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Trends in Indian Ocean marine fisheries since 1950: synthesis of reconstructed catch and effort data

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ABSTRACT

Context. Contrary to other ocean basins, Indian Ocean catches have increased consistently since 1950, although reported data are known to be incomplete. Fish is a crucial food source in the Indian Ocean; however, ineffective management often empowers over-exploitation. **Aims.** We synthesised and reviewed Indian Ocean reconstructed catch and effort data by fishing sector and fishing country at the ocean-basin scale. **Methods.** We aggregated reported and reconstructed unreported catch and effort data for the Indian Ocean and derived catch-per-unit-effort (CPUE) time-series by sector. **Key results.** Indian Ocean rim country catches dominated in the Indian Ocean. Small-scale catches in the Indian Ocean have grown continuously by over 300% from 1.9×10^6 tonnes (Mg) year^{-1} in 1950 to 6.5×10^6 tonnes year^{-1} by 2018. By contrast, total industrial catches from the Indian Ocean have reached a plateau at ~8.5×10^6 tonnes year^{-1} since the late 1990s, after having steadily risen from very low levels in the early 1960s. Unreported catches declined from 45 to 25% of total catches. Total fishing effort, driven by the industrial sector, has increased 30-fold since 1950 from 0.4×10^9 to 11×10^9 kW-days by 2010, whereas CPUE has declined 78%, with steeper declines in the small-scale (>80% since 1950) than in the industrial sector (65% from its 1981 peak). **Conclusions.** The different sectoral patterns in the Indian Ocean compared with other ocean basins are likely to be due to the region's high dependence on small-scale fisheries and the later onset but swift growth of industrial fishing. The declining CPUE suggests strong decreases in stock biomass caused by strongly increasing fishing effort, especially in the industrial sector. **Implications.** Indian Ocean countries should prioritise lower-impact well-managed domestic small-scale fisheries to maximise long-term, sustainable nutrient supply for local livelihoods.

Keywords: artisanal fisheries, catch per unit effort, conservation, discards, fish, fisheries, fishing effort, food security, industrial fisheries, large-scale fisheries, landings, marine, marine resources, ocean basin, overfishing, small-scale fisheries, subsistence fisheries, sustainability, underreporting, unreported.

Introduction

The Indian Ocean is globally under-represented in large-scale studies on marine fisheries, despite being home to one-third of the global human population (Roy 2019), which could be increasing to half the global population by 2050 (Doyle 2016). The region contains some of the world's most utilised shipping lanes and accounts for ~30% of global shipping traffic (Tournadre 2014), as well as extensive natural resources (Llewellyn *et al.* 2016; Moustahfid *et al.* 2019). Recognition of the geopolitical and strategic importance of the region has grown in recent years (Bouchard and Crumplin 2010), and over 20% of global GDP is expected to come from the Indian Ocean economies by 2025 (Wignaraja *et al.* 2019). Therefore, the Indian Ocean needs to be recognised as a single region of immense economic, strategic and environmental significance (Doyle 2016).

Globally, marine fisheries catches have been declining steadily since peaking in 1996 (Pauly and Zeller 2016, 2019; Food and Agriculture Organization of the United Nations 2018). By contrast, the Indian Ocean basin seems to have experienced an ongoing increase in marine catches over time (Pauly and Zeller 2016), although there are concerns about localised resource depletions (Karim *et al.* 2020). This divergent trend in catches has been variously explained by (1) a shift in global fishing effort to the Indian Ocean from historically overexploited regions elsewhere owing to the existence of stocks that might not have been overfished at that time (Worm and Branch 2012), (2) an increasing dependence of Indian Ocean rim countries (Indian Ocean Rim Association, IORA, www.iora.int/en) on marine fisheries (De Young 2006; Selig *et al.* 2019), and (3) the very high uncertainty around official catch data from the Indian Ocean region, as the statistics of various fishing countries operating in the Indian Ocean may be unreliable (Pauly and Zeller 2016; Food and Agriculture Organization of the United Nations 2022). The presence of distant-water fishing fleets, i.e. vessels from countries outside the Indian Ocean region (Li *et al.* 2021), may lead to confounding of catches taken *in* the Indian Ocean *v.* catches taken *by* Indian Ocean rim countries. This can mask food-security problems for the regional countries that are far more heavily dependent on local fisheries resources than thought (Taylor *et al.* 2019).

The Indian Ocean region (Fig. 1), including the semi-enclosed Red Sea (Tesfamichael and Pauly 2016) and Persian–Arabian Gulf (Al-Abdulrazzak *et al.* 2015; Palomares *et al.* 2021*a*), is highly diverse in socio-economic terms (Techera 2018), and includes countries with the highest, and many with the lowest, per capita income in the world (https://data.worldbank.org; Llewellyn *et al.* 2016). This variety also affects the capacity of coastal countries to manage and control fisheries in the region, where a few examples of reasonably well-managed fisheries contrast with a general lack of management, regulation, control and enforcement (De Young 2006). Such a lack of effective management and enforcement capacity often results in development-driven policies in national fisheries that largely encourage unfettered and unsustainable growth and exploitation (van der Elst *et al.* 2005, 2009; De Young 2006; van der Elst and Everett 2015) and the substantial presence of illegal, unreported and unregulated (IUU) fishing in the region (Karim *et al.* 2020; Samy-Kamal 2022).

