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REVIEWS

Status and challenges for sustainable billfish fisheries in the Western Indian Ocean

N. I. Kadagi · N. Wambiji · B. Mann · D. Parker · R. Daly · P. Thoya · D. A. M. Rato · J. Halafo · L. Gaspare · E. A. Sweke · S. Ahmed · S. B. Raseta · M. Osore · J. Maina · S. Glaser · R. Ahrens · U. R. Sumaila

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Abstract Billfish species (families Istiophoridae and Xiphiidae) are caught in artisanal, recreational, and commercial fisheries throughout the Western Indian Ocean region. However, data and information on the interactions among these fisheries and the ecology of billfish in the WIO are not well understood. Using an in-depth analysis of peer-reviewed articles, grey literature, observation studies, and authors' insider knowledge, we summarize the current state of knowledge on billfish fisheries in 10 countries. To describe historical and current trends, we examined fisheries statistics from governmental and non-governmental agencies, sportfishing clubs' reports, diaries of sportfishing captains, and the catch and effort databases of the Indian Ocean Tuna Commission. We highlight two key points. First, billfish fisheries in the Western Indian Ocean are highly diverse, comprising two distinct segments—coastal and oceanic. However, data are poor for most countries with significant gaps in information especially for sport and artisanal fisheries. Second, the evidence assembled showed that billfish species have immense social, cultural, and economic value. Swordfish are targeted by both

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N. I. Kadagi (✉)
World Wildlife Fund, Washington, DC, USA
e-mail: nelly.kadagi@wwfus.org

N. Wambiji · P. Thoya · M. Osore
Kenya Marine and Fisheries Research Institute, Mombasa, Kenya

B. Mann · R. Daly
Oceanographic Research Institute and South African Association for Marine Biological Research, Durban, South Africa

D. Parker
Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa

P. Thoya · J. Maina
Department of Earth and Environmental Sciences, Macquarie University, Sydney, Australia

P. Thoya
Institute for Marine Ecosystem and Fisheries Science, Center for Earth System Research and Sustainability (CEN), University of Hamburg, Hamburg, Germany

P. Thoya
Leibniz Institute for Baltic Sea Research Warnemuende (IOW), Rostock, Germany

D. A. M. Rato
Fishbazaruto, Inhambane, Mozambique

J. Halafo
Mozambique Oceanographic Institute (InOM), Maputo, Mozambique

L. Gaspare
University of Dar es Salaam, Dar es Salaam, Tanzania

large-scale and semi-industrial fisheries, while other billfish species, particularly marlin, are highly sought after by sport fisheries in most countries. Our paper provides a comprehensive review of billfish fisheries and available information in the context of the WIO underscoring the need to strengthen data collection and reporting, citizen science, and collaborative sustainable development and management of billfish.

Keywords Billfish · Data–poor fisheries · Food security · WIO · Sustainable fisheries · Recreational fisheries · Blue economy

Introduction

The socio-economic and cultural importance of billfish species in the Western Indian Ocean (WIO) region has increasingly received attention (Harris et al. 2013; Pepperell et al. 2017; Kadagi et al. 2020). Historically, these valuable fisheries are highly sought after by sport fisheries in several WIO countries such as Kenya (Ndegwa and Herrera 2011; Ndegwa and Kirathe 2015; Kadagi et al. 2021a, b), Mozambique (Mutombene 2013; Chassot et al. 2019), La Réunion (Fleury et al. 2012) and South Africa (Dunlop and Mann 2013). Billfish are also caught in artisanal fisheries for food and income while swordfish are commercially important in large-scale industrial fishing fleets. Despite their significance, detailed knowledge of billfish species and associated fisheries remains limited in most countries across the WIO compared to other regions (Kadagi et al. 2011; Rohner et al. 2020; 2021).

The WIO region, for this review, falls within Food and Agriculture organization (FAO) Fishing Area 51 comprised of 10 countries: Somalia, Kenya, Tanzania, Mozambique, South Africa, Madagascar, Seychelles, Comoros, Mauritius, and the French territories (La Reunion and Mayotte) (Fig. 1). Six billfish species, belonging to Family Istiphoridae and Ziphiidae, occur in the WIO region: sailfish (*Istiophorus platypterus*), blue marlin (*Makaira nigricans*), black marlin (*Istiompax indica*), striped marlin (*Tetrapturus audax*), swordfish (*Xiphius gladius*), and the short-billed spearfish (*Tetrapturus angustirostiris*) (Harris et al. 2013; Kadagi et al. 2011; Harris et al. 2013; Pepperell et al. 2017; Kadagi et al. 2020). Stock assessments in the Indian Ocean reveal declining populations with several species harvested at over capacity (Yokoi and Nishida, 2016; Pons et al. 2017; FAO 2018; IOTC, 2019, IOTC-WPB17, 2019, IOTC 2020). To reduce overfishing, the Indian Ocean Tuna Commission (IOTC) adopted Resolution 18/05 to maintain annual species-specific catches below their estimated Maximum Sustainable Yield (MSY) (IOTC 2018; Sinan and Bailey 2020). The IOTC Scientific Committee recommends that annual species-specific

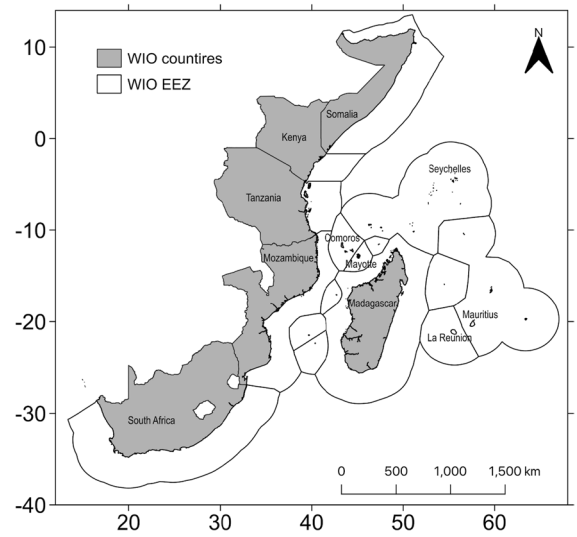

Fig. 1 The Western Indian Ocean: Somalia, Kenya, Tanzania, Mozambique, South Africa, Madagascar, Mauritius, La Reunion, Mayotte, and Comoros

E. A. Sweke
Deep Sea Fisheries Authority, Zanzibar, Tanzania

S. Ahmed
University of Dodoma, Dodoma, Tanzania

S. B. Raseta
BILLFISH-WIO Project, Zanzibar, Madagascar

S. Glaser
World Wildlife Fund, Washington, DC, USA

R. Ahrens
Pacific Islands Fisheries Science Center, National Marine Fisheries Service, 1845 Wasp Blvd., Building 176, Honolulu, HI 96818, USA

U. R. Sumaila
Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, Canada

catches, across all fisheries, should not exceed limits as follows: striped marlin—3260 tonnes; black marlin—9932 tonnes; blue marlin—11,930 tonnes; Indo Pacific sailfish—25,000 tonnes (IOTC 2018). Despite these restrictions, the most recent stock assessments of blue marlin (Parker et al. 2019) and striped marlin (Parker et al. 2018a) for the Indian Ocean indicate a high probability that these species are "overfished" (87%) and currently "subject to overfishing" (99%), respectively. The assessment for black marlin was inconclusive largely due to poor quality input data (catch and catch per unit effort (CPUE)) (Parker et al. 2018b) while swordfish were assessed "not overfished or subject to overfishing" (Parker 2020).

Data on billfish species suffer from a host of challenges: poor reporting, incomplete coverage, aggregation of billfish species into one group, and misidentification of fish. This limit understanding of stock dynamics from a historical and contemporary perspective (Fiorellato et al. 2018). Relatedly, billfish in the WIO have attracted minimal fundamental research on the magnitude and extent of fisheries interactions, their biology, their movements, or the need for sustainable management for several reasons. First, most billfish species are considered bycatch in large-scale industrial fishing fleets which undermines their socio-economic contributions, resulting in under-reporting of catches. Second, historical, and contemporary billfish landings and catches, especially for recreational and artisanal fisheries, are poorly documented in the WIO region, and therefore the impacts of fishing mortality remain unknown. Third, the transnational nature of billfish distribution and migration complicates national-level assessment and requires considering fisheries impacts across national jurisdictions. Similarly, country-specific data are insufficient for determining the historical patterns of billfish species and their socio-economic significance at local levels. Though IOTC, through the Working Party on Billfish, has made efforts to promote data collection and reporting for billfish by Member States and Contracting Parties (CPCs), official statistics reveal underreporting and a general lack of data and information from many WIO countries.

Billfish catches in the WIO region rapidly increased between 1950 and 2019 (Figs. 2, 3). Swordfish catches dominated the total billfish catch during 2010–2019 (Figs. 2a, 3a). Other billfish species were caught as bycatch in industrial fisheries (Figs. 2b, 3).

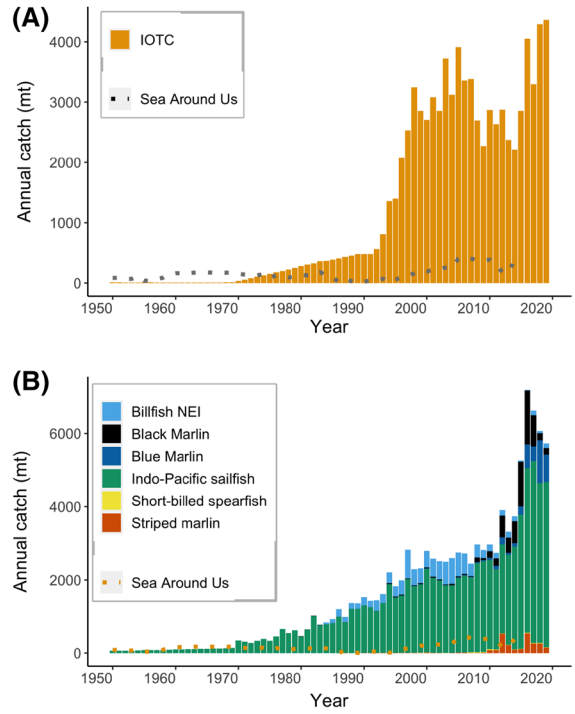

Fig. 2 **a** Annual reported and unreported catches of swordfish and **b** other billfishes in the Western Indian Ocean (FAO Area 51) between 1950 and 2019. Dotted line shows unreported catches estimated by Sea Around Us *Source* IOTC and Sea Around Us databases

While swordfish are easiest to identify, the species composition of other billfishes in industrial fisheries is difficult to quantify. As a result, the quality of data on marlins and sailfishes is still poor and resulting stock assessments are widely uncertain. In general, there is underreporting of swordfish and other billfish species as depicted by the estimates of unreported catches from Sea Around Us (Fig. 2). These challenges are replicated in artisanal, recreational and sport fisheries; consequently, the need to improve sport fisheries data resulted in the development of a regional project by IOTC to strengthen data recovery from sports and other recreational fisheries (Pepperell et al. 2017).

