



Acquisition of catch-and-effort and size data from sport fisheries in the Western Indian Ocean

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Executive summary

Gaps in information on sport fishing catches of IOTC species have long been an issue affecting comprehensive data collection in the Indian ocean. Some countries such as Mauritius and Kenya have reported data in the past, while for others, no data is reported, data are misreported or catches are known to be underestimated (e.g., Seychelles, La Réunion, Mozambique, Oman). In many cases, this is due to the non-mandatory nature of reporting of sport fishing catches, often exacerbated by lack of technical and physical resources to gather the data.

A project was therefore developed in response to recommendations from the IOTC Working Party on Billfish meeting 9, endorsed by the IOTC Scientific Committee, aimed at enhancing data recovery from sports and other recreational fisheries in the region and to facilitate the acquisition of catch, effort and size data from sport fisheries, by developing and disseminating reporting forms to Sport Fishing Centres in the region.

The pilot project involving four western Indian ocean countries commenced in August 2016, with the main objectives being to:

- Build technical capacity (data collection and reporting mechanisms) for National fisheries institutions in the context of sports/recreational fisheries,
- Strengthen IOTC's awareness of sport fisheries operations in the Western Indian Ocean, and
- Improve management of IOTC species in the Indian Ocean.

Four pilot countries were selected: Kenya, Seychelles, La Réunion and Mauritius. Each was visited by consultants (JP and NK) in October/November 2016 in order to describe and document sport fishing activities, consider relevant historic data, and determine how better data might be collected from the sector in future.

Prior to the country visits, an extensive review of a wide range of methods used for gathering catch, effort and size data from sport fisheries in many jurisdictions around the world was undertaken. These were considered during country visits in relation to likely available resources and constraints for application of specific methodologies.

Country visits

Kenya has a particularly long history of mainly charter boat sport fishing. Currently there are an estimated 40 charter boats operating along the coast, and smaller numbers of private boats. All boats are required to hold licences of various forms. Clubs and charter operators have voluntarily reported catch data for many years, which has been regularly reported by the Kenyan Association of Sea Anglers (KASA). The Kenyan Fisheries Department has digitized this data from 1989 to 2011 and produced reports to IOTC analysing these data for different species groups (tuna, mackerel, billfish). Those data were reported to IOTC, but not necessarily as sport fishing. Reporting ceased after 2010. The Kenyan-based African Billfish Foundation issues conventional tags to fishers for tag and release of billfish. Currently, there are more than 55,000 tag records in that database, mostly for sailfish and marlin (three species) released in Kenyan waters.

The Seychelles also has a very active sportfish charter fishery that caters to tourist fishing, including the high international end of the market. It is estimated that about 40 charter boats operate on a full time basis, and that there are at least a further 50 privately own vessels capable of targeting IOTC species. There is one relatively large, active sport fishing club on Mahe that participates in an international billfish tagging program. The Ministry of Tourism licences sport fishing boats. The Seychelles Fishing Authority collects some size data from club competitions, but has recently implemented a licence frame survey of all fishing sectors including the offshore pelagic sector that may provide a basis for a general data collection system.

La Réunion has a very active sport fishing charter industry based primarily in Saint-Gilles-les-Bains, but also other ports. It was estimated that about 40 charter boats are active on the island, although that number may be considerably higher. Because they may sell their catch, sport fishing charter operators on La Réunion are classified as professional operators and hold European commercial fishing licences. They are required to complete daily logs that are submitted monthly. Such data are reported to IOTC but as Handline/Troll, not sport fishing. IFREMER has analysed 12 years of self-collected catch and effort data from competitions held by one fishing club on the island (CRPPS). There are many hundreds of private (non-professional) boats on La Réunion capable of fishing for IOTC species. Catches by this sector have not been estimated. A single 'snapshot' survey of private boat owners is recommended, which would provide order of magnitude data for this sector over a 12 month period.

Mauritius has a strong international reputation as a centre for offshore sport fishing, especially for billfish. There are an estimated 40 active sport fishing charter vessels on Mauritius, with some companies operating up to three vessels each. The number of private sport fishing vessels fishing for IOTC species was estimated at 50-60. Le Morne Anglers Club is the largest recreational fishing club on the island, catering for 350 members and operating several annual game fishing tournaments. All sport fishing boats must hold a licence from the Tourist Authority. Charter operators may sell fish. The Fisheries Department collected sport fishing data between 2007 to 2011 but this ended due to lack of resources.

Following the country visits, two preferred methods were identified: An electronic logbook to be used by the sport fishing charter sectors, and a snapshot survey of owners of private vessels covering a 12 month period. The project focused primarily on the design of the new logbook.

Electronic logbook

The logbook was designed in conjunction with the database manager of IOTC. It is a macro-enabled Microsoft Excel file (.xlsm), meaning there are automated functions embedded within the file that assist the user in completing data entry. Entries are made for each fishing trip (day or part thereof) and the file is submitted to a National Fisheries officer each month, where the data are extracted and stored in a secure Microsoft Access database for each country. Data entry is performed by key strokes, or by selecting from pre-defined responses in drop-down menus. The logbook has undergone extensive testing on both Mac and PC platforms using Windows XP, 7 and 10.

A detailed manual has been written for ease of use of the logbook. At each step the manual provides a screen shot and an explanation of options for completing each field. The logbook may also be completed in paper form, in which case, National Fisheries officers would transfer the data

to the electronic form. Data for each fisher is compiled, error checked and exported to the National Sport fishing database.

Training

Training modules were designed for in-country presentation to both National Fisheries personnel and sport fishing charter operators. For National Fisheries personnel, the training modules outline the background to, aims and purpose of the project, the electronic logbook and how data are compiled and exported from the logbook to National Fisheries Access databases, and ultimately submitted to the IOTC. For sport fishing charter operators, the training modules also outline the background to, aims and purpose of the project and step-by-step details of how to complete the log sheets and submit at the end of each month.

Work was still in progress on the training part of the project just prior to the WPB15 meeting. A full report on the project will be finalized soon after the meeting concludes. All outputs from the project, including the full report, training modules, electronic logbook, National Sportfishing database and user manual will form a package of materials that the Secretariat and countries can use (and re-use in the case of additional countries interested in adopting a similar approach to collecting sports fishery data).

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Introduction

Background to the project

The Indian Ocean Tuna Commission (IOTC) is an intergovernmental Regional Fisheries Management Organisation responsible for the management of tunas and tuna-like species in the Indian Ocean and adjacent seas under the *Agreement for the Establishment of the Indian Ocean Tuna Commission* that was entered into force in 1996. The principal objective of the IOTC, as defined in Article V of the Agreement, is to ensure “... through appropriate management, the conservation and optimum utilization of stocks covered by this Agreement and encouraging sustainable development of fisheries based on such stocks” (FAO, 1993). To achieve this objective, reliable information is required relating to the exploitation of fish stocks by all resource users, including commercial, artisanal and recreational sectors.

Recreational fishing (hereafter termed sport fishing) in particular, has generally received little attention in the assessment and management of tunas and billfish stocks managed by tuna RFMOs, including the IOTC. In comparison to the commercial fishery, sport fishing vessels have limited gear deployment capabilities and fish storage capacity and historically have been restricted to predominately coastal waters that are on the fringes of the distribution of most pelagic species. Consequently, sport fishing has been presumed to have a negligible impact on the stocks of commercially important tunas and billfishes caught by industrial vessels on the high seas (Griffiths and Fay, 2015).

However, over the past decade sport fishing has become an increasingly important component of global fisheries with an estimated 11% of the population of industrialised countries participating in the activity (Arlinghaus et al., 2015). The once considered benign coastal leisure activity undertaken has manifested into a specialised and sophisticated fishery that has directed increasing effort towards many species that have traditionally been targeted by commercial fisheries on the high seas, such as broadbill swordfish, *Xiphias gladius* (Vojtkovich and Barsky, 1998) and southern bluefin tuna, *Thunnus maccoyii* (Green et al., 2012). The expansion of the fishery has largely been facilitated by increases in the sophistication, affordability and availability of navigation (e.g. GPS), searching (e.g. sonar, bird radar) and tackle (e.g. electric reels, braided lines) technologies (McPhee et al., 2002; Cooke and Schramm, 2007; Griffiths et al., 2010c).

In the IOTC area of competence, there are numerous recreational fisheries that target species that are the responsibility of the IOTC including several species of tuna, billfish, and seerfish. The primary recreationally important IOTC species caught in the Indian Ocean are black, blue and striped marlin, Indo-Pacific sailfish, yellowfin, skipjack, kawaka and longtail tunas and in some locales, southern bluefin tunas, which are targeted in several countries throughout the area such as Kenya (Ndegwa and Herrera, 2011; Ndegwa and Kiilu, 2013; Ndegwa and Benson, 2015), Mozambique (Mutombene, 2013), La Réunion (Fleury et al., 2012) and India (Kar et al., 2015). In order for IOTC fishery managers to reliably assess the biological status of fish stocks and to manage fishery resources sustainably and to share resources equitably among stakeholders, it is important for the recreational fishery to be included in stock assessments as a mortality source. Griffiths and Fay (2015) recently showed that ignoring the recreational catch in a stock assessment of striped marlin in the Western Pacific Ocean would result in a significant overestimation of the total allowable catch (TAC) if the recreational catch was just 10% of the commercial catch. The overestimate was projected to worsen if the age structure of the recreational fishery was skewed

towards older (i.e. trophy) fish in the population, which is often the case in recreational fisheries (Shiffman et al., 2014).

Unfortunately, cost-effectively collecting reliable recreational catch, effort and size frequency data for stock assessment is expensive and logistically and statistically complex (Griffiths et al., 2010a). Stock assessment models are often driven by time series of commercial catch and effort data, which are routinely collected via compulsory logbooks and in some cases validated by on-board scientific observers as a requirement under conditions of their fishing licence. In contrast, recreational fishers are generally not required to report catch or effort, or even hold a licence to fish. As a consequence, fishery agencies requiring information on recreational fishing need to undertake customised surveys to obtain self-reported data with the cooperation from fishers (Griffiths et al., 2014). However, the often highly heterogeneous spatial and temporal distribution of recreational fishing effort and the existence of an enormous number of access points to most fisheries (e.g. boat launching ramps, marinas, private moorings) makes intercepting fishers throughout the large managed area of tuna RMFOs to gather trip-specific data is cost prohibitive using traditional on-site survey methods. Therefore, alternative cost-effective approaches are required to collect recreational fisheries data that is compatible with existing stock assessment frameworks.

Need

Under the IOTC Agreement, the IOTC has a responsibility to ensure the long-term sustainability of 16 tuna and tuna-like species and their equitable allocation among resource users. Despite the continual growth and increasing efficiency of the recreational fishery over the past decade, this fishery has not been included as a potential mortality source in the most recent Indian Ocean stock assessments for principal billfish species striped marlin (Nishida, 2015), blue marlin (Wang and Huang, 2016), black marlin (Yokoi and Nishida, 2016), swordfish (Sharma and Herrera, 2014b), and Indo-Pacific sailfish (Andrade, 2015), and also principal tuna species yellowfin tuna (Langley et al., 2012), bigeye tuna (Langley, 2016), skipjack (Sharma and Herrera, 2014a) and albacore (Langley and Hoyle, 2016).