Although domestic fisheries are socially and historically important in many countries (Moustahfid *et al.* 2019), the

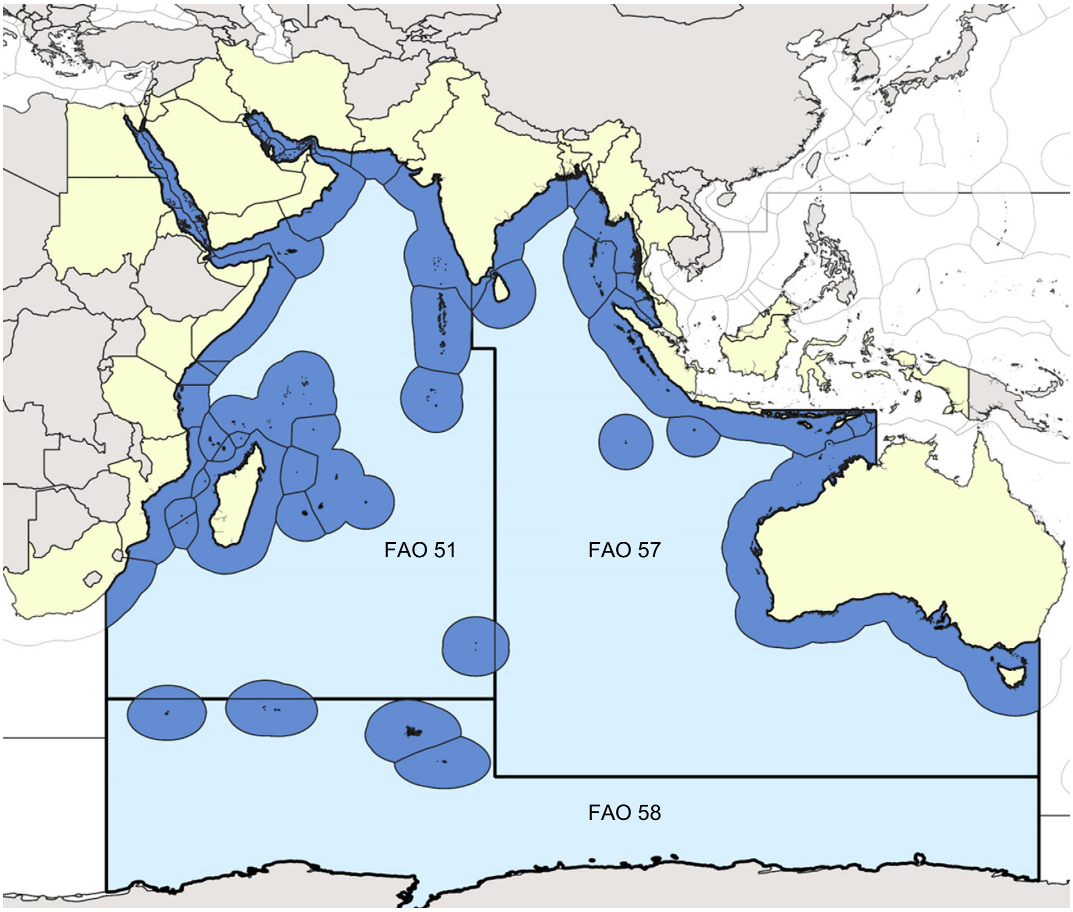

Fig. 1. The Indian Ocean basin, as delineated by FAO Statistical Areas 51, 57 and 58. Dark blue denotes the exclusive economic zones (EEZ) of Indian Ocean rim countries that are within the Indian Ocean basin. EEZ and FAO area boundaries taken from the *Sea Around Us* (Zeller *et al.* 2023). Scale 1:73 000 000.

economic cash revenues generated by permitting foreign fishing interests direct, reflagged or joint-venture access to the exclusive economic zones (EEZs) of countries represents a very strong incentive for national fisheries policy (Sheppard 2018; Belhabib *et al.* 2019). However, despite the perceived importance of domestic and foreign industrial (i.e. large-scale) fishing, small-scale fisheries actually play a far more crucial socio-economic and food-security role across Indian Ocean rim countries (Taylor *et al.* 2019; Techera 2020) as well as globally (Zeller and Pauly 2019), yet are generally overlooked or given less credence in policy circles (Bennett *et al.* 2021). Small-scale fisheries data are traditionally under-reported (e.g. Zeller *et al.* 2015) and not differentiated in the official international statistics (Pauly and Charles 2015). These factors heavily contribute to the political marginalisation of small-scale fisheries around the world (Pauly 2006; however, see Food and Agriculture Organization of the United Nations 2015; Pauly and Charles 2015). Consequently, the socio-economic, food-security and livelihood importance of small-scale fisheries across the Indian Ocean is likely to be much higher than thought or indicated by their share of officially documented fisheries catch volumes alone (van der Elst *et al.* 2005; Walmsley *et al.* 2006; van der Elst and Everett 2015; Pauly and Zeller 2016; Zeller and Pauly 2019).

Small-scale fisheries, i.e. artisanal and subsistence sectors (Zeller *et al.* 2015; Pauly and Zeller 2016) in the Indian Ocean region constitute a major element of poverty alleviation and food and nutritional security (Golden *et al.* 2016; Taylor *et al.* 2019; Vianna *et al.* 2020*a*) for some of the poorest coastal communities in the world (van der Elst *et al.* 2005; De Young 2006). In 2006, the small-scale fishing sector was thought to employ 2.5 times more people than was the industrial sector in the Indian Ocean region (De Young 2006). In the interest of food, nutritional and health security, economic development goals need to be cautiously balanced with sustainability and recognition of the high dependence of coastal populations on marine nutrients, especially for countries in the Indian Ocean region with high population densities (van der Elst *et al.* 2005; De Young 2006; Walmsley *et al.* 2006; van der Elst and Everett 2015; Golden *et al.* 2016; Belhabib *et al.* 2019; Vianna *et al.* 2020*a*; Bennett *et al.* 2021). For this reason, a better understanding of total catches by fishing sector and fishing country, as well as the status of fish stocks in the region is fundamental, because it may assist the capacity of coastal countries to maintain and enhance livelihood opportunities, as well as sustainably supply animal protein and critical nutrients for the increasing demand of a growing population (Rumley *et al.* 2009).