Given these challenges, this paper presents a comprehensive overview of billfish fisheries in WIO countries with two objectives. First, we document the available historical data and local ecological information. Second, we identify knowledge gaps and contribute to the ongoing discourse on rebuilding sustainable fisheries at local and regional levels,

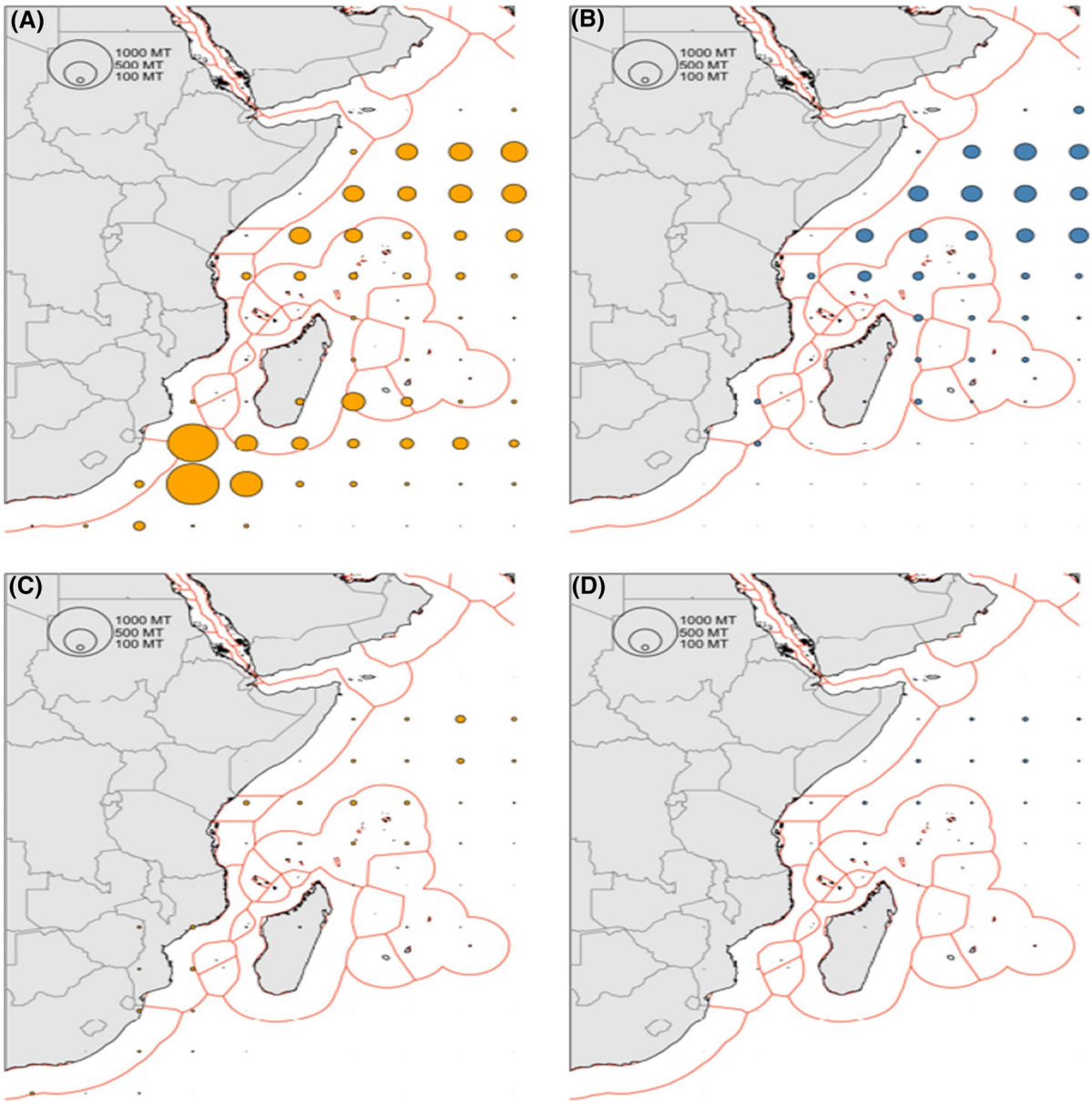

Fig. 3 **a** Average longline annual catch (2010–2019) in the IOTC spatial catch and effort database of swordfish (orange) and **b** other billfish (blue). Panels A and B are for non WIO countries (foreign longline fishing fleets) combined, and panels C and D are WIO countries combined

especially for transboundary species. Information and data were gathered from a wide range of sources including peer-reviewed literature, reports, databases, experts' viewpoints and experiences, and 'grey' literature. Limited information on billfish species in the WIO has been published in peer-reviewed literature. Therefore, this review relied heavily on screening of keywords in technical reports, government documents, National Reports to IOTC, working papers, and other reports from the different countries. Fisheries statistics summarized in this paper were obtained from government and non-governmental agencies. For reported and unreported billfish catches, we used the Indian Ocean Tuna Commission (IOTC) and Sea

Around Us statistics for Indian Ocean Major Fishing Area 51, focusing on the study countries (Figs. 1, 2 and 3). Unpublished tagging data for billfish was provided by the African Billfish Foundation (ABF) and the Oceanographic Research Institute (ORI). Additionally, we obtained data from individual captains and annual reports from sport fishing clubs.

Our paper is divided into six sections. Following the introduction, section two explores billfish fisheries in the WIO region, including the prominence of sport fishing for billfish in several countries and the role of tagging programmes in data collection. Section three examines billfish fisheries on a country-by-country basis. Section four focuses on the interactions of foreign industrial longline fleets with billfish species in the study area while sections five and six delve into the research and management recommendations in a changing world.

Billfish in the WIO region

Six billfish species are documented in the WIO, of which the sailfish, black marlin, blue marlin, swordfish, and striped marlin are mostly widely distributed. Limited information exists for the short-billed spearfish (Kadagi et al. 2020). Billfish species are mostly sought after in recreational and sport fisheries in Kenya, Seychelles, Mauritius, Mozambique (Pepperell et al. 2017). Billfish are also caught in artisanal fisheries as either a target or opportunistic species, providing a source of food and income (Kadagi et al. 2020). Swordfish are commercially important, while marlin and sailfish are regarded as bycatch in industrial fisheries. Seasonal patterns of billfish fishing in the WIO region are characterized by a reversing monsoon wind system consisting of the northeast and southeast monsoons (Williams 1970; Harris et al. 2013; Kadagi et al. 2020). The northwards and southwards winds occur at different times of the year resulting in meso-scale processes that determine productivity of fisheries (Jebri et al. 2020). The northeast monsoon, which lasts from around November to March, determines two types of billfish runs: the sailfish run (November to January) and the marlin run (January to March) (Howard and Starck II 1975; Adibi et al. 1977; Kadagi et al. 2020).

The WIO region has a long-established and internationally recognized recreational and sport fishery particularly in Kenya, Seychelles, Mozambique, Mauritius, La Reunion, and South Africa (Pepperell et al. 2017; Kadagi et al. 2021a, b). Sport fishing clubs, tagging programmes and individual captains have kept detailed records of billfish catch, tag and release for several years. Sportfishing charter boats dominate tagging efforts while private or recreational boats take part in tournaments which provide an incentive to tag billfish and collect data. Most sport and recreational billfish fisheries target all billfish species, though the species vary with place and months.

Conventional tags have been deployed on various billfish species in the WIO from programmes led by the ABF, ORI, and The Billfish Foundation (TBF) (Romanov 2016; Pepperell et al. 2017). These tagging programmes aim to provide information on the migratory patterns, movement, and (in some cases) growth and length of time at sea, utilization across depth ranges, and vulnerability of the species (IGFA 2020). Between 1998 and 2018, pop-up archival and MiniPAT tags were deployed on billfish in Kenya, Seychelles, La Reunion, South Africa, Mozambique, and Mauritius (Romanov 2016). These were funded by various entities including the Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), International Gamefish Association (IGFA), Stanford University, Institut de Recherche pour le Développement, France (IRD), and private sponsors (Dunlop et al. 2013; IGFA 2016; Rohner et al. 2021). Recoveries of tagged billfish have revealed movement information, especially the distance covered by these species. Black marlins tagged in Kenyan and Western Australian waters were recaptured off Sri Lanka (Pepperell 2013). Some of the pop-up archival tags deployed on marlins in Kenyan waters have popped up several thousands' nautical miles away from the deployment location. For example, a satellite tag deployed in Kenya on a black marlin popped up in the Gulf of Aden with the fish swimming a distance of 1108 nm for 46 days (IGFA 2016). Tagging data have also been used to understand the stock structure of species. Black marlin has been reported to have different stocks between eastern Australia, Western Australia, and Taiwan. It is still a mystery whether the billfish stocks in the central Pacific Ocean, eastern Pacific Ocean, northern Indian Ocean, or WIO are genetically similar or not (Williams et al. 2015). Recently it was confirmed that black marlin was split into three genetic stocks namely in the Indian Ocean,

South Pacific Ocean, and North-west Pacific Ocean (Williams 2018).

Despite these advances in our ability to collect information from tags, published studies on billfish fisheries in the WIO region are considerably limited. While some grey literature exists, such as National Reports to IOTC, national marine framework surveys, or reports from sport fishing clubs are available, much of the information on billfish in the WIO remains inaccessible. In the ensuing section, we turn our attention to historical perspectives in WIO countries.

Billfish fisheries in the WIO region summarized by country

Somalia

At 3300 km, Somalia's coastline is the longest in mainland Africa. While photos of Somali fishers carrying billfishes on their heads through the streets of Mogadishu are iconic, there is limited historic catch data (van der Elst 1997). Estimates put the number of domestic fishers between 4500 and 9500, and these mostly target tuna or coastal demersals (Hassan and Tako 1999; Sumaila and Bawumia 2014). Foreign purse seine and longline vessels target migratory tuna stocks near the Somali EEZ boundary (Glaser et al. 2019), and this fleet also captures billfishes. Historical catch reconstructions suggest the Somali domestic fleet landed just under 20,000 mt (of all fishes) per year in 1950, and total landings rose to 54,000 mt per year by 2014 (Cashion et al. 2018). About 5% of total catch by the artisanal domestic fleet consisted of billfishes, equivalent to 2700 mt per year with an estimated annual catch of swordfish at 393 tonnes (Persson et al. 2015).

Billfish have been documented in Somalia's inshore waters on the north and east coasts by both industrial boats (mainly fishing illegally) and artisanal fishers using handlines and gill nets (Musse and Mahamud 1999). Landings of swordfish and sailfish have been verified by photographs, and blue and black marlin have been reported anecdotally (SG, pers. comm.). Species-level catch compositions have not been published, but recently established data collection projects could shed light on this question in the near future.

Kenya

Documented billfish catch in Kenya dates to the 1950s during the days of Ernest Hemingway fishing on the East Coast of Africa (Williams 1970; Howard and Starck II 1975; Kadagi et al. 2020). A tagging programme was first initiated in 1963 to understand the movements and growth rates of tuna and billfish (marlin and sailfish) in Kenyan waters under the East African Marine Fisheries Research Organization (EAMFRO) laboratory in Zanzibar (FAO 1969). Tagging equipment and instruction leaflets were distributed to fishing clubs, hotels, and sport fishers along the Kenya coast. Further, fish in good condition were tagged during pelagic longlining operations by the *Menika II*, the government research vessel, and the *Manihine*, the research vessel belonging to the EAMFRO.