Anecdotal evidence and limited survey data from national fisheries agencies indicate that striped, blue and black marlin and Indo-Pacific sailfish are important billfish species of the recreational fishery in Kenya (Ndegwa and Benson, 2015) and most likely several other neighbouring countries in the Indian Ocean. However, national catch estimates for these species is lacking. This is a major concern given the recent status of billfish stocks in the Indian Ocean derived from stock assessments – that do not include fishing mortality from the recreational fishery – indicate they are overfished, overfishing currently occurring, or both. Striped and black marlin are currently most at risk of becoming unsustainable under current fishing effort with these stocks both being overfished and subjected to overfishing (Nishida, 2015; Yokoi and Nishida, 2016). Blue marlin has also become a concern for managers with a 2016 stock assessment revealing that overfishing is occurring in the Indian Ocean stock, but is currently not overfished (Wang and Huang, 2016). A preliminary stock assessment of Indo-Pacific sailfish showed the stock may be sustainable, however, significant uncertainty in commercial catches and biological parameters suggest that this species may also be overfished (Andrade, 2015).

In order for fishery managers to fulfil their obligations under the IOTC Agreement to ensure the sustainability of stocks, reliable stock assessments are required from which effective management measures can be based. Available evidence suggest that recreational fishing may potentially have

a significant impact on the Indian Ocean stocks of tunas and billfish. Consequently, reliable data needs to be collected that is representative of the recreational fisheries in each country where the activity is undertaken. Not only will this improve the realism of stock assessments and improve the reliability of model outcomes, it will also guide managers how recreational fisheries may be managed within the current IOTC management framework.

The IOTC has in the past, and does receive some sport fishing catch data from some member countries but the data vary considerably in their robustness there are many gaps. Kenya has reported some data between 1987 and 2010 and Mauritius reported some data from 2007 to 2011, but both have ceased since then. For a number of key countries which have potentially important sport fisheries, data are either underestimated, misreported or unreported. These include Seychelles, La Réunion, Mozambique and Oman.

Such gaps result from many causes including technical and/or resourcing issues such as lack of data collection and reporting systems by national fisheries targeting sport fisheries, no frame surveys for boat operators and lack of enumerators or fisheries officers to compile catch data. Another important factor mitigating against routine collection of data from sport fisheries is that reporting such data is not mandatory in most, if not all jurisdictions.

The current the project was developed in response to recommendations from the IOTC Working Party on Billfish (endorsed by the IOTC Scientific Committee):

WPB09.25 (para. 70): *The WPB **RECOMMENDED** that the IOTC Secretariat develop a project aimed at enhancing data recovery from sports and other recreational fisheries in the region, in collaboration with Kenya and other interested parties, and to report progress at the next WPB meeting.*

WPB09.27 (para. 73): *The WPB **RECOMMENDED**...the IOTC Secretariat, participating billfish foundations and other interested parties, facilitate the acquisition of catch-and-effort and size data from sport fisheries, by developing and disseminating reporting forms to Sport Fishing Centres in the region and to report back to the WPB at its meeting in 2012.*

Aims

1. Develop a directory of sport fishing centres in the western Indian Ocean region (developing CPCs west of India: east Africa, Middle-East), including contact persons, emails and telephone numbers.
2. Develop and disseminate a database, using access or any other user-friendly software, and standardised recording and reporting forms adapted to Sport Fishing Centres in the western Indian Ocean region.
3. Implement and deliver the training materials to Sports Fishing Centers, national fisheries agencies, and any other relevant organisations.
4. Support the development of a network of Sport Fishing Centres, national fisheries agencies, IOTC scientists, and any other relevant organisations, so that they may improve their own outreach and awareness campaigns, in addition to data collection, management, exchange and analysis.

5. To document the work undertaken and to provide a draft report to the IOTC Secretariat no later than 6 months after the commencement of the project.
6. To develop a presentation of the results for a third party to describe the work undertaken and the results to the next IOTC Working Party on Billfish.

Methodology

Existing information

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Countries selected

Four countries were selected as pilots for the project. They are Kenya, Seychelles, La Reunion and Mauritius. Selection of the pilot countries was based on the importance of sports fisheries amongst IOTC members; also the logistical issues (geography, and limited time/funds available for the project). Expanding the rollout of the charter logbooks/database to more countries could be a possibility if a second phase of the project is approved/needed.

Species

The species of fish that are the focus of this project are the 16 tuna and tuna like species directly under the mandate of IOTC. These are: **Billfish**: Swordfish, striped marlin, black marlin, Indo-pacific sailfish, Indo-pacific blue marlin. **Tuna**: Albacore, bigeye tuna, yellowfin tuna, skipjack tuna, southern bluefin tuna. **Neritic tuna**: Longtail tuna, kawakawa, bullet tuna, frigate tuna and **Seerfish**: Narrow barred Spanish mackerel, Indo-pacific king mackerel.

All of these species are caught by sport fisheries in at least some IOTC countries.

Because of the particular importance of billfish as target species for sport fishers, catches of billfish are a particular focus of this project. Similarly, neritic tunas are a particular focus of the project. Striped marlin have been recently assessed as being overfished and in the process of overfishing in the Indian ocean, so it is important to document as much data on this species as possible.

Preliminary contacting of key personnel

Prior to the country visits, letters were sent by the IOTC to appropriate personnel in the national fisheries agencies of each of the four countries introducing the consultants, outlining the aims of the project and detailing itineraries of country visits. The consultants also made contact with the sport fishing community in each country and arranged meetings with representatives.

Trip plan

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Results

Country Reports

The following reports are based on visits to each of the pilot countries in October/November 2016 by the project consultants, Dr Julian Pepperell and Ms Nelly Kadagi. Meetings were arranged with Government personnel and representatives of the sport fishing community in each location.

Kenya Country Report

Sport fishing using primarily charter boats has a particularly long history in Kenya, extending from at least the 1950s (Williams 1970). Of the four countries visited, Kenya has the longest history in active sport fishing, primarily by a fleet of well-equipped charter vessels along the coast. The fishery is well organized, with clubs and charter captains belonging to the Kenya Association of Sea Anglers (KASA) – formerly the Kenya Association of Sea Angling Clubs. This organization is currently reconstructing itself, but sport fishing captains periodically share their records/information with the Watamu Sea Fishing Club which is voluntarily run by Captain Andy's Fishing Supply. KASA has maintained catch statistics from the main fishing centres for several decades as well as keeping a comprehensive list of Kenyan fishing records for many species of pelagic sports fish for all recognized line classes from 1 kg to 60 kg breaking strain, for both women and men.

In the past, tourist sportfishing has been regarded as having a positive impact on the coastal economy of the main centres, perhaps well illustrated by the logo of Kilifi County which depicts two billfish on either side of symbols of the natural resources of the region.

Main ports/locations for sportfishing

Watamu: A small fleet of charter vessels moors behind the fringing reef off 'Ocean Sports', a resort with large central bar/restaurant near the town of Watamu. The venue is an informal regular meeting place of sportfishing captains, crew and anglers. Captain Andy's Fishing Supply shop adjoins the resort; charter boats (and some private) have moorings inside a barrier reef (parallel to shore). Sport fishing boats are modern and well equipped, with designs that have evolved to suit the conditions (some, for example are twin hulled).

The African Billfish Foundation (ABF) is a private organization that has operated a large pelagic fish tagging program since the 1980s. The ABF mainly collects data on billfish that are tagged and released across the East African Indian Ocean waters, as well as reported billfish recaptures. ABF is also based in Watamu and has taken advantage of the opportunity to regularly contact and interact with the sportfishing captains and crews at Ocean Sports.

Malindi: The Malindi Sea Fishing Club is a private clubhouse with a weighing gantry and access to the beach and to charter vessels at anchor behind the coastal reef. The club has a long history dating back to the early 1950s, and runs several annual local and international tournaments. This is the primary club from which the Kenya State Department of Fisheries has extracted records of fishing trips dating back to 1987 (see below).

At the time of the consultancy, it was agreed by charter operators that 80-85% of Kenyan charter boats are presently concentrated in Malindi and Watamu. Other locations from which small numbers of charter boats still operate are Shimoni, Diani, Kilifi, Mtwapa/Mombasa and Lamu.

Sizes of fleets (charter, private)

Estimates from charter captains of the number of active charter boats varied a little, but it was generally agreed that there were about 40 charter boats actively fishing for tuna and billfish on the Kenyan coast. This was supported by the Kenya Department of Fisheries licensing records which indicated 42 charter boats registered in 2011.

Regarding private boats that actively fish for tuna and billfish, it was generally agreed that the number was quite small, and definitely less than the charter fleet. Several estimates put the figure at about 20 private boats.

Number of days fished per year (charter)

The number of days fished per year varies among charter operators, ranging from about 175 days to about 75 days. One operator estimated that before the tourism downturn, most of the fleet would fish at least 180 days but most were now down to perhaps half that on average.

Seasons

Fishing can be undertaken year round, but the charter businesses close down from the start of the monsoon season – around mid March/early April, to mid July, although some boats may resume fishing in early July to target black and blue marlin.

Tournaments

Regular tournaments are held from both Watamu and Malindi. During the consultants' visit, a small tournament fished by eight charter boats was held from the Malindi Sea Anglers Club. A local fishing operator with a long history of fishing in the area was present at the tournament recording the weights of each fish weighed. He has performed this task for his own records for many years and this would be potentially a secondary source of data from Malindi tournaments.

Management and licensing

All sport fishing charter boats are required to hold a tourist licence, a fisheries licence (which allows them to fish as charter operator, but not professional, i.e. they are not permitted to sell their catch) and for larger boats, a maritime boat inspection licence. Private boats fishing for any species, including pelagic sport fish, must also have a fishing licence issued by the Kenya Department of Fisheries.

Historic and current catch data

Two non government programs in Kenya have historically collected data from the Kenyan sport fishing charter fleet.

The KASA collected and collated catch and effort data from member clubs from the early 1980s to 2014 when the Association cut back most of its activities due to a reduction in the number of memberships. The KASA published its own annual report containing some of these data until the late 1990s, and since the early 1980s in an annual magazine titled 'Rainbow Runner'. The last issue of Rainbow Runner was published in 2014 and there are concerns among the sport fishing charter operators regarding the discontinuance of this long-term recording.

The published data are derived from individual sport fishing charter operators who recorded their daily catches in notebooks held at central locations in each area. For example, a notebook has been kept at Captain Andy's Fishing Supply tackle store adjacent to Ocean Sports for many years, and most if not all operators fill in simple catch and effort data there. One person with some computer skills then entered the data electronically from which the published tables in the annual Rainbow Runner magazine were derived. The published data are in the form of annual catch by species aggregated by number and weight of landed fish by coastal region. Numbers tagged are also usually included. Various graphics showing such data as seasonal catch rates by region, species composition of the catch and so on are also included in the annual reports.

The main target species are billfish, with sailfish historically caught in large numbers, followed by striped marlin then blue and black marlin in smaller numbers. Other species caught in numbers include dolphinfish, yellowfin tuna, king mackerel (*Scomberomorus commerson*), giant trevally, wahoo and various sharks.

This continuous record of catch and effort dates back to at least 1987, quite possibly to the early 1980s. However, for a range of reasons, the collection of data has fallen away in recent years. Fortunately, the African Billfish Foundation is currently planning to take over the role of collecting and collating the same series of catch and effort data from charter operators and clubs. A starting time October 2017 has been planned but no funding has been earmarked for this purpose.

A second set of data relevant to sport fishing catches in Kenya is a tag-and-release database held by the African Billfish Foundation. Tagging of billfish in Kenya began in 1987, using US National Marine Fisheries Service tags. This function was taken over by The African Billfish Foundation, formed in Kenya in 1990 with a primary focus on tag and release of billfish by sport fishing charter boats. Conventional plastic dart tags are provided to sport fishing charter boats, and to the year 2013, about 55,000 billfish have been tagged under the program (Kadagi and Harris 2016). Sailfish is the dominant species tagged (83%) followed by striped marlin (10.2%), black marlin and swordfish (2.6% each) and blue marlin (1.5%) (Kadagi et al. 2011). The proportion of billfish tagged to billfish landed by the charter fishery has fluctuated over time. In the early 1990s, about 20% of billfish caught were tagged, climbing to about 90% in 2008. Over 2,500 recaptures of tagged billfish have been reported, the majority being sailfish that have either shown limited movement, or movement along the east African coast. A number of long distance recaptures of marlin have been recorded, including a Kenya-tagged black marlin to the southern Indian coast and a Kenya-tagged striped marlin to near the western Australian coast. The tagging database includes release data from both charter and some private boats in Kenya, and also on a smaller scale, several other locations in the western Indian Ocean region.