The state of fisheries data, science and stocks varies widely across the Indian Ocean. A few countries, such as Australia, have quite well-developed data, science and management systems (however, see Edgar *et al.* 2018, 2019; Gaughan *et al.* 2019; Little *et al.* 2019). However, there is a general paucity of comprehensive data, stock assessments and effective management on the basis of data in the majority of Indian Ocean countries (van der Elst *et al.* 2005, 2009; Rumley *et al.* 2009; van der Elst and Everett 2015; McClanahan *et al.* 2016). Consequently, reliable information on the status of many stocks exploited by industrial and small-scale fisheries is missing in the public realm (Pauly and Zeller 2016).

The Food and Agriculture Organization of the United Nations (FAO) suggests that over 65% of the fish stocks it assesses for the Indian Ocean are exploited at a sustainable level (Food and Agriculture Organization of the United Nations 2020); yet, these evaluations are generally based on incomplete and inadvertently biased datasets (Pauly and Zeller 2016; Zeller and Pauly 2018). By contrast, stock-status assessments (Froese *et al.* 2012; Kleisner *et al.* 2013) using comprehensive reconstructed catch data suggest that the time-series trends for over-exploited and collapsed stocks in both the eastern (www.seaaroundus.org/data/#/fao/57/stock-status) and western Indian Ocean (www.seaaroundus.org/data/#/fao/51/stock-status) have continued to largely increase unabated in recent years, with only some indications of trend stagnation in the western Indian Ocean for over-exploited stocks. Warnings of overfishing and declining trends in catches are common across the region for stocks that have not been formally assessed (De Young 2006; Rumley *et al.* 2009; Sheppard 2018; Belhabib *et al.* 2019). Moreover, reconstructions of total catches have shown that the official catch statistics presented by the FAO on behalf of countries underestimate actual total catches (Pauly and Zeller 2016). Recent global stock assessments by climatic zones and ocean basins using data-limited assessment methods (Froese *et al.* 2017; Palomares *et al.* 2021*b*) applied to reconstructed catch data suggest a strong and steady decline in overall stock biomass by over 50% since 1950 for all climatic zones in the Indian Ocean (Palomares *et al.* 2020).

Poor, incomplete and inconsistent data also represent major barriers for governance agencies to better manage domestic fisheries for sustainability and stock resilience, which is of utmost importance because of climate-change impacts on marine resources and fisheries (Sumaila *et al.* 2011; Aqorau *et al.* 2018; Pauly and Cheung 2018; Pinsky *et al.* 2018*a*, 2018*b*). In addition to climate-driven habitat loss, productivity changes and altered food webs, the effect of climate change could seriously affect fish stocks and domestic fisheries, particularly small-scale sectors (Clark 2006; Techera 2018). This can lead to potentially escalating conflicts between fishing sectors both domestically and internationally (Rumley *et al.* 2009; Belhabib *et al.* 2019). Poorly monitored, controlled and constrained foreign fishing interests in EEZ waters can lead to the underestimation of the real fishing pressure and impacts on stocks, especially if based on inadequate data. Such foreign industrial fishing pressures can exacerbate management challenges (World Wide Fund for Nature 2012), and ultimately prevent the recovery of overfished stocks that are of crucial economic and food-security importance to Indian Ocean countries (Le Manach *et al.* 2012; Belhabib *et al.* 2019).

Here, we present a synthesis of marine fisheries data and analyses for the Indian Ocean basin from 1950 to 2018, building on fisheries research and data activities by the *Sea Around Us* and *Sea Around Us – Indian Ocean* (Pauly 2007; Zeller *et al.* 2023), with emphasis on the reconstructed catch and fishing-effort history, as well as resulting catch-per-unit-effort (CPUE) indices. We recognise that reconstructed data may contain errors and may have higher uncertainties than do reported data (Pauly and Zeller 2017; Zeller and Pauly 2019), and we welcome collaborations and opportunities for engagements to correct any potential errors to improve the underlying data. Initiatives that generate and synthesise data on regional and ocean-basin scales are foundational to understanding broad priorities for national institutions and regional collaborations, and to allow for the implementation of effective action plans to recover and manage exploited stocks.

Materials and methods

Catch time-series

We present the reconstructed catch time-series from 1950 to 2018 for marine fisheries in the entire Indian Ocean (Fig. 1), including the Red Sea (Tesfamichael and Pauly 2016) and the Persian Gulf (Al-Abdulrazzak *et al.* 2015; Wabnitz *et al.* 2018). The catch reconstruction approach, as described in Zeller *et al.* (2016) and applied to every maritime country in the world in Pauly and Zeller (2016), complements the reported catch statistics published annually by the FAO on behalf of countries with estimates of unreported catches. The official FAO statistics, based on reports from member countries (Garibaldi 2012; Food and Agriculture Organization of the United Nations 2020), focus mainly on landings from commercial fisheries and often exclude or under-report other sources of catches, such as from many small-scale and non-commercial fisheries. The reconstructed catch data synthesised here add comprehensive estimates of unreported landed catches, including by small-scale fisheries (Zeller *et al.* 2015), and conservative estimates of major discards, which are otherwise explicitly excluded from national FAO data reports (Zeller *et al.* 2018). In this context, catch data that are not included in the data provided by countries to the FAO are considered 'unreported', even if they may be in local or state data sets or reports. Thus, the catch reconstruction approach addresses an inherent negative bias (i.e. underreporting) in official national and, by extension, internationally reported catch data, although uncertainty in both reported and unreported catch data remains (Pauly and Zeller 2016, 2017).