In the 1950s, the Malindi-Lamu area was the main recreational fishing site due to the abundance of all pelagic fishes, ranging from small pelagic sardines and anchovies to the large pelagic billfishes (Williams 1970). Over 50% of the total recreational catch in Kenya is composed of billfish species (Le Manach et al. 2010; Kadagi et al. 2011); sailfish are the most sought by sports fishers and make up to 30% of the total catch. Most sailfish catches occur from November to February, peaking between November and January (Williams 1970; Ndegwa and Herrera 2011). The marlin, specifically, the black marlin, are caught during two runs, first from January to March with a peak in February, and second from July to September with a peak in September. The blue and striped marlin are also targeted in recreational and sport fisheries between December and March when they are most abundant (Ndegwa and Herrera 2011). Past studies by William (1970) have linked the occurrence of billfish to high primary production rates throughout the year with the northeast monsoon season having the highest biological productivity.

Sport fishing for billfish in Kenya is mostly done from between July/August and April using hook and line as the main fishing gear (Le Manach et al. 2010; Kadagi et al. 2020). The fishery consists of private and charter sportfishing boats that operate, on average, between 96 and 120 trips per year. The season varies among charter sportfishing operators and ranges from 75 to 180 days (Pepperrell et al. 2017). Between 2016 and 2017, Pepperrell et al.

(2017) noted that about 40–60 charter sportfishing boats operated along the Kenya coast, with a few other private boats. Boats ranged from 5 to 12 m long and were medium to highly mechanized. Sport fishing centres are mostly concentrated in Watamu, Malindi, Kilifi, Diani, Shimoni and Mombasa with coordinated annual tournaments and competitions conducted in Malindi, Watamu and Diani (Abuodha 1999; Kadagi et al. 2020). Further, Malindi and Watamu are known as two of the top billfish destinations on the East coast of Africa, among the few game fishing destinations where an angler has a likelihood of catching a 'fantasy slam' (five different billfish). The first record of a fantasy slam was in 2005 and two other fantasy slams occured in 2009.

Since the early 1980s, the Kenya billfish sportfishing community has predominantly practiced catch and release culture (Kadagi et al. 2011; Ndegwa and Kirathe 2015). The emergence of catch, tag and release followed the establishment of the ABF in the late 1980s. ABF is a private organization that has operated a large pelagic fish tagging program for over 30 years. The ABF mainly collects data on billfish that are tagged and released as well as reported recaptures across the Western Indian Ocean waters, although other species such as giant trevally, sharks and rays are tagged (Wambiji et al. 2022). Over 60,000 fish have been tagged to date, with close to 3,000 tag recoveries mostly from artisanal fisheries across the East Africa coastal waters (ABF, *unpublished data*).

Sport fishing landings, particularly for billfish, have generally declined in the last 10 years. Ndegwa and Kirathe (2015) reported about 138 tonnes in 2013 and 18 tonnes in the year 2014. Similarly, sport fisheries data reported to IOTC between 2010 and 2019 indicate fluctuations in catches with an average billfish catch of 43 tonnes, comprising mostly sailfish, with the highest catch of 115 tonnes in 2017. The decrease in landings is potentially due to a reduction in tourism in the main sport fishing centers of Watamu and Malindi in the past seven years (Kadagi et al. 2020). Consequently, several sportfishing charter operations have closed their businesses or moved to other fishing areas because of decreased international tourism. International travel advisories in response to the state of security, such as after terrorist attacks, have a direct effect on tourism and recreational fishing (Abuodha 1999; Ndegwa and Okemwa 2015).

Billfish catch has also been reported in pelagic longline vessels in coastal and offshore waters of Kenya since the 1950s (Williams 1970; Le Manach et al. 2010, 2015). For example, between 2016 and 2019, artisanal annual catches for swordfish ranged between 166 and 215.8 tonnes, while marlin catches were between 200.6 to 427.3 tonnes. Swordfish catches from Kenya-flagged industrial vessels ranged between 2.3 and 385.3, while marlins ranged from 2.3 to 14.3 tonnesbetween 2016 and 2019 (Ndegwa et al. 2020; Kimani et al. 2021). IOTC reports showed industrial longline vessels targeting swordfish reported an average billfish catch of 66 tonnes, with the highest catch reported of 388 tonnes in 2019.

South Africa

All six billfish species are caught in South African (SA) commercial and recreational fisheries. Swordfish is the primary billfish species caught by the SA commercial large pelagic longline fishery in the Indian Ocean. While swordfish were historically targeted in South Africa's EEZ by permitted foreign longline fleets from Japan and Taiwan under bilateral agreements, South Africa's own longline fishery first started targeting swordfish in 1997 when 30 vessel permits were allocated for an experimental pelagic longline fishery (Penney and Griffiths 1999). The local SA longline vessels are relatively small (approx. 25 m) and the number of hooks deployed per set ranges from approximately 800–1000; hooks are generally baited with squid and have a lightstick attached to the branch lines (Penney and Griffiths 1999).

South Africa's swordfish catches within the Indian Ocean peaked in 2011 at 492 tons and have been on the decline since. The average annual swordfish catch by SA longline vessels in the Indian Ocean over the last 5 years is 125 tonnes, which accounts for less than 0.5% of the total annual swordfish catch by all countries reporting to the IOTC. However, a recent study analyzing swordfish catch rates from the SA pelagic longline fishery showed that standardized CPUE was relatively stable for the period 2004–2019 and peaked in 2008 at 530 kg/1000 hooks (Parker and Kerwath 2020).

After 2012, CPUE was relatively low and the lowest estimate, observed in 2014 at 262 kg/1000 hooks,

was approximately half of the highest observed catch rates. The SA longline fishery targets a mixture of tunas and billfish species whereby tuna catches are widely dominant in the catches and have been steadily increasing in recent years. The observed fluctuation in swordfish CPUE is probably due to changes in species targeted by SA longliners, and their increased targeting of tunas in recent years. Longline fishing effort is distributed across the SA coastline, with three areas of high effort occurring offshore of Richards Bay, Port Elizabeth, and Mossel Bay (Fig. 4a). While billfish species other than swordfish (i.e., marlins and sailfish) are also caught by large pelagic longliners, these species are considered bycatch, with most of the swordfish catches from the SA EEZ taken offshore of Richards Bay in the east, and offshore of Mossel Bay in the south (Fig. 4b).

Billfish species are also targeted by recreational boat-based fishers in South African waters, mostly in the warmer waters off the KwaZulu-Natal (KZN) coast (Mann 2013). Recreationally targeting billfish is a niche sport and it is estimated that less than 3% of all recreational fishing effort off KZN targets billfish species (Daly and Mann 2020a). Annual recreational catch (in numbers) of billfish reported in categories of black marlin, blue marlin, unspecified marlin, sailfish, short-billed spearfish, striped marlin, and swordfish are recorded on the National Marine Linefish System (NMLS) for the period 1984–2019 (Table S1). The NMLS was originally established to encourage voluntary catch and effort data collection from the recreational line-fishery in 1984 (van der Elst 1990; van der Elst and Penney 1995). Sailfish dominated billfish catch, followed by black marlin.

The annual mean weight (±standard deviation) of the four most common billfish species landed are: sailfish (34.4 ± 6.2 kg), striped marlin (67.8 ± 15.9 kg), blue marlin (112.5 ± 12.9 kg), and black marlin (121.2 ± 24.2 kg). While most billfish caught in the 1980s were weighed, reliability of weight data since the introduction of catch and release in the 1990s has decreased: tag and release is now common practice in the recreational fishery (Penney et al. 1999; Daly and Mann 2020a). All billfish species caught in the recreational fishery have a daily bag limit of five fish per person per day and no sale is allowed by recreational anglers.

In addition to the NMLS, the KZN Boat Launch Site Monitoring System (BLSMS) established in 2004 plays a role in monitoring recreational boat-based catches from popular boat launching sites (Mann et al. 2015, 2019). Locations such as Sodwana Bay, Cape Vidal, St Lucia, Richards Bay and Durban

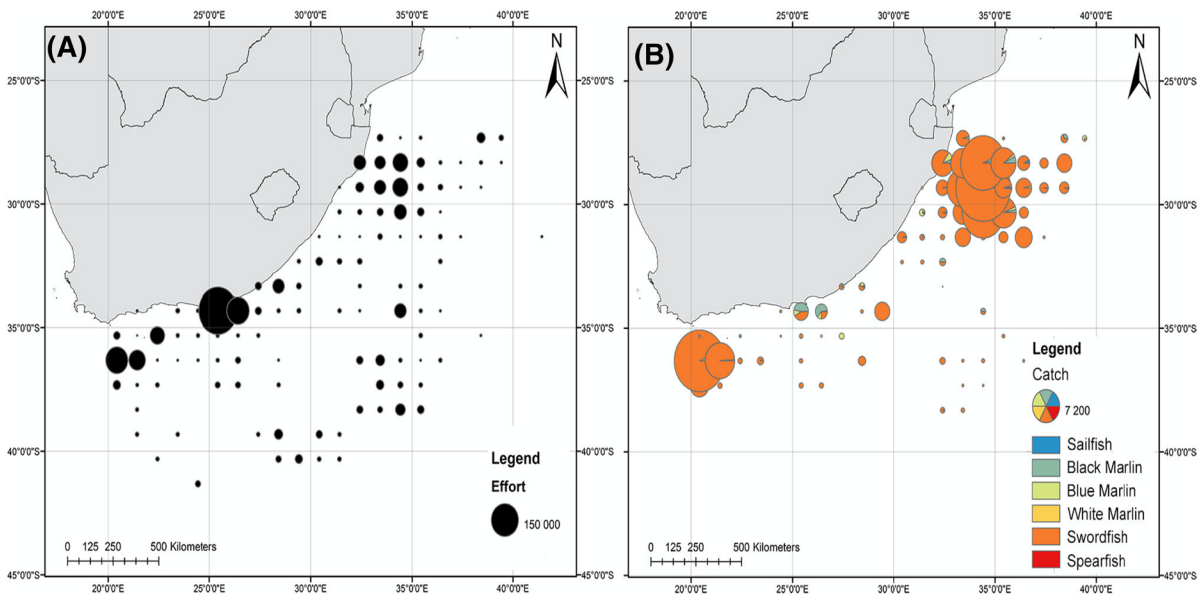

Fig. 4 Map of the distribution of average effort (thousands of hooks) **a** and swordfish catch **b** of the South African large pelagic longline fishing fleet in the IOTC area of competence for the period 2015–2020

Harbour documented the highest number of billfish caught (Fig. 5).

Mozambique

Mozambique has the third longest coastline in the Indian Ocean, covering 2700 km from Rovuma River in the North to Ponta do Ouro in the South. The Northern Mozambique Channel is bordered by Madagascar, Northern Mozambique, southern Tanzania, Comoros archipelago, and the Aldabra group of Islands, and it supports both artisanal and industrial fisheries that catch about 20,000 mt of tuna, sharks, and billfish each year (Potier et al. 2014; Chassot et al. 2019). It is also considered an important fishing ground for industrial fishing fleets.