The Kenya Department of Fisheries has been collecting some at least some data from the charter sport fishery since 1940, although data to 1987 was not digitized and since then, data for some years is missing (Ndegwa 2010).

An IOTC-OFCF project to improve the accuracy of data collection and statistical analysis of the catches of tuna in the Indian ocean was implemented from April 2002 to March 2007 (Anon 2007, Anon 2010). One of the aims of that project was “Computerization of Historical Size Data from Kenya Sport Fishing Club”. This occurred from August to December 2006 during which centralised notebooks from Watamu Sea Sport Fishing Club and Malindi Sea Sport Fishing Club were borrowed, scanned and returned. From the scans, data from Malindi for 1987 through 2006 were entered, and data from Watamu for 2000 through 2006 were entered, with various missing years and months noted. These data did not just contain size information, but also catch (numbers) and effort, as recorded by individual sport fishing charter boats for each day’s fishing.

The resulting data were utilized in a series of IOTC working papers which have summarised and analysed catch and effort for tuna (Ndegwa 2010), kawakawa and frigate tuna (Ndegwa 2011, Ndegwa et al. 2013), sailfish (Ndegwa and Herrera 2011), narrow barred Spanish mackerel (Wekesa and Ndegwa 2013) and marlins (Ndegwa and Kirathe 2015). The data were also partially used in a study of seasonality, morphometrics and feeding behaviour of sailfish (Ndegwa and Kiilu 2013). Table X summarises the data sources described in these papers, which are largely consistent but mainly emphasise the data held by the Malindi Sea Fishing Club only.

As far as can be determined, the data that was digitized under the IOTC-OFCF project is essentially the same as that coordinated and collected by KASA and published annually in Rainbow Runner magazine in the form of tables and graphs. It is recommended that these two data sets be compared for consistency and verification purposes.

Since the conclusion of the IOTC-OFCF project, data has apparently continued to be collected from Watamu and Malindi by the Fisheries Department, but it is unclear whether this is being entered onto the same database for continuity.

Willingness to cooperate in a data program

The consultants met with numbers of charter boat owners at both Watamu and Malindi. A talk was presented on the project one evening during a fishing tournament at Malindi. There was general consensus among the charter operators that they would be willing to complete a daily log, and to submit this on a monthly basis.

They are used to collecting data (although this has been done in the past by filling in books at key places, like the tackle shop, and data was always electronically entered by one keen person).

At a meeting held with officers of the Kenya Department of Fisheries and the Kenya Marine Fisheries Research Institutes in Mombasa, a willingness to service a logbook program for sport fishing was indicated, although concerns were expressed regarding possible lack of resources to undertake such work.

Other observations

There has been a notable downturn in coastal tourism in Kenya due mainly to terrorist incidents in Nairobi and in the northern coastal region. This has had a marked effect on client numbers for the charter sportfish fishery.

In addition, it was reported that the past three or four seasons have been very poor for sailfish fishing, the species which, in the past, has been the mainstay of the fishery with respect to catch rates of billfish. Some charter operators ascribe this downturn to increased coastal gill netting in Somalia, although evidence for this was anecdotal.

Challenges regarding data collection

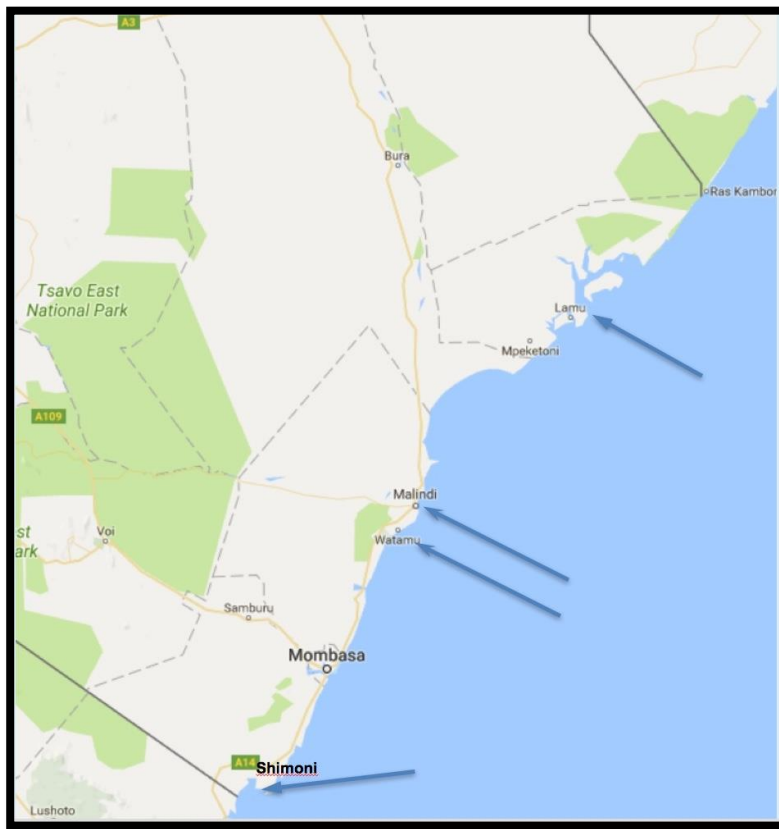
The main challenge to data collection in Kenya appears to be adequate resourcing of the Fisheries Department to undertake this role.

On the positive side, access to the charter fleet is very good for the two main sport fishing locations. Charter operators regularly gather at the two venues and tournaments also offer opportunities to access most operators at the same time and place. In fact, the African Billfish Foundation has been accessing charter operators in this way since it began its operations.

Table: Reports derived from data collected by the Kenya Association of Sea Anglers with details of source of data from each report.

IOTC REPORT	Species	Methods	Years covered	Missing data	Incomplete data
Ndegwa and Herrera 2009. IOTC-2011-WPB09-09	Sailfish	Data is recorded by Malindi Sea Fishing Club on a daily basis in a hard cover note book . Includes date, name of boat, species of fish caught; number caught total weight per species,	1987-2006	1988, 1989	2002, 2003
Ndegwa 2010. IOTC-2010-WPTT-42	Tuna	Data is recorded by Malindi Sea Fishing Club on a daily basis in a hard cover note book . Includes date, name of boat, species of fish caught; number caught total weight per species,	1987-2006	1988, 1989	2002, 2003
Ndegwa 2011. IOTC-2011-WPNT01-28	Kawakawa & Frigate tuna	Data is recorded by Malindi Sea Fishing Club on a daily basis in a hard cover note book . Includes date, name of boat, species of fish caught; number caught total weight per species,	1987-2006	1988, 1989	2002, 2003
Ndegwa et al. 2013. IOTC-2013-WPNT03-22	Frigate tuna & kawakawa	Catch and effort data set (1990-2009) available in the Malindi sport fishing	1990-2009		1995, 1996, 2002, 2003, 2009
Wekesa and Ndegwa 2013 IOTC-2013-WPNT03-28 Rev_1	Narrow barred Spanish mackerel	Daily vessel records kept by with the support of IOTC-OFCF project this data was stored in a database respective sport fishing club using a systematic data recording protocol that is	1990-2009		1995-96, 2002-03
Ndegwa and Kirathe 2015. IOTC-2015-WPB13-15	Marlins	State Department of Fisheries and sport fishing clubs located in Malindi Records of Marlins caught during sport fishing are taken and maintained in the boat's logbook and subsequently archived by respective Sport Fishing Club. The information recorded is then availed to the State Department of Fisheries. Records of important data such as the date of capture, weight (actual or estimated), boat name, home area, species caught and	1987-2012	1988, 1989	
Acquisition of catch and effort and size data from sport fisheries in the Western Indian Ocean					

Map with key sport fishing locations mentioned





Clockwise from top left: 1. Logo of Kilifi County showing billfish. 2. Swordfish cast at Ocean Sports, Watamu. 3. Fishing tackle shop where sport fishing data is recorded in book. 4. Speaking at Malindi Sea Anglers Club. 5. Meeting with Fisheries Department staff, Mombasa. 6. Group photo, Fisheries Department, Mombasa. 7. Sport fishing charter fleet at anchor off Ocean Sports, Watamu. 8. Reception at Driftwood Hotel, Malindi, showing game fishing flags and cast of black marlin.

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Seychelles Country Report

Sportfishing is active in the Seychelles, with large and smaller well-equipped vessels available for charter. There is active promotion of sportfishing for pelagic fish on the internet, in hotels on Mahe, and on Beau Vallon beach. Billfish are key target species, but other pelagics such as tuna, wahoo and dolphinfish are actively sought.

Main ports/locations for sportfishing

The main ports or locations from which sport fishing operates on Mahe are:

Eden Island marina: Situated on the eastern side of the island, this is a large, modern marina where many charter and private boats are berthed. The charter boats here tend to be large to very large, modern and very well equipped for sport fishing. Some are owned by companies that operate two or three boats (for example, Bluewater Charters) while several other large charter boats (50' to 60') are privately owned and employ a full time captain and crew.

Bel Ombre harbour: A small, public harbour on the northwest side of the island with good access to pelagic fishing grounds. A range of sportfishing and private boats are moored there. There are 10 to 12 charter vessels operating from Bel Ombre, three of which are well appointed and well equipped for tuna and billfish fishing. Other boats there that advertise charters are more basic, but nevertheless quite active.

Beau Vallon: A beach resort area, adjacent to Bel Ombre. Several charter operators have permanent or temporary offices there for taking bookings for charters.

Sizes of fleets (charter, private)

There was general agreement that about 40 sport fishing charter boats were active around Mahe. Another 7-10 boats capable of fishing for billfish and tuna are located on Praslin Island, but only one of those is regarded as a serious sport fishing boat. Sport fishing for pelagic fish is also conducted from La Digue although the number of active boats based there was reported to be very small. Some boats from the Seychelles Sport Fishing Club travel from Mahe to La Digue to fish an annual tournament there.

It was difficult to obtain an estimate of the number of private boats that might fish for tuna and billfish in the Seychelles. A list provided by the Seychelles Sport Fishing Club showed 20 member boats based on Mahe, of which 5 were charter, 4 were charter/private and 11 were private. Another 6 member boats, all private, were based on Praslin. The number of private boats fitted out for sportfishing that were observed around the island was relatively small – probably no more than 50.

Clubs

There is one major sportfishing club in the Seychelles – the Seychelles Sportfishing Club, which meets regularly at the Seychelles Sailing Club in Victoria. This is an active club that holds various competitions through the year and actively takes part in tagging and research programs.

Number of days fished per year (charter)

Several operators of charter boats in the Bel Ombre area indicated that they fish 200 to 300 days per year, although in addition to trolling for pelagic fish, a typical charter may also commonly involve bottom fishing and snorkelling. Charter boats based at Eden Island tend to be larger and with full time professional crews. The number of days fished by these boats was not able to be determined, but would vary depending on demand. The cost to charter these larger vessels was of the order of 6,000 Euros per day, a very high rate by international standards which would be expected to have a limiting effect on the number of days fished in a given year.

Management and Licensing

In the Seychelles, the Ministry of Tourism ‘manages’ sportfishing, but in effect, this simply involves the collection of a licence fee. Nevertheless, the resulting licence frame could be very useful for a survey of private boat owners who fish for tuna and billfish.

