments and ecosystem models forces us to use less informative indicators of fishing pressure including indicators of fishing capacity (e.g. number of vessels), indicators of fishing effort (e.g. number of days at sea) and indicators of frequency and intensity of fishing activity (e.g. number of fishing vessels in a given area and time) (Piet, G.J., Quirijns, F.J., Robinson, L. & Green street, S.P.R. 2007).

For the pressure component, it is planned to develop and test a set of complementing fishing pressure indicators to monitor the spatial temporal patterns of fishing pressure exerted by IOTC fisheries on the different ecosystem components. It is widely recognized that no single or type of indicators is able to provide a complete picture of the actual fishing pressure exerted by IOTC fisheries on the ecosystem. The complex nature of estimating fishing pressure and the dynamics of fisher´s behaviour demands to use a suite of complementary indicators to provide a complete picture of the fishing pressure. At the end, the suite of indicators chosen need to be able to monitor and highlight changes in the fishing pressure and help to diagnose the causes of those changes.

A snapshot of potential indicators is presented that could be estimated to capture and describe the changes in the spatial-temporal patterns of fishing pressure exerted by IOTC fisheries on several ecosystem components from species, to communities and food webs (Table2). A brief description is provided for each type of pressure indicator with a reference to the type of attribute it tries to capture and describe. A distinction is also made whether the indicator can be empirically estimated using the data regularly collected by IOTC member states, or whether it can also be derived from external sources.

The example indicators illustrated in Table 2 require different levels of data needs and information at different spatial and temporal scales. Most of them rely in the data collected by IOTC CPCs which is submitted to the Secretariat. In a nutshell, the development of pressure indicators rely on the catch data, fishing vessels statistics data and catch and effort data collected by CPCs and that it is submitted to the secretariat. The submission of annual catches (IOTC form I) for each species per fleet, gear and year (which includes retained catches and discards), the submission of fishing vessel statistics (IOTC form II) which refers to the number of vessels operated by fleet, type of vessel, size class, gear and year, and the submission of catch and effort data (IOTC form III) which refers to the fine scale data reported by fleet, year, gear, month, spatial grid and species), is mandatory for each IOTC CPC. However, the compliance by CPC is far from being completed and in most of the cases catch-and-effort data is not submitted for the complete fleet covering all the annual catches reported by CPC in form I (IOTC, 2017).

Table 2- Candidate fishing pressure indicators

Indicator Type and Attribute Measured	Indicator Examples	Potential Data Sources
Fleet Capacity	1-Number of active vessels for each major gear type operating in the IOTC area annually, 2-Type and size of vessels, 3-vessels GT,	IOTC databases
Fishing Effort	1-Number of hooks deployed by long-liners spatially and over time 2-Number of fishing sets by purse seiners (by fishing strategy) spatially and over time 3-Number of searching days by purse seiners spatially and over time 4-Total number of buoys used for tracking FADs in purse seine fisheries spatially and over time 5-Number of active days spatially for gill netters. 6-CPUE	IOTC databases
Fishing Activity, Intensity per Area/time	1-Total fishing activity as hours per square km by vessels with AIS or VMS systems. 2-Vessel track intensity measured with AIS or VMS systems.	IOTC databases Global fishing watch project
Fishing Mortality	1- Fishing mortality expressed as annual fishing catch. 2-Instantaneous fishing mortality rate (F) over time for IOTC species assessed with fishery stock assessments.	IOTC assessments
Other Proxies of Fishing Pressure	1-Total catch spatially and over time aggregated across all gears 2-Total catch and effort (and size) distribution spatially and over time for all gears 3-Biometric data including length frequency,	IOTC databases

IOTC maintains a dataset of nominal catch for each species per fleet, gear and year, and this information is disaggregated to major areas (East and West Indian Ocean). It does not maintain a database of geo-referenced catches by gear, fleet and time for the same IOTC species. Geo-referenced catches by major gear and fleet is only available for the major tuna species (4 species) and swordfish with time-area strata of 1x1 degrees or 5x5 degrees squares depending on the fleet. A more complete geo-referenced dataset for catches covering a wider range of species would allow monitoring and analysing total catches spatially and over time for at least the IOTC species within IOTC convention area.

IOTC also maintains a database of catch and effort distributed by time-area strata (month and 1x1 or 5x5 degree square), similar to the one maintained in ICCAT. However, ICCAT has also estimated the overall Atlantic long line and purse seine effort by time area strata (5x5 degrees squares and quarter) which IOTC has not. However, there is an on-going discussion about the adequacy of the scales used in the ICCAT dataset, which uses 5 degrees squares and months as the minimum spatial and temporal resolution, which may be too poor to inform some area-based management responses.

IOTC monitors the total number of active IOTC vessels operating in the convention area. It is believed that the number of vessels fishing for IOTC species in the Indian Ocean is known with more accuracy in the recent years. However, the vessel statistics are generally available only for industrial fleets whose catches are available, and vessels statistics are not available, are incomplete or inaccurate for many artisanal fleets (IOTC, 2017).

The recent expansion of the automatic identification system (AIS) presents an opportunity to monitor fishing activity at fine spatial-temporal scales to quantify the behaviour of global fishing fleets, including fleets targeting tuna and tuna-like species, down to the individual vessels (Kroodsman *et al.*, 2018). However, AIS is a mandatory requirements for the vessels which have more than 300 Gross tones, (McCauley & etal, 2016). Similarly, VMS systems have been implemented in IOTC vessels for many years for all commercial fishing vessels exceeding 24 meters length overall and for those smaller than 24 meters which are operating outside its EEZs (IOTC Resolution 15/03). But it is mostly a compliance tool and the data belong to the member countries, so it is not usually shared for scientific purposes at the IOTC scientific committee level. In fact, VMS has actually been implemented for much longer than AIS and could also be very useful for monitoring the spatial-temporal dynamics of fishing vessels. Practically combining the VMS and AIs could provide a better cover of fishing effort spatial distribution in the IOTC area of competence.

Recommendation for indicator developments and future work

In total 15 indicators were suggested towards monitoring the fishing pressure component. According to current condition, the data needed to support the development of the suggested indicators are available in IOTC database, but its quality and quantity are not sufficient and need more improvement. Also in order to implementation EAFM, biological and ecological data collection are as important as the collection of the fishing pressure data to give a complete picture of the main pressures on and the state of ecosystem in the IOTC area of competence. In order to develop an EAFM plan, IOTC need more capacity building among Indian Ocean Tuna Commission CPCs to collect accurate data.

Below we summarize some future steps planned to advance work towards monitoring the “fishing pressure component”, which we plan to update annually at the WPEB meetings. This is work in progress which requires the collaboration of multiple experts with experience on the multiple gears operating in the IOTC area of competence. We invite the IOTC community to contribute towards the development of the "fishing pressure component", to support the IOTC ecosystem report card. If interested, contact the corresponding authors to find out how you can contribute to this initiative.

Future steps

1-Develop a geo-referenced catch dataset and geo-referenced effort dataset for all IOTC species, gears and countries.
2-Determine the best unit of effort for each gear.
3-Develop complete catch-and-effort datasets by gear.
4-Develop a complete database for active IOTC vessels and its characteristics.
5-Develop an appropriate stock assessment analysis for a condition with low level data.
6-Explore the utility of AIS and VMS to monitor the spatial-temporal dynamics of IOTC fishing fleets.

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