Data reported to IOTC from 2010 to 2019 indicate swordfish dominated billfish catch in industrial longline fisheries, ranging from 3 to 216 tonnes per year while other billfishes ranged from 1 to 10 tonnes. Sailfish and black marlin are regularly caught by artisanal fishers, mostly by handline on dhows, dugout canoes, and fishing skis. The artisanal fisheries data reported to IOTC showed gaps during 2010–2019, with catches consisting mainly of blue marlin, black marlin and sailfish and ranging from 1 to 66 tonnes per year.

In general, data relating to these fisheries is poor and underreported to IOTC. Efforts to improve fisheries statistics in Mozambique from all coastal districts and main inland water bodies have been underway with the creation of a National Sampling System for Artisanal Fisheries (SNAPA) in 1997 by the National Fisheries Research Institute (IIP) under the Ministry of Fisheries (Mutombene et al. 2015). However, significant gaps persist in major areas such as the provinces of Cabo Delgado and Nampula, which recorded high catches of tuna and billfishes but suffer from poor species-level identification.

Since the late 1950s and early 1960s, billfish species, primarily black marlin, and sailfish, and to a lesser extent blue and striped marlin, have been reported in sport fisheries operations in Mozambique (Simões 1984; Howard and Starck II 1975; IIP 2007; de Sousa 2012). Three main areas of prolific billfish catch, all of them spatially distinct, include the Bazaruto Archipelago, the Inhaca/Maputo area in southern Mozambique, and the Pemba and Quirimba Archipelago in northern Mozambique (Pereira and Van der Elst 2014). Additionally, the area from Pomene (just south of the Bazaruto Archipelago) all the way south to Macaneta, with areas such as Barra, Tofo, Guinjata, Paindane, Zavora, Chidinguele, Xai and Zongoene, are tourist destinations associated with sport fishing clubs and resorts with regular recreational catches of billfish.

Similarly, Santa Maria all the way to the south including Ponta Mamoli, Ponta Tane, Ponta Malongane, Ponta do Ouro till the South African border supports billfish fisheries (RD, pers. comm.). Despite being irregularly fished, recreational boats fishing the area offshore from Quelimane, and all the way north to Ilha do Fogo, report catches of sailfish and small black marlin.

Bazaruto archipelago

The Bazaruto Archipelago is indisputably Mozambique´s most iconic billfish destination and the Indian Ocean's best destination for giant black marlin. Except for one fish caught in Tofo, over 100 miles south (November 1969) which weighed at 492 kg, all other "grander" black marlins (fish over 454 kg or 1000 lbs) in the Indian Ocean have come from the Bazaruto area. Between the late 1950s and the mid-1970s, black marlins were caught in abundance (RD, pers. comms.). Although some data may not be readable because of aging of the pages, these catches are well reported on the Santa Carolina Island Billfish Record Book. These included many big fish, among them nine over 454 kg. Mozambique´s civil war then disrupted sport fishing in the area until the mid-90 s. In November 1998, the African black marlin record (still-standing) was 589 kg (1298 pounds) (Santa Carolina Island Billfish Record Book, *unpublished data*). Black marlins are caught off the archipelago year-round, but the peak time for numbers and big females is between September and December, with October and November being the peak. Although not yet scientifically documented, decades of angler observation of fish behavior, morphology and gonads suggests that this area is a spawning ground. The presence of small fish (6–20 kg) in the region and in the shallow, predator-free waters between the Islands and the mainland are also a strong indicator. Duarte, a long-term sport fisher in the Bazaruto Archipelago notes:

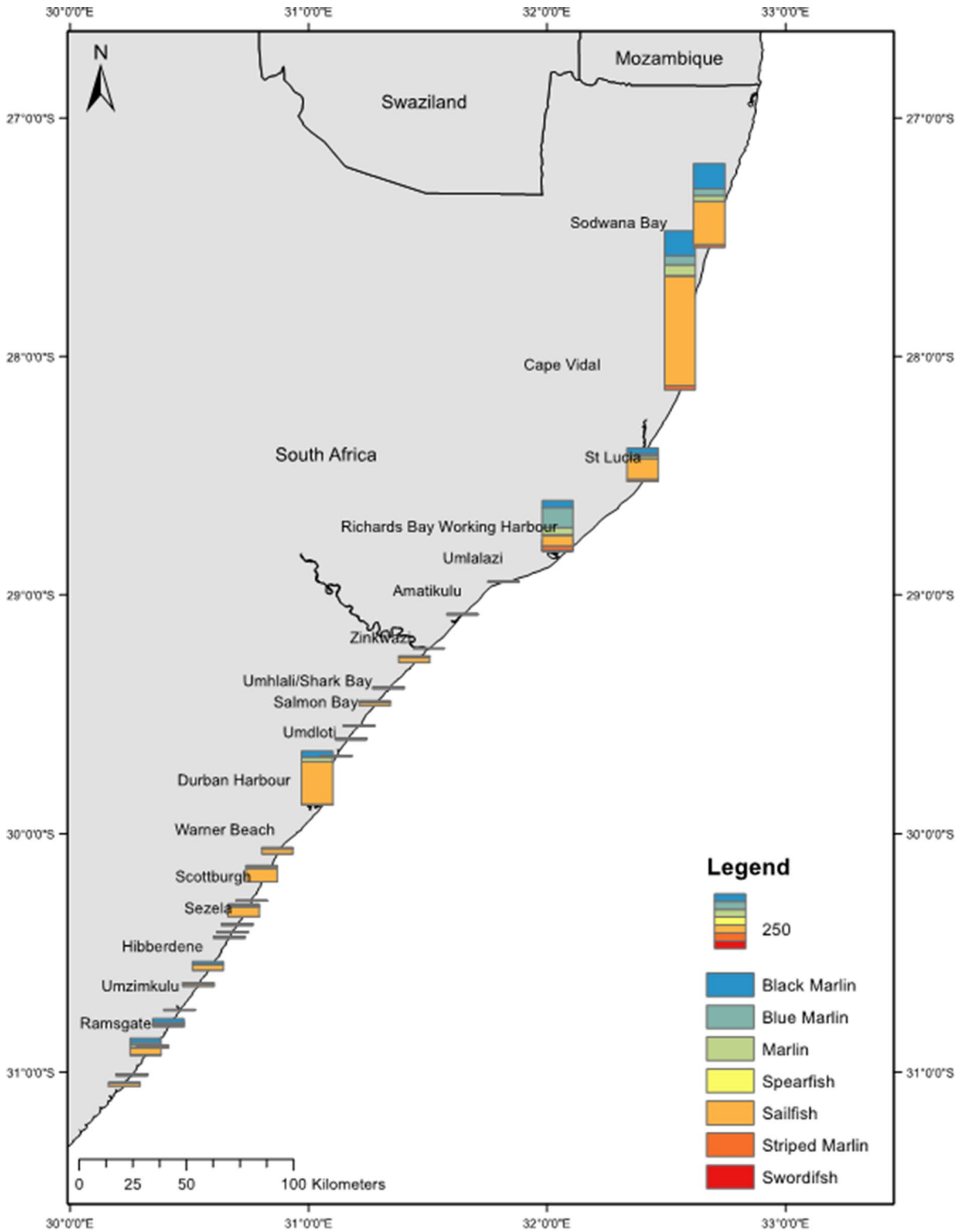

Fig. 5 Recreational billfish landing locations along the KwaZulu-Natal coast from 2004–2018. Stacked bar charts show relative numbers and composition of billfish catches. Data and map source: Daly and Mann 2020b

I have very little doubt this is the case and, in the 20 years I have fished the area, I have regularly seen mating behavior, have caught some big fish full of gonads (which we photographed and were said to be about to spawn by experts) and I have also caught many big fish which looked thin, tired as they had just spawned.

A second season with smaller fish averaging between 40 and 150 kg occurs between March to May of every year. Several big fish have been caught outside the historic big fish season, including a 386 kg fish (March 2011) and one estimated to be greater than 454 kg (May 2011). Juvenile fish are caught throughout the year, by both recreational and artisanal fishers, with January to April being the most common period for these fish.

Billfish records available from 1958 and 1988 showed that black marlin were the most caught species, followed by sailfish (Santa Carolina Island Billfish Record Book, *unpublished data)*. National reports submitted to IOTC from 2002 to 2020 indicate that annual catches of black marlin were high in sport and recreational fishers. However, during the early 2000s to around 2009, sailfish was the most commonly caught, especially in the southern Mozambican coast (Potier et al. 2014; Chacate and Mutombene 2015).

There are no commercial and artisanal records of billfish in the Bazaruto Archipelago. But local dhows using hand line gear between the mainland and the islands, and in the shallow waters on the windward side of the islands, regularly catch small black marlin, and to a lesser extent sailfish (RD, pers. comm). During the late 1950s to mid-1970s, sailfish were rarely caught as boats almost exclusively targeted black marlin. Most of them were by-catch from bait fishing. However, when the area opened to sport fishing again and until 2009, these were, by a large extent, the most caught billfish by the recreational fleet in the area. Subsequently, there was a sharp decline in catch. Although they are still caught, the numbers are far from those days when raising between 20 and 40 sailfish per day per boat was common in peak season. Sailfish are also caught all year round, but their main season is in the winter months, between May and September, with mid-May to July normally being the peak. The average size of sailfish is about 27 to 32 kg, with fish commonly ranging from 15 to 65 kg.

Because adult black marlin are primarily caught at depths ranging from 40 to 160 m, until recently little effort had been put into targeting blue and striped marlin in deeper waters (RD, pers. comm.). That has changed in recent years, and a good blue marlin fishery exploits depths ranging between 300 and 550 m. The blue marlin season seems to coincide with that of the black marlin, although some years they have also shown in good numbers during winter (May to July).

A few shortbill spearfish have been caught in the same deep-water areas where anglers target blue marlin. No effort has been put on sport fishing for swordfish in the area and only one has been caught. However, logbooks we inspected from a commercial longline vessel, which operated in the area between the late 80 s to mid-90 s, showed a very healthy population of swordfish. Since the early 2000s, charter boats in the Bazaruto area have tagged billfish, initially mostly sailfish and occasionally black marlin, with tags from ORI. More recently, black marlins were tagged using tags from ABF (ABF, *unpublished data)*.

Inhaca/Maputo area

There are a few charter operations in the area, and most fishing is done by the local private sport fishing community (from Clube Naval and Clube Maritimo in Maputo) and visiting private boats, mainly from South Africa, based out of Maputo, Inhaca Island or Santa Maria. Until 10 years ago most of the billfish in the area consisted of sailfish and black marlin, caught mostly by sport fishers. Commercial and artisanal capture records are scarce.

Sailfish and black marlin tend to be caught between October and May. Black marlin average weight is around 70 to 150 kg, with the largest specimens caught in the 250 kg bracket. A commercially caught black marlin, in shallow water of Maputo Bay, in the early 90 s weighed just over 500 kg (dressed). This has all changed in the last years as boats explored and discovered excellent blue marlin fisheries out deep (mostly between 300 and 550 m of depth). Along with striped marlin, blue marlin are now the most caught billfish species in the area by sport fishing boats. Blue marlin average around 70 to 300 kg, but several bigger fish have been caught or released. This includes a fish over 454 kg caught in March 2018.