The Seychelles Fisheries Authority (SFA) is involved in a number of activities relevant to sport fisheries over the next few years. These include an assessment of sport and recreational fishery importance to the economy, integrating these fisheries in monitoring for the MSP sustainable use zones, support for the tag and release program being undertaken by the Seychelles Sport Fishing Club, education and awareness support and development of electronic apps for reporting and tag and release data.

The SFA is also currently developing a Fishing Fleet Management and Licensing System. A consultancy for this was due to commence in July 2017 and is due to be completed by the end of 2017. The aims of the project are:

- Estimate national fishing capacity across sectors and develop a fishing boat and gear registry
- Develop a fleet management plan based on recommended capacity limits for major fisheries
- Develop a fishery-specific licensing system that links to the boat and gear registry

This work will involve the design and planning of a fishing unit frame survey encompassing commercial, recreational and sport fishery sub-sectors and also develop a fishing boat and gear registry for integration in SIH and other information systems.

It will also provide guidance and oversight for the adoption of fishery-specific licenses in addition to the currently prescribed fishing boat licenses, prioritising the demersal line and trap fisheries, the sport fishery and semi-industrial longline fishery.

The results of this survey would be of considerable benefit to the current project, especially in assessing the success of the frame survey in being able to contact private sport fishing boat owners who regularly fish for pelagic species.

Historic and current catch data

A logbook program for sportfishing was apparently in operation in the early 1980s but it did not continue. The Seychelles Sport Fishing Club keeps records of tournament catches (and presumably number of boats fishing each day of a tournament). One very active angler based on Praslin has kept good records of catches by most boats on that island for the past four years and will provide these data on request. Some charter captains stated that they keep their own personal records of catches, but others do not. Such data would need to be examined in detail to determine its utility.

The Seychelles Fisheries Authority (SFA) noted that it does have some length frequency data from game fishing tournaments, but not catch/effort data. These data appear to be most likely collected at competitions run by the Seychelles Sport Fishing Club on an ad hoc basis.

Willingness to cooperate in a data program

All of the charter operators spoken to at both Eden Island and Bel Ombre indicated a willingness to complete daily logs and be contacted monthly for submitting.

A meeting with the Seychelles Sport Fishing Club was held at which the purpose and benefits of the pilot project was outlined. The official club position was that they chose not to cooperate at this stage, nor provide any of the data collected by the club in previous years. As noted, membership of the club includes both private boat owners (out of scope of this project) and some charter operators (in scope).

A meeting with the Seychelles Fisheries Authority indicated support for the pilot program. Given that the Authority is planning a frame survey and possible mandatory data collection from the recreational fishing sector, this project would likely fill a gap in data collection in the short term until that process was implemented.

Other observations

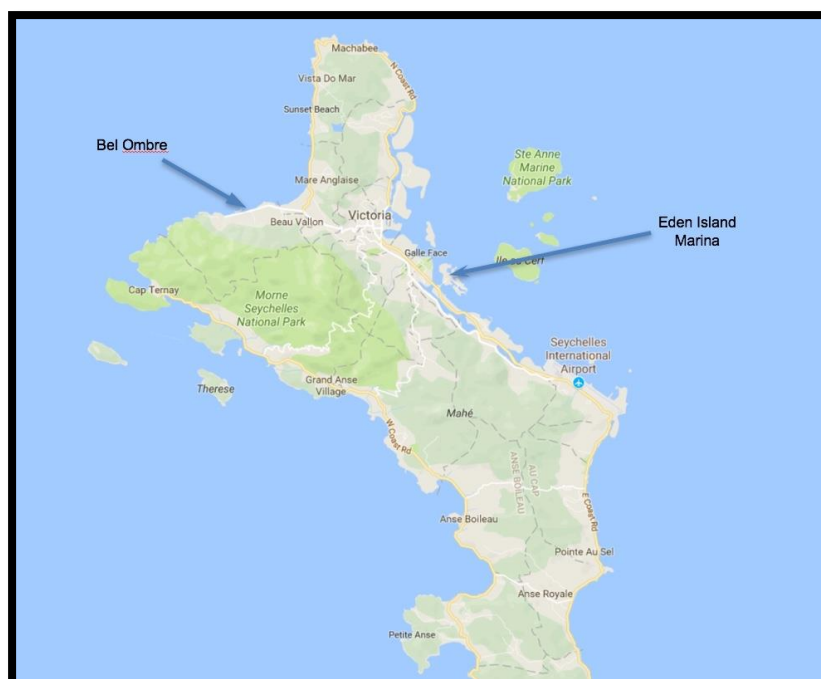
As noted, the Seychelles Sportfishing club is very active in tagging of billfish, for which purpose they use tags supplied by the US-based Billfish Foundation. About 600 billfish, mainly sailfish, had been tagged by the club as of October 2016. The club is also actively involved in a billfish popup satellite tagging project, which has the support of the Seychelles Fisheries Authority.

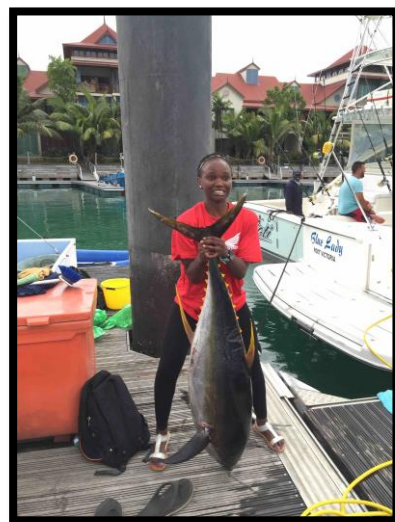
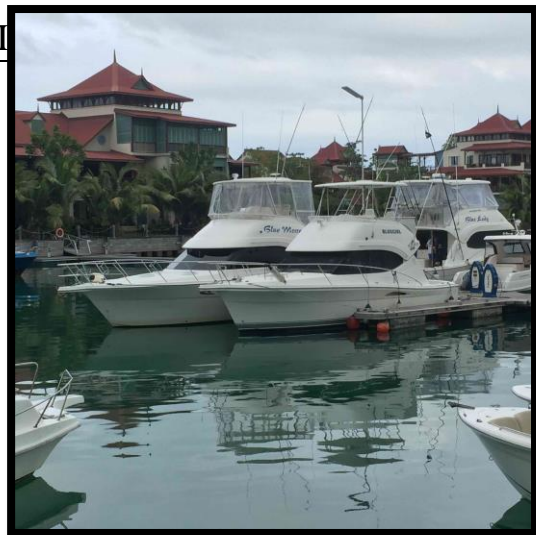
Challenges regarding data collection

Ideally, cooperation of the Seychelles Sport Fishing Club in the data collection program would be highly desirable since the club is a centre of sport fishing activity for both private and at least some charter boats. This will require some further discussions.

Contact with the larger charter vessels moored at Eden Island was via captains who were employed by owners, some of whom may reside overseas. The captains indicated willingness to fill in log sheets, but this would depend on the agreement of the owners.

Map with key sport fishing locations mentioned





Clockwise from top left: 1. Large charter vessels, Eden Island. 2. Three charter vessels owned by one company, Eden Island. 3. Charter vessel at public wharf, Bel Ombre. 4. Large yellowfin tuna caught by charter vessel, Eden Island. 5. Meeting with SFA staff, Mahe. 6. Advertising charter fishing in Hotel, Beau Valon. 7. Interviewing charter captain, Eden Island.

La Réunion Country Report

La Réunion is a region of France, but for the purposes of this report, we use the term ‘country’ for ease of comparison with the three other countries visited (Seychelles, Mauritius and Kenya). In La Réunion the consultants were accompanied by an interpreter, Aude Gauthier, who was born in La Réunion and completed a Master of Marine Science degree at the University of Queensland, Australia and proved to be a valuable asset for our discussions and fact finding.

Before outlining sport fishing activities in La Réunion, it is important to define what may or may not be meant by ‘sport fishing’ there. Whereas the charter fisheries that target billfish, tuna and other pelagic fish in the other three countries are understood and accepted as undertaking ‘sport fishing’, that is, recreational fishing, the same kinds of vessels in La Réunion, which also take paying customers for fishing trips, are classified as ‘professional’ fishing vessels and catch data are included with that sector (Manach et al 2015, S. Bonhommeau *pers comm.*). Even so, the charter operators spoken to certainly regard their activities at least partly as sport fishing, hence the many ‘big game fishing’ (‘Pêche au Gros’) references and depictions of billfish as logos, and photographs of billfish and tuna in their advertising material and signs. One long standing charter company even calls itself the La Réunion Game Fishing Club and operates a well-stocked fishing tackle shop selling typical sport fishing equipment. The charter boats in La Réunion use standard sport fishing gear seen in similar fisheries around the world and advertise their businesses in the same way as do sport fishing charter businesses in the other three countries, and in fact, around the world.

From a government perspective, in La Réunion the term ‘sport fishing’ (pêche sportive) is usually associated with private, non-professional activities. This would include non-organized personal fishing by individuals, or fishing in organized events by members of fishing clubs (see below).

Main ports/locations for sportfishing

The main ports from which sportfishing charter boats operate are:

Saint-Gilles-Les-Bains: Port de Plaisance is a protected harbour within the village of Saint-Gilles on the west coast of La Réunion with well-equipped marinas, berthing and on shore facilities. Charter boats advertise their businesses around the harbour with signs and placards, and fish are unloaded onto docks so that the public can see the catch (and perhaps be persuaded to book a trip). On the consultant visits, catches included dolphinfish, yellowfin tuna, bigeye tuna, skipjack tuna, wahoo and a black marlin.

Le Port: This is a large port berthing many mixed vessels on a number of pontoons and jetties. There is apparently one charter vessel that operates from Le Port. This is also the site of the club house of CRPPS (Comité Régional des Pêcheurs Plaisanciers et Sportifs de La Réunion, a non professional fishing club which runs competitions for members through the year.

Saint-Pierre: This port was not visited. It was indicated by other operators that there was only one charter boat at that location.

Sizes of fleets (charter, private)

Charter operators in Saint-Gilles stated that there are nine charter boats at that location (although several other boats were observed fitted out for game fishing, but not charter vessels). As noted, one charter boat is based in Le Port and one in St Pierre.

In both Saint-Gilles and Le Port, large numbers of private boats can be observed moored in the marinas, many of which would be capable of short trips to the ocean. These are typically 4 to 5 metres in length, with outboard motors, but most are not obviously fitted out for sportfishing, especially for targeting billfish and other pelagic species.

Regarding the numbers of private boats that might actually fish for billfish, tuna and other pelagic species, there were mixed opinions. A past chairman of the Comité Regional des Pecheurs Plaisanciers et Sportifs de La Réunion (CRPPS) was of the opinion that even though there may be as many as 2,000 private boats in La Réunion, only perhaps 300-500 would be used for fishing, of which, less than 100 would regularly target pelagic fish such as large tuna and billfish. CRPPS membership numbers 30 to 50 boats, 6.5 to 14 m in length, all of which are private (ie, non professional).

Number of days fished per year (charter)

Because they can legally sell their catch, charter boat captains fish as often as possible, with or without paying clients. One captain reported that he fished 360 days per year. For a system wishing to record the catch and effort of the sport fishing sector, it would be important to distinguish those trips of charter boats that carry paying anglers from those that do not.

Management and licensing

As noted above, sport fishing charter boats are classified as commercial (professional) and carry a European commercial fishing licence as well as a permit to transport passengers. They sell their catch, and as noted, some operators indicated that they fish nearly every day, weather permitting, even if they do not have paying clients.

There are about 30 Fish Aggregating Devices (FADs) around the island of La Réunion which are deployed mainly for the use of professional fishermen (including charter boats). Private boats are only permitted to fish around FADs on weekends and public holidays.

It is illegal for private fishermen to sell fish, but it was the opinion of some charter operators that many do. By law, fish caught by non-commercial fishers must have one lobe of the caudal fin, and one pectoral fin cut off. The level of compliance is unknown, but is considered at least a measure to discourage illegal sales.