The present study synthesises the detailed domestic catch reconstructions undertaken for the EEZs of every Indian Ocean rim country (Supplementary Table S1) plus the foreign fishing data (distant-water fleets) as allocated to Indian Ocean EEZs and high-seas areas (Zeller *et al.* 2016, 2023). This contribution comprises both domestic waters, defined as the waters within the EEZs of individual countries (Fig. 1) as claimed or claimable under the United Nations Convention on the Law of the Sea (UNCLOS, United Nations 1982), and open-ocean high-seas waters, i.e. areas beyond national jurisdiction. Referenced country-specific methodological details used to derive EEZ-level data (i.e. reported and reconstructed data) are listed in Table S1, and are freely available at www.seaaroundus.org. The catches in the high seas are heavily influenced by fisheries for large pelagic species, notably for large tuna, billfishes and pelagic sharks, as described in Le Manach *et al.* (2016) and Coulter *et al.* (2020), but also include non-tuna data (e.g. Ainley and Pauly 2014). The specific regional fisheries management organisations with a data mandate of relevance here are the Indian Ocean Tuna Commission (IOTC), the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), and the South Indian Ocean Fisheries Agreement (SIOFA).

The country-specific, EEZ-centred catch reconstructions were undertaken by the following four fishing sectors (Zeller *et al.* 2016): industrial (large-scale, commercial), artisanal (small-scale, commercial), subsistence (small-scale, non-commercial), and recreational (small-scale, non-commercial). We recognise that overlap may exist between these sectors. A single, standardised global definition of fishing sectors, e.g. one based on vessel size, does neither exist nor would it make sense. For instance, a vessel clearly considered large-scale (i.e. industrial) in a developing country may be considered small-scale (i.e. artisanal) in developed countries (Zeller *et al.* 2016). For this reason, reconstructions generally utilise each country's individual definitions for fishing sectors, with only minor modifications (Zeller *et al.* 2016), or regional equivalents, which have been described in each country's reconstruction documentation underlying this work (Table S1). Additionally, as part of the reconstructions, we also estimated major discards for the fisheries of each country (Zeller *et al.* 2018). Because not all discarding could be evaluated, our discard estimates should be considered very conservative.

We excluded from consideration all data for marine mammals, reptiles, corals, sponges and marine plants. In addition, we did not estimate catches made for the aquarium trade (Wabnitz *et al.* 2003), which can be substantial in some areas in terms of numbers of individuals and export value, but, generally, are small in overall quantity, because most aquarium fish are small or juvenile specimen. Finally, we focus only on marine fisheries here, and thus all freshwater, i.e. inland fisheries, are excluded, despite their at times major importance for domestic food security (e.g. Schubert *et al.* 2022).

Country-specific details of each catch reconstruction are documented in the technical reports for each EEZ area listed in Table S1, and follow the basic catch-reconstruction principles (Zeller *et al.* 2016). As part of each reconstruction, we also quantified the uncertainty associated with each reconstructed time-series. We estimated the reliability of, or confidence in, the various data and data sources used in each reconstruction by using a scoring method adapted from the Intergovernmental Panel on Climate Change when using multiple and differing sources of evidence (Mastrandrea *et al.* 2010). These scores represent a form of 'uncertainty' measure regarding the data and information sources used for estimation. We estimated data reliability scores and the associated percentage uncertainty bounds (Table 1) on the basis of a qualitative evaluation of the trust in the secondary data and information sources used for each of the four fishing sectors for four time periods (1950–1969, 1970–1989, 1990–2009 and 2010–2018) in each country reconstruction. The data reliability scores are presented for each EEZ at www.seaaroundus.org, and are included in the downloadable data.

Finally, each catch reconstruction is documented either in the peer-reviewed scientific literature (e.g. Greer *et al.* 2014; Khalfallah *et al.* 2016; Christ *et al.* 2020), or as detailed technical reports that are freely available at www.seaaroundus.org (see Table S1).

Fishing effort and CPUE time-series

The global fishing-effort database of the *Sea Around Us*, which builds on earlier work on fishing effort (Anticamara *et al.* 2011) and on CO_2 emissions by the global fishing fleets (Greer *et al.* 2019), includes data on large-scale (i.e. industrial) and small-scale fishing effort for every maritime country in the world for 1950–2010. A large variety of fishery- and gear-specific units of measurement of fishing effort are used around the world, which makes global comparisons difficult owing to the non-standardised nature of these effort units. By contrast, the *Sea Around Us* effort data utilise a globally standardised unit of fishing effort for all fleets and gear types, based on the power input in fisheries, i.e. kilowatt-days (Anticamara *et al.* 2011; Belhabib *et al.* 2018). At the time of writing, these global fishing-effort data remain partially preliminary, but are being revised and improved upon (e.g. Christ *et al.* 2020; Vianna *et al.* 2020*b*; Zeller *et al.* 2021).

For each fishing country, the fishing effort was estimated by fleet, using the general reconstruction principles described above for catch data (Zeller *et al.* 2016). Importantly, fishing-effort data were estimated independently of catch data reconstructions, so as to ensure data independence. Fleets were defined by fishing country, sector, gear, length class and motorisation. Because a single, standardised global definition for fishing sectors is not applicable, country-specific definitions were applied to allocate fleet data to fishing sectors, as was undertaken during catch data reconstructions. When no country-specific definition was available, the following three main factors were used to determine fishing sector for the fishing effort estimation:

1. gear: any vessel that actively moves fishing gears across the seafloor or through the water column by using engine power, such as a bottom trawl and pelagic trawl, was assumed to be industrial, regardless of vessel size (*sensu* Martín 2012);
2. vessel size: any vessel less than 15.9 m long was considered to be small-scale;
3. motorisation: any non-motorised vessel was assumed to be small-scale.