The blue marlin season extends between October and May, peaking between mid-December to April.

Striped marlins are also regularly caught, weighing between 50 and 90 kgs. Although their season also extends from October to April, their peak seems to occur prior to the blues between October and January. Striped marlins have also been caught in the winter months (July). The area provides a large diversity of billfish with many grand, and super grand slams (3 or 4 different species of billfish being caught by one boat in a single day). Shortbill spearfish are rare but occasionally caught.

Pemba and Quirimba archipelago

A considerable number of sailfish and juvenile black marlin have, for decades, been regularly caught in the Pemba and southern Quirimba archipelago area (RD, pers. comm.). Most catch is by artisanal fishers operating on sail, and more recently, motorized dhows and dugout canoes. Sailfish catches tend to peak in the winter months between May and September and black marlin from September to April. Historically, there have been few recreational or sport fishing charter boats targeting billfish in the area. However, in the last eight years or so a healthy and reliable swordfish fishery has been conducted by the local private recreational fishing boat fraternity, outside the Bay of Pemba in very close proximity to land.

Madagascar

With a coastline of about 4828 km, Madagascar is one of the largest islands in the world and billfish make it an important sport fishing zone. Despite reports on increasing fishing tourism in the last two decades that target mainly marlin and tuna (Jain 1995; Le Manach et al. 2011), it is difficult to ascertain the trends and data are generally not official. Mitsio and Radama Archipelagos are recognized as the game fishing areas of Madagascar. Other areas include Nosy Lava Island, Narinda Bay, Moramba Bay and to the gates of Majunga (Rahombanjanahary et al. 2013).

Reports from commercial fishing show catches mainly of tuna and billfish, averaging 300 tonnes annually from longliners (65% of the total catch) (Razafimandimby et al. 2015). Swordfish were the most caught billfish species in industrial longlines, averaging about 100 tonnes between 2010 and 2012. Sailfish and marlin have historically been reported together in national records, where available data indicated that national fleets caught an average of 15 tonnes between 2010 and 2014. In addition, a report from the Ministry of Fisheries Resources of Madagascar in 2018 shows that the billfish catches by longliners represented an average of 74 tonnes per year (MRHP, CSP, USTA 2018). Data reported to IOTC between 2013 and 2019 showed fluctuations in billfish catches, mainly swordfish and sailfish, with the highest catch of about 16 mt in 2013 (Fig. S1). Swordfish were the most caught in the longline fishery as the main target species with catches ranging from 21 to 99 tonnes between 2010 and 2019. Other billfish species included black marlin (7 to 18 tonnes), striped marlin (4 to 14 tonnes) and sailfish (averaging 6 tonnes with the highest catch of 40 tonnes reported in 2014) for the duration 2010–2019.

Recreational and sport fishing for billfish appears to be concentrated around the Banc de Grand Castor, Grand Serpent, Mitsio and Radama Island. The Unité Statistique Thonière d'Antsiranana (USTA) surveyed the sport fishing of the North of Madagascar to support the development of an efficient monitoring system for this sector. There are major inconsistencies in the sport fisheries catch data reported to IOTC with records showing that the same number 842 tonnes of sailfish were caught each year from 2010 to 2019.

Relatedly, documentation of catches of billfish in artisanal fisheries remains a huge challenge in Madagascar. Estimates by Louvain Coopération au Développement (2011) revealed that in the Menabe region, swordfish constituted about 11% of artisanal catches between 2010 and 2013. Industrial longline fleets in Malagasy tuna fisheries catch most fish. However, there is substantial underreporting and limited monitoring and surveillance to ensure that vessels adequately report their catches. Further, the recreational/sport and artisanal fisheries that catch billfish are understudied and thus formal statistics on billfish species are unavailable. While in-country institutions may have such data to some extent, the missing gaps necessitate data harmonization procedures to collect data and improve the accuracy of official data.

Comoros

The Union of Comoros comprises the Grand Comore (Ngazidja), Moheli (Mwali), Anjouan

(Nzwani) and Mayotte islands with EEZ estimated at 160,000 km^2. Mayotte is administered as a French overseas department; it voted against independence from France in 1974. The fisheries in Comoros are primarily small-scale and consist of traditional, artisanal, and semi-industrial (Oirdi 2002; Breuil and Grima 2014; Toihir 2011; 2017; Doherty et al. 2015a, 2015b; Everett et al. 2015). Fishing is the second most important sector of the economy after agriculture, contributing to 10% of employment and 8% of the GDP in 2013 (Cofrepeche and Poseidon 2013; World Bank 2017).

Traditional, artisanal and industrial fisheries are concentrated in the oceanic surface waters and target pelagic fish, particularly tuna and tuna-like species. The Comoros fleet is exclusively artisanal, mostly composed of open-deck vessels, either equipped or not with engines, ranging in size from 3 to 9 m long. The most used fishing gears are trolling lines, small longlines and, less frequently, gill nets (Toihir 2017). Pelagic fishing involved domestic and Distance Water Fishing Nations (DWFNs). Official statistics reported to IOTC are mainly from artisanal fisheries using handline, troll line and gillnet. Swordfish were the most caught, with an annual average catch of 88 tonnes between 2010 and 2019. The reported data also included other billfish species with an annual average catch of 86 tonnes for sailfish, 36 tonnes of black marlin, 15 tonnes of blue marlin and 13 tonnes of striped marlin for the period 2010–2019.

While artisanal fishing is significant in Mayotte, recreational fishing for large pelagic species such as billfish has increased in recent years because of growth in tourism and modernization of fishing gears (Guézel et al. 2009a, b; Busson 2011). There are two main sectors of recreational fishing which include sport fishing (hookline) and spearfishing. Recent total catch reconstruction estimated recreational catches at 220 tonnes for the period 1985–2010 (Doherty et al. 2015a, 2015b). However, there is no official data on recreational billfish species. The available official statistics reported to IOTC for the period between 2010 and 2019 only show data for 2010, 2011, 2012 and 2013 with catches reported in two sectors: industrial and artisanal fisheries. The industrial fisheries consist mainly of longline fleets targeting swordfish, with an average annual catch of 25 tonnes between 2010 and 2013. An annual average of 2 tonnes of sailfish were also reported in this period. The reported catches in the artisanal fisheries were mainly for sailfish with an annual average of 3 tonnes for the period 2010–2013.

Seychelles

The Seychelles archipelago is made up of 115 islands (granitic and coralline in nature) and islets with a total coastline of about 600 km and EEZ of 1.3 million square kilometres. The importance of the coastal zone has been amplified by the adoption of the sovereign blue bonds which support fisheries among other sectors for generations of Seychellois citizens (Christ et al. 2020). Seychelles has two distinct longline fleets catching billfishes: the semi-industrial fleet of small longliners that are mainly fishing in the Seychelles EEZ (with average billfish catches close to 200 tonnes during the period between 2010 and 2019) and the Taiwanese longliners flagged in Seychelles and fishing in the entire WIO. Further, the Chinese industrial fishing fleets operate in and out of the Seychelles EEZ to some extent (Figs. 6, 9). The Taiwan/Seychelles fleet lands much larger billfish catches compared to the Chinese fleets operating within the EEZ (Fig. 6c and d). Swordfish were the most caught in the period between 2010 and 2019 (Fig. 6a and b), with a recent Seychelles national report to IOTC indicating that swordfish averaged 62% of the total reported billfish catch in semi-industrial fleets for the period 2013–2014 (Assan et al. 2018). Catch data reported to IOTC between 2010 and 2019 comprised catches from artisanal and industrial fisheries. Annual artisanal catches were only those caught in hand lines with sailfish as the most common caught (average of 1 tonne) while other billfish species were indicated as unidentified (average of 2 tonnes). Swordfish catches were dominant in industrial fisheries (an average of 404 tonnes, with the highest catch of 1816 tonnes reported in 2016 although the catches show fluctuations across the years). Other billfish species included black marlin (average of 224 tonnes), striped marlin (average of 83 tonnes), blue marlin (average of 29 tonnes); sailfish (an average of 8 tonnes) and short-billed spearfish (an average of 2 tonnes).

While swordfish has been one of the dominant species in semi-industrial catches, fluctuations in the CPUE have been observed in previous years could be attributed to localized depletion and increased fishing pressure (Kolody et al. 2010). This percentage has been declining since 2014 with less than 20% of

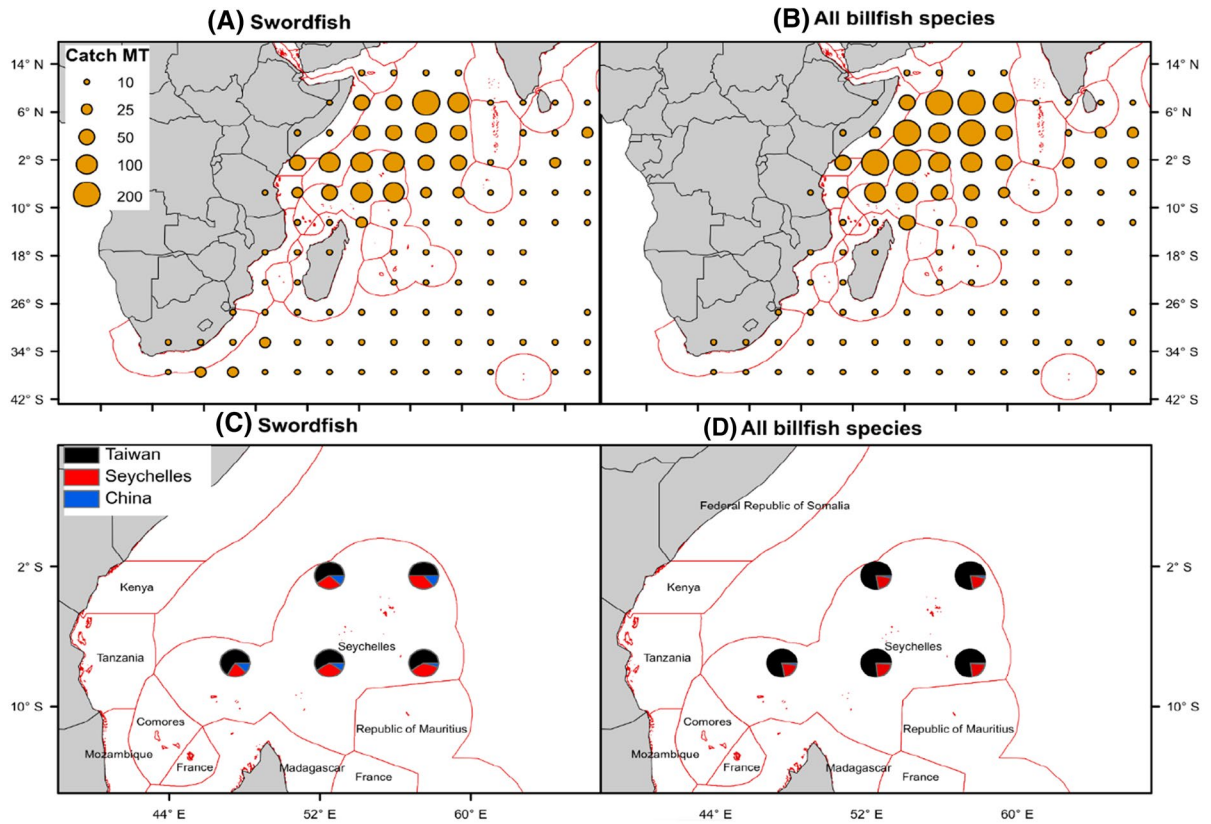

Fig. 6 **a** Average catches of swordfish and **b** other billfish species (orange) of the Seychelles/Taiwan longliners beyond the Seychelles EEZ, period 2010–2019. **c** Average catches of swordfish and other **d** billfish of the Seychelles/Taiwanese (black and red) longliners compared to Chinese vessels (blue) fishing in the Seychelles EEZ for the period 2010 and 2019

swordfish in the 2015–2019 landings (Lucas et al. 2019). A decline in the swordfish CPUE in the past four years could be indicative of a shift in the target species to an increase in the yellowfin and bigeye catches. Recent fisheries catch for Seychelles from 1950 to 2017 had fluctuations in CPUE by semi-industrial fishers which could be due to increased fishing effort and movement of pelagic species temporally and spatially across the oceans (Christ et al. 2020).