Historic and current catch data

Charter operators are required by law to complete log books that record catch and effort, but it is understood that these data are not separated from other professional data so as to identify sport fishing charter boats *per se*.

The primary sport fishing club on La Réunion, the Comité Regional des Pecheurs Plaisanciers et Sportifs de La Réunion (CRPPS), holds about 25 one-day competitions per year, with an average of

about 10 boats fishing each day. Members fish under International Game Fish Association (IGFA) rules, and do not fish around the Government FADS in competitions.

In the past, club members had tagged and released 100-150 billfish with tags supplied by the US Billfish Foundation but this practice has fallen away since little feedback was received on recaptures (if any). As with the charter operators, club members also release marlin estimated at less than 80kg in size. (It would be possible to obtain full details of billfish tagged from the Billfish Foundation, if desired).

The records of CRPPS fishing competitions from 2000 to 2012 have been analysed in some detail but not yet fully published (Fleury et al 2012, Fleury et al 2013). A total of 133 fishing days of competition consisting of 1,600 fishing trips were analysed. The main species caught are dolphinfish (dorade), skipjack tuna (large specimens are called 'bonite kalou'), yellowfin tuna and wahoo. All three Indo-Pacific species of marlin are also caught, although these do not appear to be separated in club statistics. Sharks are no longer included in club competitions, but club members indicated that mako sharks caught outside competitions were more common in the past but have largely disappeared over the past ten years.

The proprietor of the charter company Maevasion indicated that his boats each catch about 40 blue and black marlin (combined) per year of which, about 5 are released since they would weigh less than 80kg. This is a 'self policy' of releasing smaller marlin which is apparently the case for other charter operators as well.

The proprietors of the charter company, La Réunion Game Fishing Club, have over 30 years of self-maintained catch data on billfish and tuna from their two vessels. These data are in the form of hand-written note books. This material was not observed but the proprietors indicated willingness for the data to be accessed, digitized and analysed.

The proprietor of Maevasion has four years of similar data in the form of his own diary, and also indicated willingness for the data to be accessed. It is likely that other charter operators also maintain personal logs or diaries.

Willingness to cooperate in a data program

The several charter boat operators spoken to were quite amenable to filling in log sheets. As noted, they already do fill in a daily sheet, similar to the one designed for use in this study, but they were also supportive of the concept of a specific sport fishing log.

Other observations

There was a general belief among charter operators that fishing success had declined over the past decade, or less. High levels of commercial (purse seine) fishing around the Seychelles was attributed as the cause of perceived declines in numbers of all species of pelagic fish as well as sizes of skipjack and yellowfin tuna. Large yellowfin tuna are allegedly rare to catch these days. Perceived declines in marlin catches were attributed in part to a decline in skipjack tuna in the region, but also to domestic longline vessels.

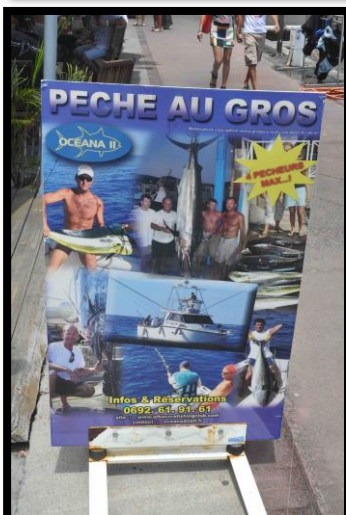
Challenges regarding data collection

The fact that sport fishing charter operators already complete daily fishing log sheets may cause issues with requests to also fill in a similar voluntary sheet into the future. The perceived benefits to the sector, however, may be sufficient incentive to do so.

Alternatively, the data being collected from charter boats by this existing system may potentially be able to be provided separately to IOTC for the purpose of better understanding the catch and effort of the sport fishing sector.

Map with key sport fishing locations mentioned





Top row, L to R: 1. Sport fishing charter boats at Saint Gilles. **2.** A view of private boats in marina at Le Port. **Second row, L to R: 1.** Advertising sign at Saint Gilles. **2.** Mixed catch of yellowfin tuna and dolphinfish. **3.** Club house of sport fishing club, Le Port. **Third row, L to R: 1.** Black marlin caught by charter boat, Saint Gilles. **2.** Interviewing charter captain, Saint Gilles. **Bottom:** Fish caught by charter boats are sold direct to the public.

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Mauritius Country Report

There is an active and internationally regarded sportfish fishery in Mauritius with a long history and strong reputation, especially for catching large blue and black marlin. One of the early studies on age and growth of blue marlin was based on 223 fish landed at sport fishing tournaments on Mauritius in the mid 1980s (Cyr et al. 1990).

Charter operations in Mauritius are concentrated in several locations, mainly on the western side of the island. A number of companies own and operate multiple vessels (two to five). Boats are generally large (8 metres and above) and the standard of the fishing equipment on boats is high. Interestingly, many of the charter boats observed with similar hull designs were built on Mauritius.

Main ports/locations for sportfishing

The main ports or locations from which sport fishing charter boats operate are:

Grand Baie: A large harbour on the northeastern tip of the island providing anchorage on moorings for many vessels. However, very few of these were fitted out as sportfishing vessels. There is one main jetty (a floating pontoon) in Grand Baie which is used by charter operators. The main charter operators in this area are Sportfisher (5 boats), Horizon and Le Performant. The latter maintains an office in Grand Baie but anchors its vessels off Pereyebere Beach, to the north of Grand Baie.

Black River: Several charter businesses operate from this area. The main one is J.P. Henry Charters, with three large, modern vessels berthed at La Balise Marina in Black River estuary. Another charter company, La Carangue Centre de Pêche, operates from a jetty just to the north of Black River. Le Morne Anglers Club, the largest club associated with sportfishing on the island, is located near the jetty of La Carangue. It is a private club which operates its own marina for the use of members.

Trou d'Eau Douce: Royal Big Game Fishing is the only charter operator on the eastern side of the island. The company has three large well-equipped sport fishing vessels with professional captains and crew and caters mainly to overseas clients.

Fishing areas: On the west coast, a fishing chart showing the permitted area of fishing for the 2016 South Indian Ocean Billfish Competition extends about 15 nautical miles to sea.

Two companies, Sportfisher and Le Performant, are about to commence dedicated live-aboard charters for long distance sportfishing trips to remote atolls within the Mauritian EEZ.

There is one active charter operator on Rodrigues Island, which was not visited. A company there, Rod Fishing Club, operates one vessel. Its website indicates a mixed fishery, including reef fish, inshore sportfish such as carangids and some offshore pelagic catches including billfish and tuna.

Sizes of fleets (charter, private)

Charter operators and club officials estimated that there are approximately 40 charter boats on the island. This was generally agreed by Fisheries Department personnel. The most experienced charter operator on Mauritius who has been in the business for 40 years, estimated there were

approximately 25 charter boats in Mauritius in the 1990s, but that number had now grown to 40 charter boats. He also estimated that there were 50-60 active private boats that were capable of catching billfish and tuna. These numbers were supported by others, including independently by one very active private boat owner and sport fisherman.

Le Morne Anglers Club has 350 members, half of whom are active recreational fishers. It is the only club on Mauritius registered with the International Game Fish Association (IGFA). The main competition run by the club is the National Billfish Tournament which attracts about 20 boats with 80 anglers, most of which are charter vessels.

Number of days fished per year (charter)

On average, each of J-P Henry's three boats are now fishing a minimum of 120 days per year. However, clientele has definitely declined as a result of a perceived decline in fish numbers and therefore, success rate. A four or five year decline in tourist numbers from Europe was alluded to, but not sourced. The three charter boats owned and operated by Le Performant each fish 200-300 days per year.

Seasons

The overall season for pelagic sport fishing is October to April with the peak season for marlin and yellowfin tuna being February to March. December to February is a particularly busy time, whereas the slowest period is June through August.

Peak season for marlin and yellowfin tuna is February through March.

Tournaments

Mauritius has a number of regular tournaments for sportfishing, viz:

- Grand Baie Yacht Club tournament. This is an annual one day event attracting around 40 boats, 80% of which are private and 20% charter. During tournaments, marlin are released if estimated at less than 300lb, but outside tournaments, marlin are rarely released.
- The annual International Offshore Billfish Tournament is an annual even run from Le Morne Anglers Club.
- Mauritius Billfish Release International Tournament. Next tournament to be fished over four fishing days in January 2018, from La Balise Marina.

Management and licensing

In Mauritius, all sport fishing boats, both private and charter, must have a licence from the Tourist Authority, plus a Mauritius skippers' permit, and a mooring permit. Such permits would be very useful for a survey of private boat owners who fish for tuna and billfish. There is no legal framework for monitoring and managing catches in sport fishing. Charter and private boats are all licenced under the Ministry of Tourism, not Fisheries.

The type of licence is based on the size of the vessel and the number of persons it may carry. Sport fishing boats are restricted as to the distance offshore they are permitted to operate. The Fisheries

Department issues licences to sell fish to fish mongers, which includes charter operators. The market is not regulated.

Historic and current catch data

The charter operators interviewed indicated that they did not keep records of catches or catch rates. The Le Morne Anglers Club does keep records of tournament catches, but only number and weight of landed fish. These data would be made available on request.

In the office of J-P Henry, a senior employee estimated that their three boats catch about 500 marlin per year. The commonest species is blue marlin, followed by black marlin, followed by striped marlin. The average size of blue marlin is 150 lb (70 kg), but range up to 1,000 lb (450 kg).

It was believed that catches of sharks had dropped by 90% compared with several decades ago, and that marlin and tuna catches were down by 70%, although these comments were anecdotal in nature.

There does not appear to be any historic or current data on sport fishing catch/effort or size data collected by the Fisheries Department.

Willingness to cooperate in a data program

Fisheries Research personnel are highly supportive of the proposed data monitoring program and were enthusiastic and most helpful in contacting charter operators and arranging meetings.

All charter operators interviewed indicated their willingness for captains to complete catch forms and be contacted on a monthly basis. The main operator at Black River, J-P Henry, agreed to have his three boats fill in monthly forms if this would assist the fishery.

Both the Manager and the Chairman of the Le Morne Anglers Club agreed to assist in having sport fishers fill in monthly forms, indicating that the club would indeed be a good point of contact for a proportion of charter boats. Some private boats in the club may also be interested in completing log sheets.

Challenges regarding data collection

Mauritius would appear to be an excellent choice for one of the countries to trial a charter log system. The consultants were received very well by most charter operators, captains and club officials and all indicated willingness to take part. In addition, the Fisheries Department personnel also embraced the concept of the program, and generally appeared to have good relationships within the sport fishery.