Greer *et al.* (2019) derived *nominal* fishing effort as the power input, i.e. engine capacity (kW), per vessel within each fleet. A fleet is the number of vessels in the same length class and motorisation category, and utilising the same or similar fishing gears. Engine capacity (kW) per fishing vessel in a given fleet was determined by length and motorisation (Table 2). Thus, total nominal fishing effort is the product of the engine capacity and the number of boats operating within a fleet segment in a given year. Non-motorised fishing, i.e. by vessels or shore-based fishers powered by human or wind power, were considered to have an engine-equivalent capacity of 0.37 kW per vessel for fishing vessels of length class 1, 0.75 kW per vessel for length class 2, and in rare occasions 1.12 kW per vessel for any potentially non-motorised vessels of length class 3 (Table 2).

To fully quantify actual fishing effort by fishing fleets, the duration of fishing activities also needs to be accounted for in estimates of fishing effort. Thus, *effective* fishing effort

Table 1. Data reliability 'scores' for evaluating the quality of time-series of reconstructed catches, with their approximate confidence intervals (IPCC criteria from fig. 1 of Mastrandrea *et al.* 2010).

Score	Data reliability	Uncertainty	Corresponding IPCC criteria
4	Very high	±10%	High agreement and robust evidence
3	High	±20%	High agreement and medium evidence *or* medium agreement and robust evidence
2	Low	±30%	High agreement and limited evidence *or* medium agreement and medium evidence *or* low agreement and robust evidence.
1	Very low	±50%	Low agreement and low evidence

Mastrandrea *et al.* (2010) noted that 'confidence increases' (and, hence, confidence intervals are reduced) 'when there are multiple, consistent independent lines of high-quality evidence'.

Table 2. Power-input or capacity of motorised and non-motorised fishing vessels by length class and fishing sector.

General length class	Vessel length range (m)	Average vessel length (m)	Sector – motorised	Motorised capacity (kW per vessel)	Sector – non-motorised	Non-motorised capacity (kW per vessel)
1	<7.9	4.5	Small-scale	9.11	Small-scale	0.37
2	8–15.9	11.3	Small-scale	58.7	Small-scale	0.75
3	16–24.9	20.0	Large-scale	185	Small-scale	1.12
4	25–49.9	35.4	Large-scale	587	NA	NA
5	50–99.9	70.7	Large-scale	2383	NA	NA
6	100–150	122.5	Large-scale	7235	NA	NA

Modified from Greer *et al.* (2019). The geometric mean was used for average vessel length classes 1 and 2; and the arithmetic mean for length class 3 and up. If no country-specific information was identified for the 'Sector – motorised' category, all motorised vessels less than length class 3 were assumed to be small-scale and all motorised fleets in length classes 3–6 were deemed to be large-scale. All non-motorised vessels were deemed to be small-scale vessels for the 'Sector – non-motorised' category.

(kW-day) is the product of nominal fishing effort (power input × number of vessels within a fleet) in kilowatts and the number of days spent fishing per year. The number of days spend fishing was derived by literature searches during individual-country fishing-effort reconstructions. In instances where fleet- and country-specific data were not available, Greer *et al.* (2019) estimated the number of fishing days by gear type and region (Table 3).

A standardised fishing effort measurement unit (kW-day) enables us to combine the reconstructed catch data for every country fishing in the Indian Ocean with that country's standardised fishing-effort estimate to determine CPUE time-series for 1950–2010. Such time-series can provide general indicators of the broad status and trend of the marine resources underlying fisheries in a given area, for example, in West Africa (Belhabib *et al.* 2018) or the Mozambique Channel region in the western Indian Ocean (Zeller *et al.* 2021).

Here, we use the fishing-effort data for 1950–2010, in combination with the reconstructed catch data to derive a generalised broad CPUE time-series for the fisheries in the Indian Ocean by large-scale (industrial) and small-scale fishing sectors. Because of the nature of the effort data, which were derived by fishing (flag) country and not by the spatial location where fishing occurs, we cannot readily derive independent CPUE time-series for industrial fishing in Indian Ocean waters by distant-water fishing countries that are not Indian Ocean rim countries. As a result, approximate effort estimates of distant-water fishing fleets were based on the proportion of a distant-water fishing country's catch made in Indian Ocean waters in relation to that country's global catch. This same logic was applied for estimating fishing effort of Indian Ocean rim countries where some fishing (and effort) may take place outside Indian Ocean waters, on the basis of FAO reported catches for FAO areas that are not part of the Indian Ocean.

Table 3. The assumed number of days at sea, i.e. fishing-trip days by marine fishing vessels, by gear type and by geographic country region as relevant to the Indian Ocean.

Gear type	Annual fishing trip days for countries in:	
	Africa	Asia and Australia
Gillnet	140	171
Hook and Line	243	297
Longline	274	334
Purse Seine	159	195
Trap	104	128
Trawl	180	220
Unknown	175	213

Data are derived from Greer *et al.* (2019) based on earlier work by Anticamara *et al.* (2011). These values were applied only in the absence of fleet- and country-specific data on the number of fishing days.