Sport and recreational fishing for billfish in Seychelles began around 1971 and has gained more prominence since the 2000s, growing into a vibrant activity on Mahe and other surrounding islands. By 2016–2017, Pepperrell et al. (2017) estimated that about 40 sport fishing boats were active on Mahe while another 7–10 were found on Praslin Island. The main centers for sport fishing include Eden Island marine, Bel Ombre harbor and Beau Vallon, which are located on Mahe. The Seychelles Sport Fishing Club is the main club in the Seychelles which actively holds yearly tournaments and competitions and is responsible for running a billfish tag and release program. Billfish are the main target species although other species are caught including tunas. Seychelles has not been providing its catches by sport fisheries to the IOTC. However, the growing value of sport fisheries for billfish as a tourism opportunity in Seychelles necessitates the inclusion of this sector in the blue economy agenda along with emphasis on improving current data collection systems and monitoring to support fisheries management decisions (Robinson et al. 2020; Christ et al. 2020).

Tanzania

The United Republic of Tanzania (URT) that comprises mainland Tanzania and Zanzibar has a

coastline of 1,424 km with territorial waters of 64,000 km^2 and an EEZ of 223,000 km^2 (Breuil and Grima 2014). As such, the marine fisheries resources in Tanzania, including their statistics, are managed by three institutions: the Departments of Fisheries Development in the Ministries responsible for Fisheries in Mainland Tanzania (MLF) and Zanzibar (MANRLF) for the inner waters and territorial sea fisheries, and the Deep-Sea Fishing Authority (DSFA), which came into operation in 2010, for EEZ fisheries (Igulu and El Kharousy 2013). The presence of several management legislations for marine resources makes data acquisition challenging. However, recently efforts have been made to harmonize the data collection system to solve the problem of data disparities within the country.

Billfishes are also caught in sport fishing activities by tourists in Dar es Salaam, Zanzibar, and Mafia islands (Adibi et al. 1977). However, catch records from sport fisheries are not well documented. Benansio and Jiddawi (2016) reported that only 19 species out of the 27 recorded were submitted to the Department of Fisheries. Evidence for the social, economic, and cultural value of billfish in Tanzania dates to 1966 when the Tanzania government issued a coin of five cents with a portrait of a sailfish on the reverse side. During that time, fishing activities were undertaken in the near-shore areas as a form of recreation or a source of food and income (Adibi et al. 1977). Consequently, billfish likely were caught by British colonial masters who fished for leisure. An early study of billfish of the East coast of Africa by Merrett (1971) noted that sailfish were commonly caught in longline tuna fishing fleets. Generally, little to no studies exist on the dynamics of billfish exploitation by sport, artisanal local fishers, or foreign fishing fleets in Tanzanian marine waters.

A frame survey conducted in 2018 reported that swordfish and other targeted unspecified species constituted about 11% in the longline fishery in mainland Tanzania (Ministry of Livestock and Fisheries 2018). The fish species targeted by small-scale fishers are diverse. However, a limited number of fishers 4511 (8.5%) target large pelagics such as swordfish in deeper waters (Ministry of Livestock and Fisheries 2018). On the other hand, about 18% of all vessels in Zanzibar target tuna and tuna-like species (including billfishes) with dhows and fibreglass boats leading by 50% and 26%, respectively (DFD 2018). Tuna and tuna-like species in Zanzibar are predominantly targeted by gillnet (43.9%), hand line (19.1%), long line (10.5%) and the rest from other gears. Overall, data reported to IOTC for artisanal fisheries using hand lines and gillnets for the period 2010–2019, comprised only sailfish catches ranging from 123 to 2105 tonnes, with the highest reported sailfish catch of 2105 tonnes reported in gillnets in 2019. There is limited recorded data of billfish species in the URT marine waters, especially for marlin and sailfish, as most of the data available is for swordfish catches. Between 2010 and 2019, the annual average catch of swordfish by longliners was 30 tonnes. Catches of other billfish species ranged from 1 to 92 tonnes (with blue marlin dominating, followed by black marlin and striped marlin). Other billfish catches were reported as unidentified ranging from 1 to 3 tonnes for the duration between 2010 and 2014. Generally, in Zanzibar, billfishes are reported in the tuna category. Since early 2018, however, catches of tuna and tuna-like species in the territorial waters of Tanzania have increased following a noticeable decrease in industrial fishing in the EEZ after enactment of new legislation in 2016 (EAS and SA, pers. comm.).

Historical catch data for swordfish are the only available data on billfish catches, and recorded prices in Zanzibar increased dramatically between 2000 and 2004 (URT 2019) (Fig. S2). Billfish catches show seasonality with high catches reported between October and February (Fig. S3). The seasonality of the catches is attributed to the monsoon regime: the southeast monsoon occurs from May to early September, and the northeast monsoon from November to March. The same catch trend was also reported by Adibi et al. (1977). Notably, there are considerable gaps in catches submitted to IOTC as much of data especially from sport and artisanal fisheries are not included in the official catch statistics (Igulu and El Kharousy 2013). The importance of these fisheries for socio-economic and food security requires improvements in the national data collection system and strengthening the direct engagement with sport fishing captains, crews and clubs in Mainland Tanzania and Zanzibar to submit their catches (Katikiro et al. 2014).

La Reunion

Billfish in La Reunion are caught in two sectors: the offshore longline fishing fleets and coastal fisheries whose vessels are less than 10 m in length (Bourjea et al. 2008). The domestic longliners, which started in early 1990, predominantly target swordfish (René et al. 1998; Poisson and Taquet 2001a, b; Bach et al. 2013) with drifting longlines that are set at night (Sabarros et al. 2013; Chevallier et al. 2015). Scientific, observer and self-reporting data of the longline fishery reveal that other billfish species including istriophorids (black marlin, blue marlin, striped marlin, sailfish, and shortbill spearfish) are often caught in the daytime. Between 2007 and 2014, 1844 fishing operations were monitored representing a total effort of 2,296,839 hooks and 633 billfish caught which comprised 31% of shortbill spearfish, 16% of blue marlin, 15% of Indo-Pacific sailfish, 7% of striped marlin, 4% of black marlin, 22% of unidentified istiophorids and 5% of unidentified marlins (Chevallier et al. 2015). Annual catches are widely distributed within the EEZ, particularly high for swordfish compared to other billfish species, with instances of over 100 mt reported for the period between 2010 and 2019 (Fig. 7). There is also evidence of annual catches from a few offshore vessels fishing for swordfish and catching other billfish species as bycatch particularly in the Malagasy EEZ (Fig. 3), in the context of the bilateral fishing agreement between Madagascar and the European Union (Le Manach et al. 2012; Sabarros et al. 2013).

The recreational fishery is categorized as (i) the big game fishing ('Peche au Gros') which comprises commercial professional fishing vessels who can legally sell their catch with or without paying clients, and (ii) the non-professional private boat operators who may fish as individuals or are members of a club (Pepperrell et al. 2017). The main ports from which sport fishing vessels operate include Saint-Gilles-Les-Bains, Le Port and Saint-Pierre. Pepperrell et al. (2017) estimated that there are about 300–500 private boats that target a mix of pelagic species such as billfish and tuna. Recreational or sport fishing vessels in the La Reunion area are categorized as professional fishing vessels and thus they are required to self-report their catch data for that specific sector (Bourjea et al. 2008; Le Manach et al. 2015, NIK, pers. comm). In cases where these data are submitted to the IOTC, they are not reported as sport fishing, but instead as a combination of troll line, hand line, or hand line and troll line (Pepperrell et al. 2017).

Mauritius

Mauritius has an EEZ of 1.9 million km^2 extending from the coasts of the islands of Mauritius, Rodrigues, St Brandon (Cargados Carajos Shoals), Agalega, Tromelin and Chagos Archipelago. Billfish species are caught in semi- and large-scale industrial longline fisheries, artisanal and sport fisheries (Ardill 1986; Houbert 2009; Boistol et al. 2011; Pepperell et al. 2017). The longline fishery in Mauritius comprises the large-scale fishing fleets (foreign owned vessels operating under the Mauritian flag) and the local semi-longline fleets (Roullot et al. 1988; Poisson and Taquet 2001a, b; Mamode et al. 2019). Commercial fishing for swordfish started in 1999 through support from the Indian Ocean Commission in 1996 to conduct research trials (Houbert 2009). Fisheries catch data reported to IOTC between 2010 and 2019 only depicted catches from industrial fisheries, mainly longliners targeting swordfish (Mootoosamy et al. 2016). Swordfish catches averaged 79 tonnes in 2010–2017, with the highest catch of 203 tonnes reported in 2017. Other billfish species include sailfish (average of 2 tonnes in 2013–2017); black marlin (average of 8 tonnes in 2015–2017); blue marlin (average of 4 tonnes between 2015 and 2017); striped marlin (average of 6 tonnes between 2016–2017) and short-billed spearfish (average of 1 tonne in 2016–2017). In 2018, swordfish comprised 16% of the total catch in semi-industrial longliners operating both inside and outside the EEZ while in 2019 most of the catch consisted of swordfish (44.5%) with marlins making up 5.5% (Mamode et al. 2019). The geographical distribution of the average annual catch (between 2010 and 2019) showed they were centred around the EEZ, with a few spreads outside the EEZ (Fig. 7). Artisanal fishers exploited a mixture of fish species including billfish around Fish Aggregating Devices (AFADS) within and outside the lagoons in Mauritius, Rodrigues, and the outer islands. However, there are no official catches for billfish from these fisheries.