Other observations

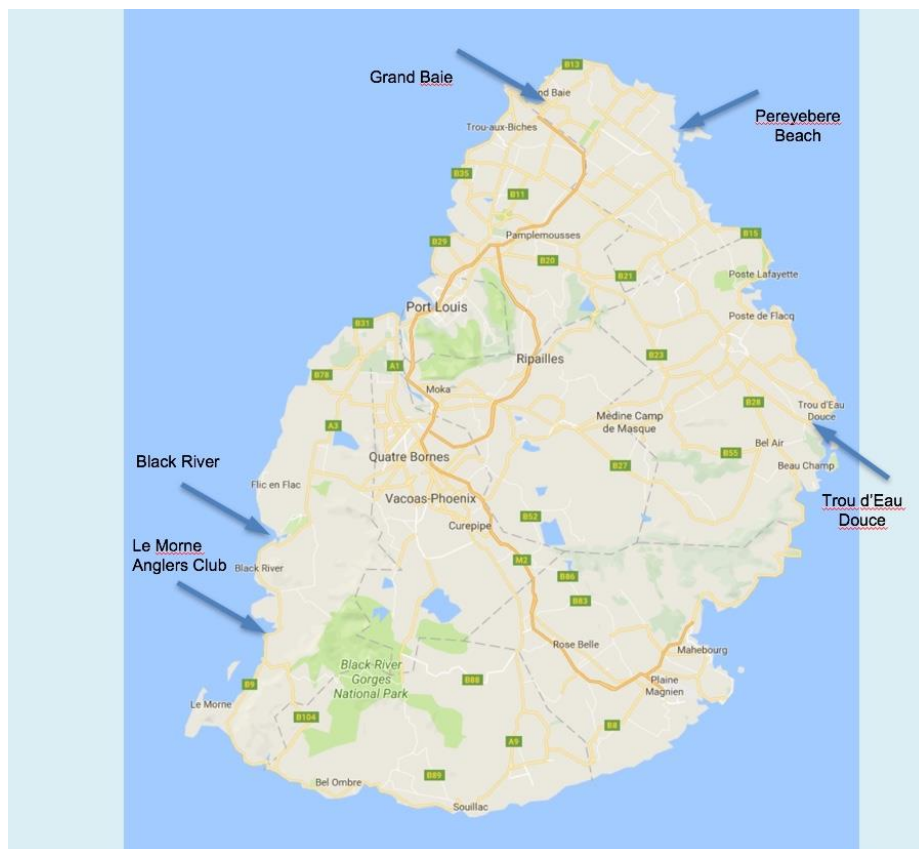
Marlin (usually smoked) is a staple on the menu at most restaurants and hotels in Mauritius which is not often the case in other areas. This suggested to be mainly frozen (-60°C) byproduct of foreign longliners which are required to sell bycatch in Mauritius including sailfish, dolphinfish, wahoo and swordfish. There are also five local longliners (<24 metres) that also supply the market. Others interviewed thought that charter boat operators selling their catch was also a significant

source of marlin consumed locally, including the product sold at the local market and supermarkets.

Even though an unrecorded proportion of billfish are released by charter boats, it appears that none take part in any tagging programs. One operator in particular indicated enthusiasm in becoming involved in tagging of billfish.

As indicated by an experienced captain, the general method of fishing for billfish in Mauritius is to stop the boat when a hookup occurs, with the captain inside the cabin rather than driving the boat from the flybridge. This would be considered rather unusual in other countries and likely to result in a higher rate of loss of hooked fish compared with the normal method of driving the boat from a higher vantage point and manoeuvring the boat in order to help the angler to retrieve line from time to time. Such subtle differences in fishing techniques would need to be taken into account if comparing catch rates of sport fishing in different countries of the Indian Ocean.

Map with key sport fishing locations mentioned





Clockwise from top left: 1. Clients being ferried to shore after a half day charter. 2. Part of the fleet of J.P. Henry at Black River. 3. Charter vessel of Royal Big Game Fishing. 4. Interview with owner of Le Performant game fishing company. 5. Meeting with Fisheries Research staff, Albion. 6. Interview with manager of Royal Big Game Fishing. 7. Wahoo and yellowfin tuna caught on half day charter.

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Survey design options

Understanding recreational (sport) fisheries involves a distinctly different scientific process compared to that of commercial fisheries research. Because recreational fishers participate for the primary purpose of recreation and social engagement rather than to harvest food (Henry and Lyle, 2003), they are generally not mandated to report on their activities, such as catch and effort. In many countries, recreational fishing is free and does not require a licence or permit, and thus there can be many thousands of undocumented participants distributed disparately in space and time (Cooke and Cowx, 2004). As a result, a census of fishers is generally not possible, or at least cost-effective. Instead, human populations are required to be sampled, from which individuals are self-identified as fishers, and requested to provide scientifically accurate self-reported information. Although fishers generally have no legal obligation to divulge fishing-related information, they often freely cooperate with researchers under a presumed moral obligation to provide useful information that can be used to ensure the long-term sustainability of fishery resources (Copeland et al., 2017).

Of course, the extent of, and motives for, cooperation and the ability to accurately recall specific details of fishing events (e.g. number of undersized fish released) can vary significantly among fishers (Tarrant et al., 1993). Therefore, understanding the psychology of fishers and being able to quantify and correct for specific cognitive biases – such as rounding large numbers in multiples of 5 or 10, or over-reporting catch numbers due to enhance one's social status among their peers – has been a necessary component of recreational fisheries research for increasing the accuracy and precision of self-reported data (Tarrant and Manfredo, 1993).

Recreational fisheries research therefore concentrates far more heavily on representatively sampling the demographic and behavioural characteristics of human populations, as opposed to the operational aspects and exploitation dynamics (e.g. gear selectivity, spatial fleet dynamics) that are often the focus of commercial fisheries research. As such, the methods required to sample recreational fisheries are quite different, and oftentimes more expensive to implement, to what would normally be used in the study of commercial fisheries.

Because entire recreational fishing populations cannot generally be surveyed by a census, sampling of the population is required. The sample is expanded to the number of participants in the fishery to provide estimates that are representative of the entire population. This normally involves a 'complimented' survey design, where for example, one method may be used to collect information from fishers (e.g. catch and effort), while a second method is used to estimate the total size of the population to which the information from the first survey method can be expanded to represent the overall population.

Traditional recreational fishing survey designs

A number of basic survey methods have been used to collect recreational fisheries data worldwide including mail surveys, door-to-door and telephone surveys, fisher diaries, and access point, roving, and aerial surveys. Pollock et al. (1994) details the full range of survey methods are used to gather catch, effort and socio-economic data from recreational fishers and their potential shortcomings. This short review aims to provide a basic overview of the main survey methodologies used to collect data on various aspects of recreational fisheries, with an emphasis on methodologies that may be applicable to large-scale jurisdictions such as the IOTC Area of Competence.

Survey methods used to collect recreational fishing data broadly fall into one of two categories, which largely depend upon where the data is collected. “Off-site” surveys are generally conducted away from fishing sites. They also rely upon the fisher to report their own catch and effort in the absence of a trained interviewer. The remaining three methods are commonly referred to as “on-site” methods because data is collected at the fishing site by trained survey staff. Historically, these methods have been used as stand-alone methods as they were initially developed for surveying fishers on relatively small water bodies. However, through time, there has been increasing need to survey larger-scale, and more complex, recreational fisheries. To effectively deal with these types of fisheries, it is now common practice to use a combination of basic survey methods, known as ‘complemented surveys’, such as using an on-site access point survey to estimate catch rates and an off-site telephone survey to estimate total effort in the fishery.

Whichever method is used, it is important to understand that the accuracy and precision of data collected will depend on the level of resources available, and will not be without uncertainty. Some of this uncertainty may arise due to variability in the data provided by fishers (non-sampling error), while other parts may be due to uncontrollable or unknown biases in the way the data are collected (sampling errors). It is important to understand the sources of uncertainty as this error can propagate through each stage of sampling and significantly bias the final estimates of important parameters such as total catch of a particular species (Pollock et al., 1994).

Off-site survey methods

Off-site surveys are undertaken away from the fishing site and generally involve selecting individuals from a list of participants (e.g. fishing licence holders), or ‘sampling frame’, and inviting them to complete a questionnaire by mail or telephone. Fishers can also be selected at the fishing site and invited to complete fishing diaries or questionnaires once they have left the fishing site. The primary advantage of off-site methods is that they can cost-effectively gain access to a large number of fishers, or sample across large spatial scales, where it may be cost prohibitive to have field staff at fishing sites. However, the main disadvantage is that they rely on fisher-reported data, for which the quality and legitimacy can often not be verified without conducting expensive ancillary surveys (Tarrant et al., 1993; Fisher, 1996).

Mail and telephone surveys

Mail and telephone surveys are two distinctly different survey methods, but are similar in that they both rely on a sampling frame whereby the researcher selects a representative sample of households in which to mail or call to administer a questionnaire. This can be done by using non-specific or specific sampling frames. A non-specific list frame may be a general population telephone directory, whereby a probability sample of households is selected to survey. A questionnaire is posted to the household, or residents called by telephone, in hope that at least one fisher resides in the household, and completes the questionnaire over the phone with a trainer interviewer, or returns the questionnaire to the researcher in the case of a mail survey. Although inexpensive, mail and telephone surveys using non-specific list frames often yield very poor response rates – particularly for specialised fishing activities – as eligible fishers generally reside in a reasonably low proportion of contacted households (Pollock et al., 1994).

In contrast, specific sampling frames are lists of individuals or households of direct relevance to the fishing activity of interest. For example, the Highly Migratory Species permit in the United States may be a useful list to access specialised fishers who target large pelagic species. Having access to specific list frames can significantly reduce the cost involved in contacting eligible respondents. However, in the case of mail surveys, response rates are often low due to the time burden to complete and mail the questionnaire back to the researcher. The percentage of surveys returned is generally not the main concern, but rather the potential difference in the types of responses between respondents and non-respondents, which can bias results if the two groups have different demographic and/or fishing characteristics. In contrast, once eligible fishers are contacted during telephone surveys, the response rate is generally high, often exceeding 90% (Weithman and Haverland, 1991; Lyle et al., 2002).

Both mail and telephone surveys are generally not suitable for collecting data for individual fishing trips. For mail surveys, this is due to the time required for questionnaires to be posted to and returned from recipients. For telephone surveys, it is costly to dedicate personnel to contact large numbers of fishers, particularly if non-specific list frames need to be used each time. Instead mail and phone surveys have generally been used for recall surveys, where fishers are asked to recall the details of specific trips over periods of weeks to months, and sometimes the past year. Unfortunately, recall surveys rarely yield reliable data due to problems associated with recall bias; the accuracy of specific details of a fishing event that progressively diminishes after around two months (Pollock et al., 1994; Hart and Reynolds, 2002). Other potential biases may also be apparent in particular fisheries, such as intentional deception and under-reporting where possession limits apply, or 'prestige bias' where fishers may intentionally exaggerate the number or size of fish caught.

Nevertheless, mail or telephone recall surveys may be a cost-effective method in some circumstances for collecting trip-specific data, such as in a fishery that extends across a large spatial scale where the target population has a complete list frame and targets trophy species where catches are reasonably infrequent and memorable, such as gamefish fisheries.

Telephone surveys are particularly useful for large scale recreational fishing surveys where the objective is to either estimate the total number of fishers in the general population, or as a screening tool to recruit fishers to more specific surveys like longitudinal diary surveys where trip-specific data is required (Henry and Lyle, 2003; Higgs and McInnes, 2003). However, in some countries like the United States, response rates in telephone surveys have been dramatically declining due to a number of factors including telemarketing saturation, suspicion by the public, and the attrition of home land-lines due to the increasing use of mobile phones (N.R.C. 2006).

One of the main problems with mail and telephone surveys is that even available specific list frames (e.g. licence holders) are often incomplete in terms of representing the full spectrum of fishery participants. For example, it is common for fishery agencies to grant licence exemptions related to age, race or socio-economic status (e.g. unemployed or pension). There are also fishers who simply do not purchase a licence and fish illegally. Therefore, not including 'out of frame' fishers in the sample can significantly bias survey results if their fishing activities differ from in-frame respondents (Ryan et al., 2009). Ancillary surveys using specialised sampling designs are therefore required to study out of frame fishers to resolve the bias, but adds significant expense to the research (Fisher, 1996; Teixeira et al., 2016).

Diaries and logbooks

Angler diaries (sometimes referred to as logbooks) are used when detailed information for individual fishing trips is required from a large number of fishers over a long period. Traditionally, diaries are supplied in paper form with instructions for the fisher to follow in data recording. When completed, the diaries are mailed back to survey staff. Despite being inexpensive and simple to apply, they have the disadvantage of collecting fisher-reported data. Problems associated with prestige bias, misidentification of fish species, and incorrect recording of fish lengths and weights can make the data unreliable if diarists are not sufficiently trained.