Results

Global marine fisheries catches peaked in 1996 and have been declining ever since (Fig. 2; see also Pauly and Zeller 2016). Although global catches in the earlier decades were dominated by Atlantic Ocean fisheries, since the 1980s, the Pacific Ocean basin has dominated global fisheries catches, contributing ~55% of the global catch, whereras the Atlantic Ocean has accounted for 31% in recent years (Fig. 2). Since 1950, the contribution of the Indian Ocean towards total global catches has almost doubled, from ~7% or 2×10^6 tonnes (Tg) per year, to ~14% or over 15×10^6 tonnes $year^{-1}$. Most importantly, however, the Indian Ocean basin is the only area in the world with an increasing catch trend since global catches peaked in 1996 (Fig. 2, 3).

Total reconstructed catches in the Indian Ocean, i.e. for FAO Areas 51, 57 and 58, including the Red Sea and Persian Gulf (Fig. 1), increased steadily from just over 2×10^6 tonnes in 1950, of which 924 000 tonnes were reported, to just under 16×10^6 tonnes in 2017, of which 12×10^6 tonnes were reported (Fig. 3*a*). Unreported catches, both

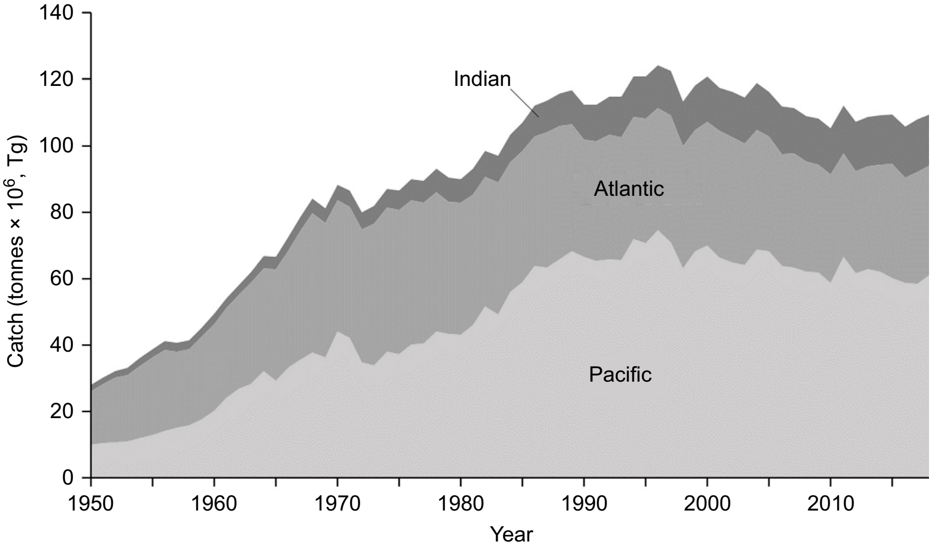

Fig. 2. Global reconstructed catches by major ocean basins. Very low catches from FAO Statistical Area 18 (Arctic Sea) are included as Atlantic Ocean catches here. Data have been updated from Pauly and Zeller (2016).

unreported landings and discards, accounted for ~45% of total catches in the early decades, but have declined to a still substantial 25% by the late 2010s (Fig. 3*a*). Total catches in this ocean basin are dominated by the industrial (large-scale) fishing sector, whose catch increased from a very modest 60 000 tonnes year^{-1} in the early 1950s to ~9.5×10^6 tonnes in 2018 (Fig. 3*a*). Industrial fishing thus accounts for nearly 60% of total catches in recent years, but only began steadily increasing in the mid–late 1970s and 1980s. Industrial catches show a clear sign of reaching a plateau or generally stagnating since the late 1990s (Fig. 3*a*, Supplementary Fig. S1). Small-scale fisheries, i.e. artisanal and subsistence sectors, have always played a crucial food-security and livelihood role in the Indian Ocean, accounting for over 90% of total catches in the 1950s, and still account for ~40% of total catches in recent years (Fig. 3*a*). Recreational catches are limited in this region, with the exception of Australia and South Africa. Small-scale catches have continued to increase over the entire time period, increasing from ~2×10^6 tonnes in 1950 to 6.5×10^6 tonnes by 2018 (Fig. 3*a*). The artisanal (small-scale, commercial) sector dominates small-scale fisheries, accounting for ~83% of small-scale and 35% of total catches in 2018 (Fig. 3*a*). Discarding peaked at just under 1.1×10^6 tonnes in 1993, and declined to ~600 000 tonnes year^{-1} by the late 2010s (Fig. 3*a*). Nearly all discards that could be accounted for in the reconstructed data were from the industrial sector, which accounted for ~94% of total discards.

Demersal fishes and invertebrates (including crustaceans such as lobster and shrimp) dominate total catches in the Indian Ocean, accounting for ~55% of total ocean basin catches, or 8.3×10^6 tonnes year^{-1} in recent years (Fig. 3*b*). The contribution of pelagic taxa has increased over time, and pelagic taxa have accounted for slightly over 40%, or ~600 000–650 000 tonnes year^{-1} in recent years (Fig. 3*b*). Interestingly, pelagic catches are dominated by small or medium-sized pelagic taxa, i.e. everything from sardines to smaller scombrids such as mackerels, whereas large tuna and billfishes accounted for only ~7–8% of total ocean basin catches and 17% of pelagic catches in the late 2010s (Fig. 3*b*). Demersal and pelagic sharks and rays accounted for slightly over 2.5% of reconstructed catches in the late 2010s (Fig. 3*b*). Given the challenges of estimating shark and ray catches, this may be an underestimate.