Historically, billfish species have been prominent in Mauritius particularly in sport fishing, which is internationally recognized for large blue and black

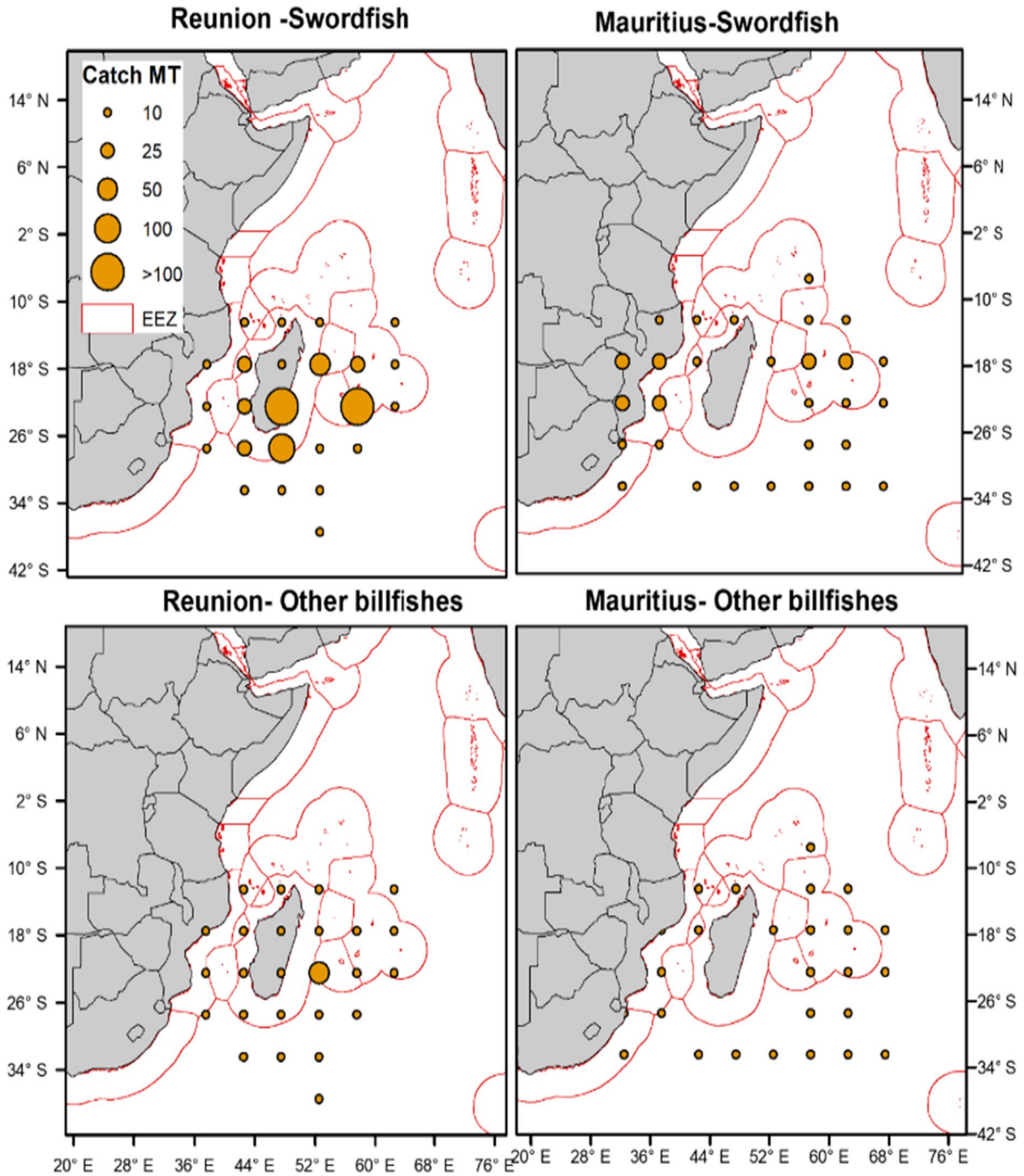

Fig. 7 Average longline annual catch (2010–2019) in the IOTC spatial catch and effort database of swordfish and other billfish species for Reunion and Mauritius

marlin caught in big game tournaments (Cayré and Stequert 1988; Houbert 2009; Pepperrell et al. 2017). Reported catches dating back from 1976 to 1986 indicated that blue marlin and black marlin were the most important target species (respectively 53.7% and 14.5% of the catches) (Cayré and Stequert 1988). The

sport fishery is categorized under the recreational/tourist-based fisheries and non-consumptive fisheries of the country. Following the introduction of FADs in the open sea (outside of 12 nm) in the 1980s to encourage both artisanal and sport fishers to venture offshore, sportfishers fished around FADs and targeted skipjacks to be used as bait for catching marlins and sailfish (Houbert 2009). Sport or big-game fishing is one of the major driving forces in the tourism industry (Diffey 2012; Pepperell et al. 2017).

Pepperell et al (2017) estimated that 62 charter sport fishing boats operate in Mauritius and are concentrated in several locations, mainly on the western side of the island including: Grand Baie, in the north-eastern tip of the island, where there one main jetty which is used by sport fishing boats with several charter operations located in this area; Black River, where a number of sport fishing and recreational boats are located in this area; and Trou d'Eau Douce on the eastern side of the island, where one main charter sport fishing company (the Royal Big Game Fishing) operated in 2016–2017. Several sport fishing boats were reported to be based on Rodrigues Island, although it remains unclear from our observation and information received on their operations. It should be noted that official data on sport fisheries in Mauritius are yet to be submitted to IOTC despite the historical prominence of these fisheries and the unique opportunity for socio-economic development presented through fishing tourism.

Catches by species of foreign industrial longline fisheries in the study area

Billfish in the study area are predominantly caught by foreign industrial longline fisheries which have operated in the Indian Ocean since the 1950s with several coastal states providing fishing access to Distance Water Fishing Nations (DWFNs). In the last decade, swordfish comprised over 50% of the total billfish caught, with maximum catches over 800 mt, extending from the northern to the central southern WIO (Fig. 8). Other billfishes are regarded as bycatch and their catches are mostly concentrated in the northern Indian Ocean. Foreign fishing fleets catch a significant amount of billfish in the study area. During 2010–2019, Taiwan had a high average annual catch followed by Spain (Fig. 9). Taiwan's spatial catch and effort was distributed across the north and southern

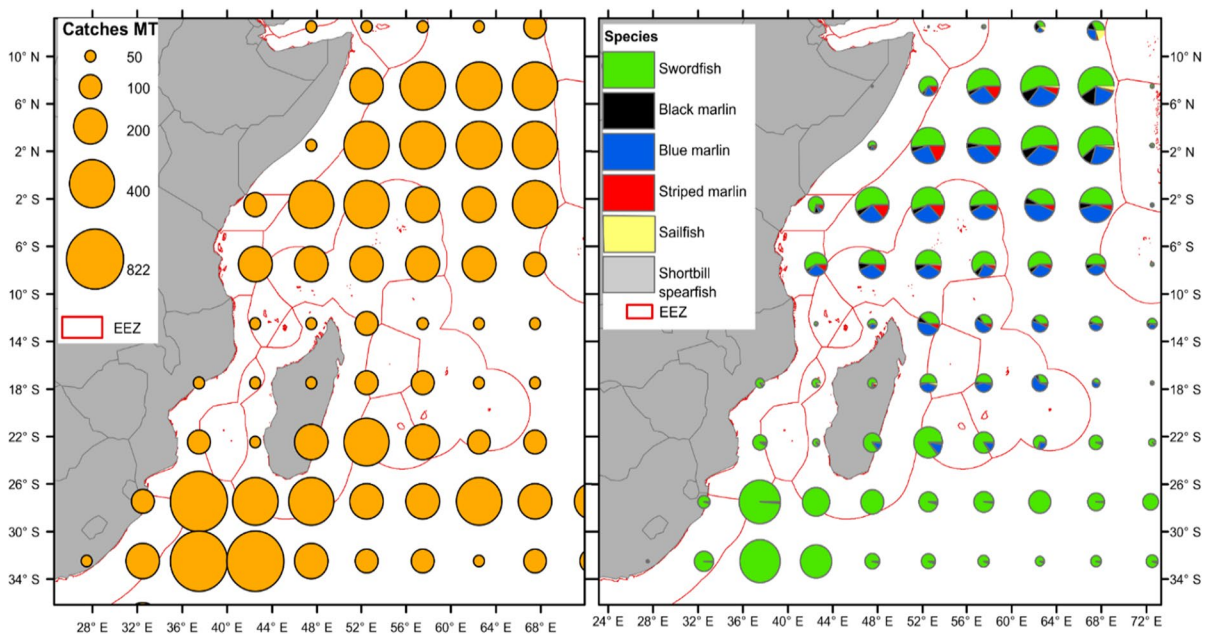

Fig. 8 Average longline annual catch (2010–2019) in the IOTC spatial catch and effort database of swordfish (orange) and other billfish for foreign industrial longlines fisheries combined

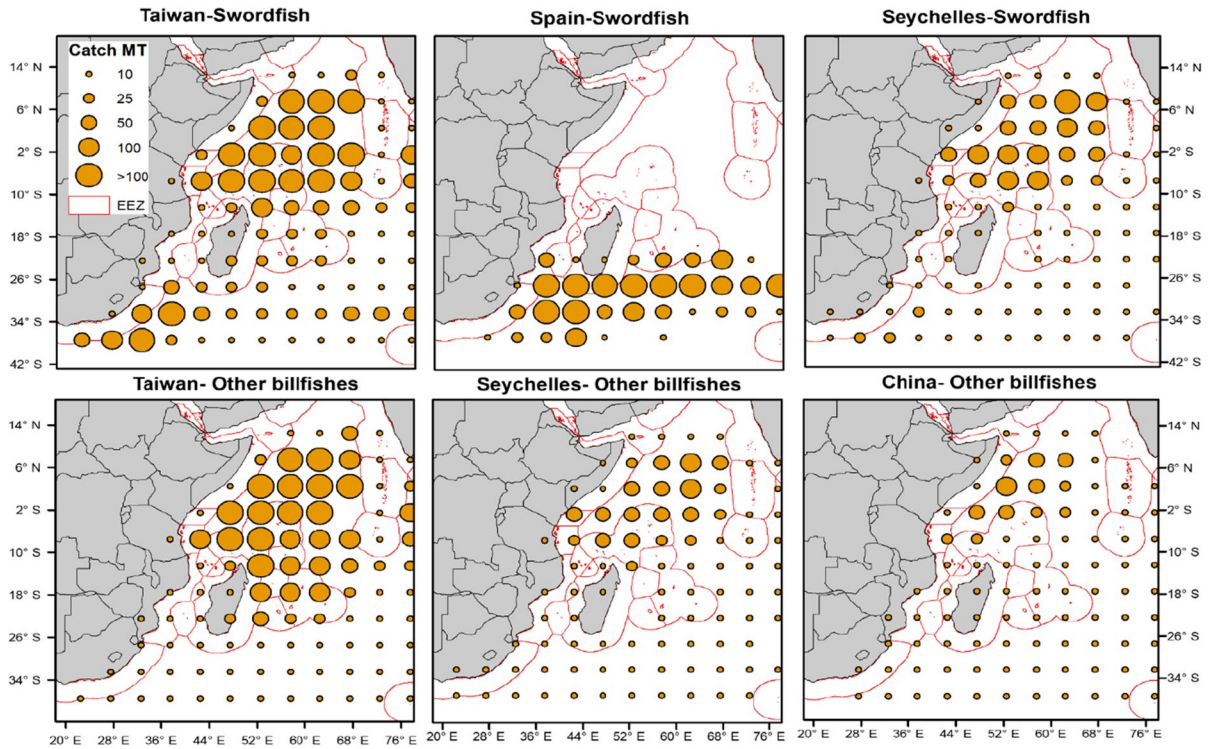

Fig. 9 Average longline annual catch (2010–2019) in the IOTC spatial catch and effort database of swordfish and other billfish for top three fleets

IO while Spanish longline fleets concentrated in the southern IO. Taiwan and China had the highest annual average catch of other billfish species during this period, with the Taiwanese catch in the north and central IO while the Chinese fleets concentrated in the northern IO. The shifts and patterns in the concentration of catch and effort by DWFNs illustrate the variations in the fishing capacity and distribution of billfish species, implicating their management in the EEZ and the Areas Beyond National Jurisdiction (ABNJ) (Thoya et al. 2022).