Recall bias can be a major problem in diary surveys but can be minimised if diaries are completed immediately after a fishing trip is completed. Non-response, decrease in participation, and accuracy/completeness of data are other common problems in voluntary diary surveys, especially when the survey period is long (Pollock et al., 1994). For example, in New Zealand, diarists admitted during an exit survey for the 2000–2001 national survey that they did not record all of their fishing trips or all of their catch (Gowing and Boyd, 2004). This is not only due to diarists simply forgetting to complete diaries, but also due to the time burden of completing too many data fields over a long study period.

In recent years there has been increased use of telephone diary surveys, particularly by Australian researchers, to reduce respondent burden and reduce some of the major biases such as recall bias (Webley et al., 2015; West et al., 2015; Lyle and Tracey, 2016). Instead of diarists receiving a physical diary to complete, survey staff maintain frequent contact with each diarist via telephone. When the diarist indicates an intention to undertake a fishing trip in the near future, the survey staff schedules a telephone call within days of the trip being completed. Staff then record all details of the fishing trip relating to catch and effort and other information pertinent to the particular study.

Charter logbooks

Sportfishing charter operations may fall between definitions of both sport and commercial fishing and are therefore not always included in recreational fishing surveys. Alternatively, they may be classed as commercial fishing and therefore included under mandatory commercial logbook systems.

Charter logbooks are physical books of forms, usually self carboning for multiple copies, that are designed to gather daily catch information. Electronic logbooks are increasingly being used in commercial fisheries, where submission of catch data is mandatory, but have not been widely used in sport fisheries.

Logbooks have been designed for use in sportfishing charter fisheries in a number of countries and jurisdictions. These have nearly always been designed for specific use for that fishery, not for merging with large commercial fishery databases as would ideally be the case of the current project. For example, New Zealand, New South Wales Fisheries, Australian Institute of Marine Science charter logbooks were primarily designed to record catch/effort information on billfish. Some jurisdictions require the mandatory completion of logbooks by charter operators, although if these are mixed fishing operations, they are not always useful for pelagic fish catches which may be rare events compared with demersal catches.

Door-to-door surveys

Door-to-door surveys are generally not considered to be a suitable option for surveying large-scale recreational fisheries as they are labour intensive, expensive and logistically cumbersome. However, in the case of IOTC Area of Competence, there may be countries where such a survey would be feasible and highly effective. Door-to-door surveys generally involve probability sampling of households within spatial strata using a list frame, which may be derived from licence or postal frames. Survey staff physically visit households and ask to interview eligible resident fishers. Similar to other off-site methods, the major disadvantage of door-to-door surveys is that data is recalled and self-reported, resulting in many of the aforementioned biases. However non-response bias is often greatly reduced compared to surveys conducted by phone or mail (Pollock et al., 1994). Although there have been reasonably few large-scale door-to-door recreational fishing surveys, probably due to high cost, the Ministry for Primary Industries in New Zealand recently employed the method in their national survey of recreational fishing. The main reason for choosing the method was to ‘future proof’ the survey design so that the results of future surveys could be comparable in the face of increasing non-response biases in other common survey methods such as telephone (Heinemann et al., 2015).

On-site survey methods

Creel surveys

Creel surveys are probably the most commonly used recreational fishing survey method, especially for specific fisheries in defined water bodies (Newman et al., 1997). Sampling involves survey staff intercepting fishers at specific times and locations to record data relating to completed or current fishing trip, such as catch and effort, and size of retained fish.

Creel surveys can take the form of an access point or roving creel survey. Access point surveys are useful where the majority of fishers use publicly accessible sites to access the fishery, such as public boat ramps, piers and marinas and where a limited number of access points exist that can be sampled adequately with available staff resources. In contrast, roving surveys are used when a fishery can be accessed from too many points that can be visited by a traditional access point design, or where there are inaccessible private access points. The roving creel survey involves survey staff stopping at designated access points on a predetermined time schedule. These surveys are conducted by boats to intercept on-water fishers (Pascoe et al., 2014), or by foot, bicycle or car to intercept shore-based fishers (Beckley et al., 2008; Smallwood et al., 2011).

Access surveys have a distinct advantage over off-site methods in that catches can be inspected by trained staff to collect accurate species and size composition data. Because fishers are generally interviewed on completion of a trip, recall accuracy of fishing effort and details of released fish can also be maximised. However, the main disadvantage of creel surveys is they are labour-intensive and expensive. A further disadvantage of roving creel surveys is that fishers are usually interviewed before their trip is complete, which can affect catch and effort estimates (Hoenig et al., 1997; Pollock et al., 1997). ‘Length of stay’ bias is a related problem whereby fishers who fish for longer periods – often more avid fishers – have a greater likelihood of being interviewed and thus bias effort and catch rate estimates.

As a result, most studies undertaken by fisheries agencies are small-scale or short-term ‘snapshots’ of the recreational catch (e.g. Malseed et al., 2000; Morton and Lyle, 2003; Steffe et al., 2005a; Steffe et al., 2005b; Rangel and Erzini, 2007; Smallwood and Sumner, 2007), but a few

multi-year studies have been completed (Steffe et al., 1996; McGlennon, 1999; Reid and Montgomery, 2005). However, when used in conjunction with well-designed less expensive off-site surveys (e.g. telephone and diary), detailed catch and effort information collected in on-site surveys can be scaled up to provide species-specific catch estimates for the entire recreational fishing community. Specific examples of these will be discussed in detail in Section 0.

Aerial surveys

Recreational fishing effort that is dispersed across very large spatial scales can be effectively quantified by aerial surveys counting boats and shore-based fishers (Hardie et al., 2002; Volstad et al., 2006). Aerial surveys are usually combined with another on-site method (e.g. creel survey) that can estimate catch rates, which can be scaled up to the effort estimated by aerial surveys (Hartill and Edwards, 2015). Aerial surveys are particularly useful for recording large numbers of fishers or boats over large geographic areas in a relatively short period of time.

The obvious disadvantage of aerial surveys is the high cost involved with the use of an aircraft, although the use of drones after thorough testing may dramatically lower costs (Kopaska, 2014). A number of factors have the potential to compromise fishing effort estimates from aerial surveys. For example, effort may be underestimated if fishers are obscured, or overestimated if counted boats are used for other activities other than fishing. The inability to fly on randomly selected days due to poor weather may also create bias (Fraidenburg and Bargmann, 1982).

Complemented survey designs

A complemented survey refers to the concurrent or sequential use of two or more survey methodologies. The primary reason for the use of two methods is that one survey method can account for some of the shortcomings of another. The primary use of complemented surveys in recreational fisheries is to estimate total catch and effort in large-scale fisheries with a large number of participants (Lyle et al., 2002).

The combination of methods used in particular studies varies depending on the fishery characteristics, availability of sampling frames, and the level of resourcing available. For example, studies in Canada (Hardie et al., 2002), the US (Volstad et al., 2006) and New Zealand (Hartill et al., 2008) used aerial-access point surveys to make instantaneous counts of all fishers from the air and concurrent access point surveys to estimate catch rates by intercepting fishers. The effort estimates derived from the air were used to scale up catch rates from the access point interview data to estimate the catch for the entire fishery.

In recent years, many of the large-scale recreational fishing surveys in industrialised countries have used what is referred to as the telephone-telephone diary approach (Henry and Lyle, 2003; USFWS, 2014; Rocklin et al., 2014). This is mainly owing to the growing number of studies refining the method to improve its cost-effectiveness and resolution of common sampling biases (Teixeira et al., 2016), and the availability of standardised analytical tools (Lyle et al., 2010). The approach consists of a general population telephone ‘screening’ survey where a random sample of households are contacted for the presence of eligible fishers, from which the participation rate is estimated. A subset of eligible fishers is recruited to a diary survey, usually for a period of one year, where diarists are requested to provide trip-specific details of their fishing activities. However, a telephone diary is used in conjunction with a traditional paper diary, whereby survey staff maintain contact with each diarist and record trip-specific information within days of each

trip being completed. This approach has been shown to reduce recall bias, respondent burden, and diarists exiting the survey before completion (Lyle et al., 2002). The high resolution data from the diary survey are expanded to the level of effort estimated from the telephone survey to estimate the total catch of species of interest.

Although the costs of a telephone-telephone diary survey are slightly higher than a traditional telephone-diary survey, the quality of data is greatly increased. Furthermore, one of the main disadvantages of the method is that species identifications and fish lengths cannot be verified from fisher-reported data. However, with increased use of smartphones, costs may be reduced if diarists can be periodically contacted by phone and directed to report their trip catch via a customised smartphone app (Papenfuss et al., 2015; Venturelli et al., 2016) or simple text messaging (Baker and Oeschger, 2009). Similarly, an app that allows photo submissions of captured fish alongside a scale reference, may alleviate data quality issues (Jiorle et al., 2016).

Case studies in gamefish fisheries

In the United States for example, the National Marine Fisheries Service (NMFS) conducts the Large Pelagics Survey (LPS) using a complemented survey design consisting of an access point survey to collect catch rates for large pelagic species – such as tunas, billfish, sharks, wahoo, and dolphinfish – from private and chartered vessels and a telephone survey using the Highly Migratory Species licence frame. Weekly or fortnightly telephone surveys are used to contact a subset of fishers on the licence frame list to estimate effort, which is scaled up to the size of the entire directory. The access point surveys are conducted on randomly selected days at randomly selected access points to collect catch and effort data from completed trips. This survey involves real-time monitoring of the fishery which is labour-intensive and therefore expensive, but produces reliable species-specific catch, effort and some size data.

In Australia, the New South Wales Department of Primary Industries Gamefish Tournament Monitoring Program uses a two on-site complemented survey approach to estimate catch rates for gamefish species caught only during major tournaments (Lowry and Murphy, 2003; Lowry et al., 2007). Data from scheduled hourly radio reports from game boats are used to record the fishing location and species-specific catch, estimated weights if not landed and whether fish were tagged. In most years, on-site interviews also take place at boat ramps, weigh stations and marinas to not only validate reported catches, but to also measure landed fish (length and weight). Unfortunately, this data is not representative of the catch or effort of the entire game fishing sector as it only covers club boats fishing in major tournaments. However, the data provides a standardised measure of catch rates, from same locations and time periods, which may provide an index or relative abundance for target species (e.g. tuna, billfish and sharks) and bait species (e.g. blue mackerel) (Lowry et al., 2006).

Novel survey designs for specialised recreational fisheries

The increased availability and affordability of new fishing technologies has led to a rapidly diversifying recreational fishery whereby fishers are increasingly efficient at targeting and catching species that were not previously accessible by recreational fishers (Griffiths, 2012). These specialised fisheries, like gamefish fisheries, are often comprised of a relatively small number of participants relative to the broader recreational fishery, but are likely to make a disproportionate contribution to the total recreational catch of species of IOTC managed species, such as striped

marlin. This poses a significant challenge for researchers who are tasked with cost-effectively gathering representative catch, effort and size frequency data from these small but important fisheries.

The traditional survey approaches previously discussed are primarily designed to gather general recreational fisheries data. For highly specialised sport fishing, alternative survey methods that are specifically tailored to the particular fishery are required to overcome the low probability of encountering specialised fishers in general population surveys. As such, for fisheries that incorporate multiple jurisdictions, it is critical that either the relevant jurisdictions recognise the need for information about the fishery as a whole and collaborate in collecting data or the IOTC facilitate targeted cross-jurisdictional surveys of species for which they have management responsibility.