Averaged over the nearly 70-year time period considered here, the two commercial sectors, industrial and artisanal, have average reporting levels of ~75–80% of total landed catches, whereas the non-commercial subsistence sector is substantially under-reported, with average reporting levels of only ~16–20% (Fig. 4). Virtually no recreational catches are reported by Indian Ocean rim countries to the FAO, despite the FAO explicitly requesting such data (Garibaldi 2012). However, the sectoral patterns of reporting of catches has varied over time. Whereas the large-scale, industrial fishing sector has had reporting levels of 84% in recent years, compared with 68% in the 1980s, the reporting levels for this sector might have been much higher in the 1950s, suggesting a potential deterioration in reporting standards as industrial fishing has grown in popularity (Fig. 4). Despite being much more difficult to account and report on, the widely dispersed small-scale, artisanal fisheries landings have still had apparent reporting levels of ~78% in recent years. Artisanal data have shown steady improvements in levels of reporting since the 1960s (Fig. 4). Although overall extremely poor,

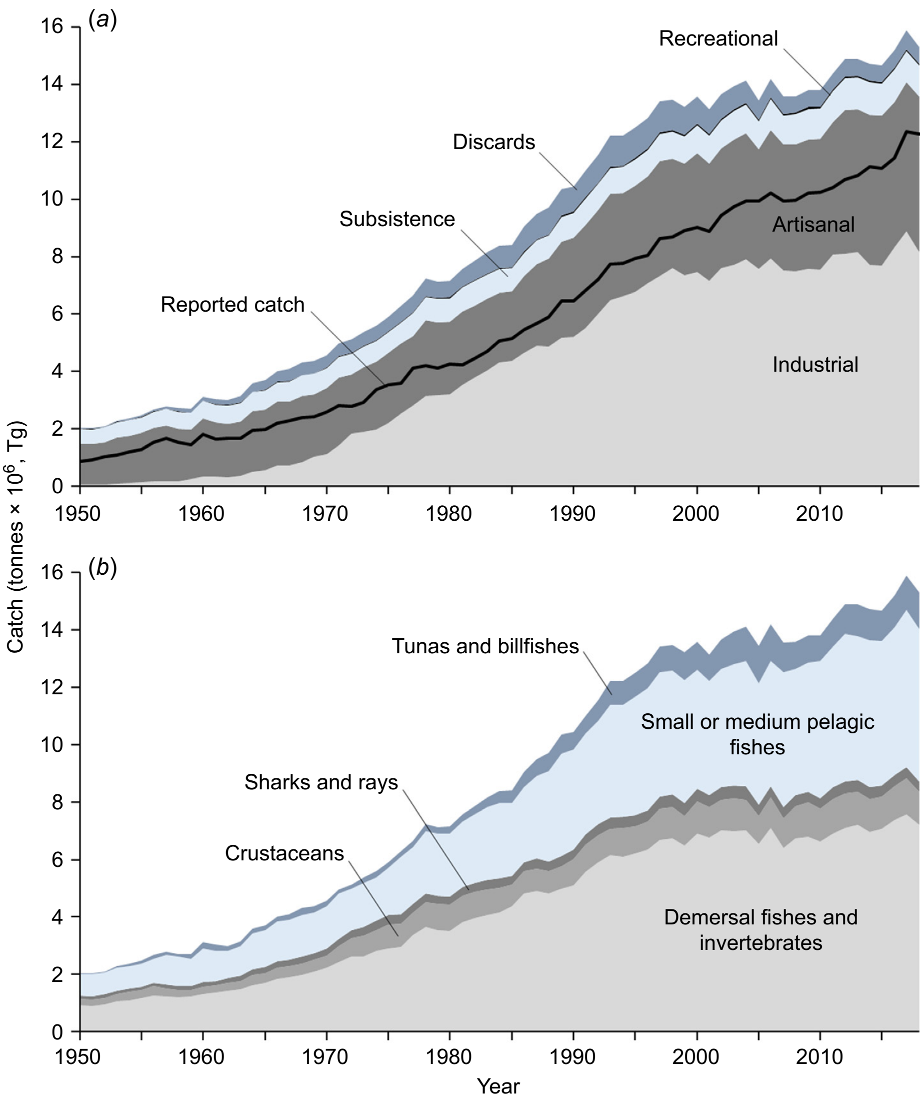

Fig. 3. Total reconstructed marine catches for the Indian Ocean, including the Red Sea and Persian Gulf, by (*a*) fishing sectors plus major discards between 1950 and 2018. Official landings data as reported by the FAO on behalf of countries fishing in the Indian Ocean is overlaid as line graph; and (*b*) major taxonomic categories.

reporting levels for non-commercial subsistence catches have improved somewhat over time, with ~21% of total estimated subsistence catches now deemed to be included in the officially reported data (Fig. 4).

The vast majority of catches in the Indian Ocean, i.e. ~95% or 14×10^6 tonnes year^{-1} in recent years, are taken from waters within national jurisdiction, i.e. from EEZ waters (Fig. 5*a*). By contrast, high-seas waters have accounted for only ~5% (or ~700 000 tonnes year^{-1}) of total ocean basin catches in recent years, down from a peak of 6.8% in 2005 (Fig. 5*a*). Catches in the Indian Ocean are dominated by fleets from Indian Ocean rim countries, accounting for 97% or almost 15×10^6 tonnes year^{-1} of total ocean basin catches in recent years, with only ~440 000 tonnes year^{-1}, i.e. 3%, being taken by distant-water fishing countries (Fig. 5*b*). Fleets flagged to the Indian Ocean rim countries India, Thailand, Indonesia, Malaysia and Myanmar account for slightly over 60% of total ocean basin catches in recent years (Fig. 5*b*). Although the share of catches taken by India has grown steadily over decades, Thailand's share of catches has declined in recent years.