Movement studies of billfish in the WIO region are currently limited (Rohner et al., 2021). Therefore, with the largest billfish catch coming from foregn longline fleets, management measures are important to control these fisheries. We recognize that our analysis only considers the foreign longline fleets operating in the study area. However, with the general lack of fisheries monitoring, surveillance, and data reporting systems for coastal states in this region, it is imperative that countries improve their compliance processes to better inform the catch allocation and agreements with foreigh industrial longliners. Put together, an IO wide examination may suggest different actors responsible for taking the bulk of the billfish catch, whether as direct or incidental catch. Issues such as geopolitical instability and conflict in the IOTC area of jurisdiction may influence the spatial distribution of catch and effort. Nevertheless, the counterintuitive information on billfish catches by foreign industrial longliners in the study area highlight the challenge of managing billfish species in the IO, particularly for most WIO countries which lack adequate data, coupled with underreporting or misreporting, and therefore complicating the capacity to implement effective management measures at national and regional level.

Discussion

This review depicts major gaps in the historical and current knowledge regarding billfish species in the WIO region. Based on the evaluation of the available

information from the various countries, it is evident that billfish catches and composition of species in different gears have fluctuated over time, although the factors leading to the variations in the catch dynamics are yet to be understood. Further, our review shows that billfish comprise part of the national and regional catch in artisanal, recreational, and large-scale industrial fisheries. However, sufficient data to assess the implications of these fisheries on billfish populations, especially for the artisanal and recreational sector, are lacking in the WIO (Zeller et al. 2018; Christ et al. 2020).

The socio-economic role of billfish species in improving the livelihoods of the fishing communities is significant. Billfish species are important to the economy of WIO countries. Nonetheless, the socio-economic value of billfish to the different countries is not well documented. While some studies have examined the socio-economic value of billfish species for commercial and recreational fishers, their significance for artisanal fishers is less understood. Kadagi et al. (2020) described competitive interactions between recreational and artisanal fishers in Kenya where both groups benefited from billfish either as a source of food and income or for leisure. Similar studies have been undertaken in West Africa (e.g., the Ghanaian artisanal fleet and the Senegalese recreational charter fleet) and in the Caribbean (Ayeisha et al. 2009; Gentner et al. 2018), and just like the East coast of Africa, they revealed potential conflicts for billfish use as a shared resource among the two user groups (Kadagi et al. 2020). Artisanal fisheries constitute a high proportion of fishers in the WIO region who may directly derive socio-economic value from billfish species and, in turn, impact their populations (Mutombene et al. 2017; Kadagi et al. 2020). However, the characteristics of interactions between billfish species and artisanal fisheries, and the socio-economic benefits, are poorly documented, which is a glaring gap revealed by this review.

While the IOTC has made considerable steps in assessing the status of several billfish species in the Indian Ocean, data collection and reporting for countries with fleets that target billfish species is required to develop a comprehensive analysis at both country and regional levels to promote collective formulation of regional policies to manage billfish in the WIO. National and regional monitoring of shared fisheries are critical, especially in the current discourse on Blue Economy (BE) (Okafor-Yarwood et al. 2020; AU-IBAR, 2019) and the growing interest for countries in the WIO region to explore the potential of the ocean economy. The highly migratory nature of billfish, as shown by conventional and tagging data, indicates that billfish stocks are shared across national jurisdictions. Thus, there is an urgent necessity for coastal nations to target some optimal management of the billfishes in their EEZ through applying the management advice given by the IOTC at the scale of the entire Indian Ocean (Thoya et al. 2022). The unique opportunity presented by the BE calls for WIO countries to adopt optimal and socio- economical value for a sustained exploitation of the local billfish resources based on the socio-economic data collected at the national level. More importantly, local management of billfish species should be developed independently of the exploitation rates of the IO billfish stocks; for instance, a total ban of local fisheries targeting billfishes and enforcing measures that sport fishery should release 100% of their catches, even when the Indian Ocean stock is estimated to be healthy at the IOTC scale. Besides strengthening local management, all statistical data collected on the national billfish catches of each country, in the past and in the future, should routinely be submitted to the IOTC to improve the availability of data for assessments and management recommendations.

The discrepancies in collection of current data and limitations in obtaining archival records on billfish catches across the WIO hampers stock assessment efforts and our ability to understand the importance of billfish. Given the transboundary nature of billfish, regional data are fundamental in addressing interests of each country and resource users whilst sustainably managing billfish species. Notably, most stock assessments of billfish species have relied on data from industrial fishing fleets, particularly from commercial fisheries in accordance with IOTC Resolution 15/02, which outlines mandatory statistical requirements for IOTC Members and Cooperating non-Contracting Parties (CPCs) to report fisheries data. Despite this resolution, billfish fisheries in the WIO region are largely data-limited especially for artisanal and recreational fisheries due to little or no reporting. The countries covered in this study had either not officially reported historical and current billfish data to IOTC or depicted significant inconsistencies in the submitted data across the years. Further, in many

countries, the data are not disaggregated, and billfish species are lumped together (Ndegwa and Kirathe 2015; IOTC 2017; Kadagi et al. 2020) suggesting the immediate need for countries to enhance the quality and frequency of reported data.

Notably, most billfish data in the WIO region have been collected through citizen science, especially from sport and recreational fisheries (e.g., in Kenya and South Africa). While such data may have disparities across the years, the contribution of the sport fishing community in billfish data collection in the WIO is worth noting. The involvement of sport fishers in tagging and other fishing sectors in the reporting of recovered tags emphasizes the need to promote citizen science given the extent of billfish movement and limited resources for national institutions to collect data (Wambiji et al. 2022).

The COVID-19 pandemic has further complicated the collection of fisheries statistics, which is likely to impact assessments not only of billfish, but also of other species, with consequences for the conservation and management of many regionally shared fish stocks (FAO 2020). As demonstrated by the availability of tagging data on billfish from sport fisheries, states will need to support citizen science to ensure biological, conventional tagging, and basic research can continue. Critical assessments of available tagging data are required to facilitate dialogue between the sport fishing community and decision makers to address short- and long-term challenges arising from competitive interactions between billfish resource users (Kadagi et al. 2021a, b). Further, fishing operations are crucial for the socio-economic and cultural well-being of coastal communities across the WIO. However, the lack of fisheries data reporting for under-studied species such as billfish can constrain their sustainable management at local and regional scale. Therefore, nations need to rethink data collection systems that strengthen the ability of fishers to report data as a part of restructuring fisheries management in these uncertain times. Beyond our understanding of billfish interactions with fisheries, efforts to prioritize research that investigates the implications of these fisheries on billfish stocks is required. The impact of the COVID-19 crisis on food and socio-economic security, for instance, provides a compelling reason to understand the contribution of billfish species to livelihoods in the WIO in the process of developing resilient food and economic systems. Given the considerable data gaps and the interconnectedness of billfish populations across the WIO, well-designed monitoring systems can assist in facilitating collaborative management and inform interventions for securing billfish populations.

With the drive to achieve sustainable development through BE initiatives in the WIO region, all coastal and island states are fully engaged albeit in different ways and different focus areas (fishing, tourism shipping, mariculture, maritime security, oil and mineral extraction, marine renewable energy, marine genetic resources, and digital connectivity) (UNECA 2015; Benzaken 2016; Okafor-Yarwood et al. 2020). This is catapulted by other regional initiatives such as the 2050 Africa's Integrated Maritime Strategy (2050 AIM-Strategy), and the declaration of the decade of African Seas and Oceans (2015–2025). Globally, these national and regional efforts build on the UN Decade of Ocean Science for Sustainable Development (2021–2030) and the UN Sustainable Development Agenda and the Sustainable Development Goals (SDGs). SDG 14 (Life Under Water) is an opportunity for WIO countries to spearhead the discussion on sustainable billfish fisheries. The importance of the WIO region for billfish species makes a case for coastal, regional fisheries authorities, and resource users to collectively facilitate, coordinate and implement actions to address the threats to their sustainability.

Klinger et al. (2018) underscore the need for regional or transboundary policies that would propel blue growth in the face of interactions by multiple players who socially and economically target marine systems. The presence of multi-sectors across different national jurisdictions in the use and management of billfish means that knowledge of the quantity of billfishes caught (by species and sizes) in each area by each type of fishery (artisanal, sport, industrial) is the key stone parameter in any prospect of BE economy. Okafor-Yarwood et al. (2020) noted that a successful BE for Africa will encompass an integrated approach, which incorporates local communities, economic needs, and sustainability of the natural ecosystem. A collaborative framework which incorporates top-down and bottom-up approaches to BE management is timely and cost effective where countries are looking to explore the potential of understudied species such as billfish but with the challenge of overexploited fisheries at IO scale.

Conclusions

The objectives of this review were two-fold. First, we highlighted what is known about billfish species and the gaps in information across the WIO region. Second, we used this baseline information to outline various recommendations to address gaps in data collection and collectively promote sustainable use and management of billfish. Data from recreational and artisanal fisheries that catch billfish remain scarce in the WIO, yet these fisheries are integral to resource users. The question remains: how can we achieve an integrated management of transboundary species? It is important to note that while our review focuses on the WIO region, the discussion contributes to the broader discourse on the management of transboundary marine species, especially in the Global South where many shared fisheries are data-poor and have competing users. Strengthening collective data collection efforts and submission of national statistics are critical especially in the face of overexploited species and the increasing demand for fish and fish products. States will need to act quickly by investing in monitoring and surveillance activities and enhancing the report of historical and current national statistics. Billfish are still understudied in many regions, especially in the Indian Ocean. Research on billfish should be prioritized at national and regional levels to examine their sustainable management.

The expansiveness of billfish habitats justifies the need for transparency and routine reporting of fisheries within and beyond EEZ to facilitate spatial management and improve management recommendations at IOTC and national level. Collective and inclusive collaborative actions by individuals, private entities, research institutions and governments are crucial in eliminating the challenges and barriers to advancing the knowledge about billfish species through addressing baseline data gaps, implementing robust data collection systems, and developing an integrated management of billfish which incorporate scientific evidence and local ecological knowledge. Member states must submit all their data, especially from artisanal and sport fishers, and any industrial vessels that may not have registered with IOTC so that, collectively, better scientific outputs on scenarios from the modelling and analysis of the data are achieved. The transnational nature of billfish species presents a unique opportunity for WIO countries to increase focus on engagement with the wider range of stakeholders, ignite greater public attention to the importance of billfish species, and enact sustainable fisheries policies for shared fish stocks.

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