Researchers in Australia in particular have begun to explore new cost-effective survey methods for sampling 'hard-to-reach' specialised recreational fishers (Griffiths et al., 2010a; Griffiths et al., 2010b; Zischke and Griffiths, 2014). Two methods that have been identified that may be of relevance to recreational fisheries are Respondent-Driven Sampling (RDS) and Time-Location Sampling (TLS). Both methods have been widely used in epidemiology and social sciences to access members of populations who are rare, hidden, or physically difficult to locate within the general population, such as the homeless and illicit drug users (see reviews by Magnani et al., 2005; Griffiths et al., 2010c). Although these methods are still in various stages of development, after adequate testing they may be useful alternatives to expensive traditional survey approaches.

Time-Location Sampling

Time-Location sampling is a method that may be used to cost-effectively sample hard-to-reach components of recreational fisheries. Many hard-to-reach populations tend to gather or congregate at certain types of locations at particular times. For example, epidemiologists found that hidden populations of illicit drug users tend to congregate at specific locations where drug or needle transactions take place, and most often during the night. TLS capitalises on such predictable behaviours of the target population, whereby a researcher identifies aggregation sites within a study region, or sampling 'universe', and a subset of the sites is chosen as a probability sample (Muhib et al., 2001; Stueve et al., 2001). The researcher then interviews individuals entering or leaving a sampling site within a pre-defined sampling interval (e.g. a randomly chosen 3-hour period on a randomly chosen day).

TLS is a similar concept to traditional recreational fishing access point surveys. However, access point surveys at boat ramps, for example, can only account for fishers who fish from vessels that can be launched from a trailer. Land-based fishers and fishers owning larger vessels berthed in marinas, on moorings or on private property are missed using boat ramp access point surveys. This may cause a significant bias in total catch and effort estimates for the overall fishery if the fishing characteristics of each component differ. In contrast, TLS may be used to sample the specialised component of the fishery if locations can be found where a representative cross-section of all fishers congregates. One such approach is to conduct a survey of customers at fishing tackle stores, since most fishers, regardless of ability, fishing experience, avidity or mode of fishing, need to purchase fishing tackle at some point. TLS was shown to be an effective sampling method in a national survey of fishers who target Longtail Tuna (Griffiths et al., 2010b), as well as a survey of offshore sport fishers in southeastern Queensland (Zischke, 2013).

Respondent-driven sampling

RDS is a non-random chain-referral sampling method, similar to that of snowball sampling, that works by an initial set of subjects from the target population – or “seeds” – receiving a small number (e.g. 3-5) of uniquely coded coupons to pass on to eligible peers within a target population. Subjects receiving a coupon contact the researcher, complete a survey, are provided with a small reward for completing the survey, and serve as the first ‘wave’ of recruits. Each recruit is provided with coupons and offered small incentives to recruit further subjects. This process continues, creating rapidly expanding recruitment chains until the sample is considered ‘stabilised’, whereby the proportion of groups within the population (e.g. males and females) defined *a priori* varies by less than 2% in the overall sample, regardless of how many further waves are recruited (Heckathorn, 1997; Salganik and Heckathorn, 2004). The final sample is then modelled with appropriate sample weightings to compensate for the non-random sampling of subjects and the various biases introduced by the tendency of subjects to recruit peers with similar characteristics similar to themselves (Heckathorn, 1997;2002). At this point, the post stratified sample is considered to have a sample composition that is representative of target population.

Because respondents are responsible for recruiting eligible peers, a sample can be cost-effectively obtained from populations that are hidden, rare, or only accessible by insiders (Wejnert, 2009). The efficacy of RDS can be attributed to its dual-incentive recruitment process that creates group-mediated social control – a form of peer pressure – strengthened by the desire of recruiters to redeem their reward (Heckathorn, 1990). Therefore, non-response bias is often very low and also not skewed towards more affluent peers, since subjects who may have little interest is recompense often participate as a favour to a peer (Magnani et al., 2005).

Although RDS has not yet been used in recreational fisheries research, a current project in Australia is trialling RDS on various specialised recreational fisheries in Tasmania (Griffiths et al., 2015). If successful, there may be options to further decrease the cost of RDS surveys and increase recruitment speed in future using online implementation of RDS (see Wejnert and Heckathorn, 2008). Despite the apparent efficacy of RDS in other disciplines, RDS would require pilot studies in major recreational fishing locations before considering widespread implementation throughout the IOTC Area of Competence.

Recommended methods for the pilot study

Having reviewed the range of methods available for collecting catch and effort data for sport fisheries, having visited each of the four countries to examine sport fisheries, and cognisant of funding and resource limitations, the recommended methods for collection of sport fishing catch and effort data for all four countries are as follows:

Charter fishery log book

Instigate a charter logbook. The logbook would be consistent across each country. National Fisheries officers would collect the logs once per month by one of four methods, or a combination:

1. Telephone the charter operators and enter data to Excel

2. Face to face visit, transcribing manually completed data on log sheets to Excel on the spot, or taking copy of log back to office for later entering.
3. Receive manually completed log sheets through the mail and transcribe to Excel
4. Receive Excel files emailed from charter operators

Receipt of electronic files would be the most cost-effective method of receiving data but some ongoing contact with charter operators would still be highly desirable to maintain their willingness to continue to provide log sheets on a voluntary basis.

A charter fishery logbook is strongly recommended for the following reasons

Charter operators are often familiar with filling in daily catch records if fishing in other jurisdictions, or through keeping their own records in the form of a personal log or diary. In the case of La Réunion, captains and/or operators are required by law to complete a daily log, since they are regarded as commercial fisheries. The forms can be filled in manually, and copies kept by the operator for his/her own records, which is an incentive. Alternatively (and preferably), operators could complete the log on a PC. As noted further in the report, the proposed electronic log has been carefully designed for ease of use by charter operators with respect to completing for each day's fishing, for exporting to the relevant fisheries agency and for retaining electronic copies for their own use.

Pros

There are, coincidentally, about 40 sportfishing charter vessels active in each of the four countries. This is not a large number to service on a regular basis, especially if at least some of the data were routinely entered digitally by the operators themselves. Also, in each country, some companies own and operate more than one boat, in which case, obtaining log sheets would be facilitated through cooperation with such companies.

It is estimated that the time taken for one Fisheries officer to collect data from the charter fleet in each country (assuming a mix of the methods of data collection listed above) would amount to perhaps 5 days per month. This would be less if all data were collected by telephone (say, 3 days per month) or if much of the data were emailed (or mailed) by the charter operators themselves (say, 3 days per month). This would be time well spent since the National Fisheries organizations would be able to retain previously unavailable data for their own management purposes.

The resultant data from the logbooks would be readily transferred to the IOTC fisheries database.

Provides very good catch effort data of the charter sector, broken down to individual fish if necessary.

Cons

Because completion of logbooks by charter operators would not be mandatory, it is unrealistic to expect that all of them will provide the data. This is not a major problem though since the log sheets that are completed, provided that they represent a cross section of the fishery, can be used to extrapolate to the rest of the fleet, with appropriate caveats etc.

A charter logbook should provide reliable estimates of the total catch, catch per effort and size composition of the catch of the sportfishing charter fleet in each country. However, it will not

deliver an estimate of total catch by the entire sportfishing sector since private boats which also undertake some directed fishing towards the pelagic species of interest in each location would not be covered by the logbook system. Even so, some assumptions could be made regarding the relative fishing efficiency of the charter vs the private sectors and an order of magnitude estimate of total catch could then be made.

Private fishery survey

If a more complete estimate of the total sport fishing catch of not just the charter sector, but also the private sportfishing sector in each country is deemed highly desirable, a specifically designed survey of that sector is recommended.

The lowest cost survey would take the form of a 'snapshot' telephone survey of owners of private boats. Fortunately, licence frames exist in each of the pilot countries which would obviate the need for a general screening telephone survey to 'find' owners of sport fishing boats (which can be very expensive). Using the appropriate licence frame, a stratified random sample of boat owners would be contacted.

Each boat owner would be asked a series of questions regarding their fishing activities in their respective country over the past 12 months. In its simplest form the survey would ask:

- Have you fished on your boat for billfish, tuna, mackerel or other pelagic fish in the past 12 months?
- If so, how many days did you fish?
- How many fish did you catch? (checked from a provided list; size of fish would also be elicited).

Of course, more questions could be asked for information of particular interest to the country Fisheries office.

Of the four pilot countries, it is considered that La Réunion would benefit most from such a survey since the number of private boats there is very large (thousands), and the proportion that may catch pelagic species, while unknown, may also be high (possibly hundreds of boats). Also, as noted in the country report for La Réunion, the professional charter boats that cater to sport fishing clients already complete daily logbooks, although these data are not currently separated from overall professional catch data. If separation of such data were to occur, then a snapshot survey of the potentially large number of private vessels would provide a single annual estimate of the overall catch and effort of IOTC species by this hitherto unknown sector.

Pros

Once designed, a snapshot survey can be conducted quite quickly, and would provide catch, catch and effort and possibly size data from a previously cryptic sector of the sport fishery.

The numbers of private sport fishing boats in each of the pilot countries that would be included in the 'universe' of boats that target or catch billfish, tuna and other pelagic species at least sometimes are not large – of the order of perhaps 100 at the most (although in the case of Reunion, due to the large 'population' of private boats, a larger snapshot survey may be necessary depending on the actual proportion of private boats that do target the key pelagic species.

Cons

A proportion of boat owners may not own a phone (this would be readily checked on the licence database, and it is considered likely that a high proportion would in fact own a cell/mobile phone)

Respondents who are asked to recall fishing activities over the past 12 months may provide biased data due to either lack of recall of events or to ‘telescoping’ of recall – ie, including events that occurred more than 12 months ago. (It is because of these potential biases that large scale recreational fishing surveys in Australia have been designed to have respondents keep a diary of their fishing activities, and then to report those data via monthly phone calls from a survey operator).

Funds would need to be allocated for such surveys. Assuming a cost of, say, \$50 to \$100 per interview (although this may be lessened if using National Fisheries officers to conduct the interviews), a snapshot survey in each country might cost of the order of \$15,000 to \$20,000. More accurate surveys conducted monthly over a 12 month period would, of course, cost considerably more.

Training

Following the design of the log sheets and thorough testing on different platforms, training modules were designed to be delivered to National Fisheries Agency staff, and to operators of sportfishing charter boats in each of the four countries. These modules consisted of:

National Fisheries Agencies Package

Module 1: Introduction

- Background
- Purpose of project
- Outputs from project
- Methods of collection of sport fishing data
- Results of country visit
- Recommendations
- Challenges

Module 2: The electronic logbook

- Logsheet flow chart
- Step by step completion of logsheet
 - Vessel and operator information
 - Entering trip information (catch, retained, discarded alive/dead)
- Submitting monthly data
- Resetting for next month of trips

Module 3: Compiling and exporting data to National Fisheries database, and to IOTC

- Logsheet flow chart
- Exporting data by National Fisheries officers
- Catch summary and error checking
- Catch export
- Importing data to National Sportfishing Database
- Performing data queries and exporting to IOTC

Charter Operators Package

Module 1: Introduction

- Background
- Purpose of project
- Outputs from project
- Methods of collection of sport fishing data
- Results of country visit
- Recommendations
- Challenges

Module 2: The electronic logbook

- Logsheet flow chart
- Step by step completion of logsheet

- Vessel and operator information
- Entering trip information (catch, retained, discarded alive/dead)
- Submitting monthly data
- Resetting for next month of trips

The full training modules can be downloaded at: XXXXXXXX

A detailed training manual for the use of National Fisheries officers was designed and is available at XXX

The training trip was scheduled to take place between 13 August and 8 September 2017 and was still in progress at the time of writing this report, so results and outcomes from this part of the project are unable to be included here. The report will be updated on completion of the training program.

Presentation to the IOTC Working Party on Billfish

A summary of the project will be prepared for presentation to the IOTC Working Party on Billfish meeting (WPB15), San Sebastian Spain, 10-14 September 2017.

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