Catches within EEZ waters of Indian Ocean rim countries are dominated by catches taken by Indian Ocean rim countries, as would be expected (Fig. 5*c*). Distant-water fleets have accounted for only ~1% of EEZ-level catches in recent years, on the basis of current catch reconstructions (Fig. 5*c*). Given the considerable challenges associated with estimating catches of distant-water fleets operating within

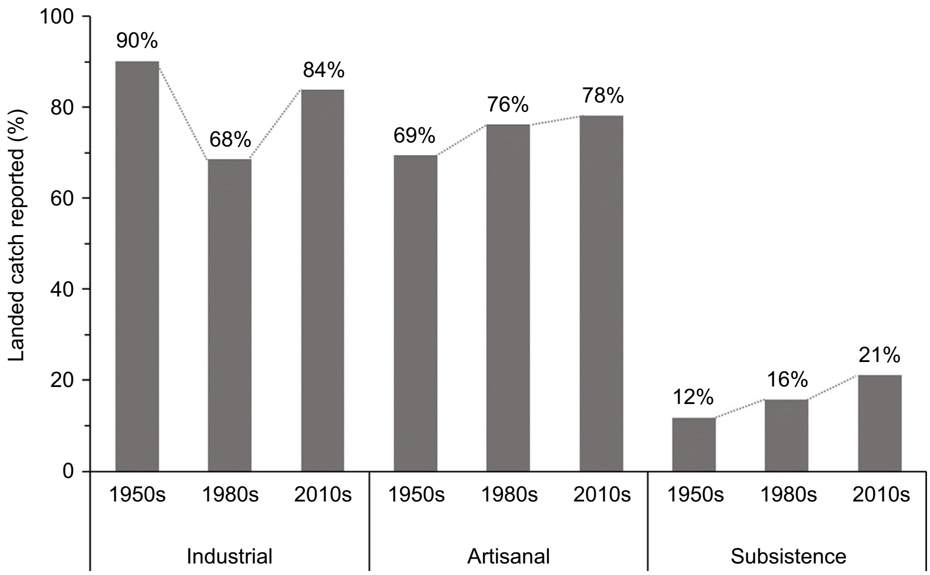

Fig. 4. Percentage of landed catch by fishing sector, i.e. excluding discards, that is deemed reported by the FAO on behalf of countries fishing in the Indian Ocean, on the basis of catch reconstructions, averaged for the 1950s, 1980s and 2010s (2010–2018). Fishing sector assignments are based on the principles in Zeller *et al.* (2016), with specific sectoral details being derived from individual-country reconstructions as described in individual technical references for each country (see Table S1). Note that FAO explicitly excludes discarded catch from the 'nominal catch' data they request from countries, and thus reported data represent landed catches only. Almost no recreational catches are reported by Indian Ocean rim countries to the FAO; thus, no recreational data are shown here.

other countries' EEZs, these estimates may be very conservative. By contrast, fisheries operating on the high seas in the Indian Ocean mostly targeting large pelagic species, i.e. tuna, billfishes and pelagic sharks, have historically been dominated by distant-water fishing fleets from outside the Indian Ocean region (Fig. 5*d*). These distant-water countries, mainly Japan and Taiwan, accounted for nearly 100% of high seas catches until 1980 (Fig. 5*d*). More recently, ~45% of total high-seas catches, or almost 350 000 tonnes year^{-1}, are taken by distant-water fleets, which are dominated by Spain and Taiwan (Fig. 5*d*). However, vessels flagged to India Ocean rim countries seem to have increased their activities in high-seas waters, and more recently account for ~55%, or ~400 000 tonnes year^{-1} of high-seas catches. These are mainly taken by vessels flagged to Indonesia, Iran and the Seychelles (Fig. 5*d*).

Fishing effort and CPUE

The overall fishing effort expended in the Indian Ocean has grown substantially since 1950, increasing 30-fold from 0.4×10^9 kW-days in 1950 to nearly 11×10^9 kW-days by 2010 (Fig. 6). Total fishing effort is dominated by the industrial fishing sector, which accounts for ~70% or 7.4×10^9 kW-days of total effort in 2010 (Fig. 6*a*). The small-scale sectors, which accounted for ~30% or nearly 3.4×10^9 kW-days of total effort in 2010 (Fig. 6*a*), are dominated by fishing effort from small-scale fleets of India, Bangladesh, Indonesia and Yemen, which accounted for 38, 19, 14 and 9% respectively of 2010 small-scale fishing effort (Fig. 6*b*). Among the large-scale, industrial fisheries in the India Ocean, effort is dominated by India (29%), Pakistan (17%), Myanmar (13%) and Iran (11%), whereas distant-water fishing fleet countries have accounted for only ~6.5% (471×10^6 kW-days) of industrial fishing effort in recent years (Fig. 6*c*).

Combining the reconstructed fisheries catches taken in the Indian Ocean with the independently estimated fishing-effort expended by fishing countries in the Indian Ocean indicated a consistently declining trend in the overall CPUE since 1950 (Fig. 7). This overall CPUE decline of ~78% since 1950, from nearly 6 kg/kW-day in the early 1950s to under 1.3 kg/kW-day in 2010 (the current end year of globally reconstructed fishing effort data), suggests a consistent decrease in the relative abundance of the underlying marine fisheries resources in the Indian Ocean. For the small-scale sectors, i.e. the commercial artisanal and non-commercial subsistence fisheries, the decline was considerably stronger, with ocean basin small-scale CPUE declining by just over 80% since 1950, from just under 13 kg/kW-day in the 1950s to ~2.4 kg/kW-day in 2010 (Fig. 7). By contrast, the large-scale (i.e. industrial) fisheries CPUE in the Indian Ocean increased in the earlier decades, in line with the

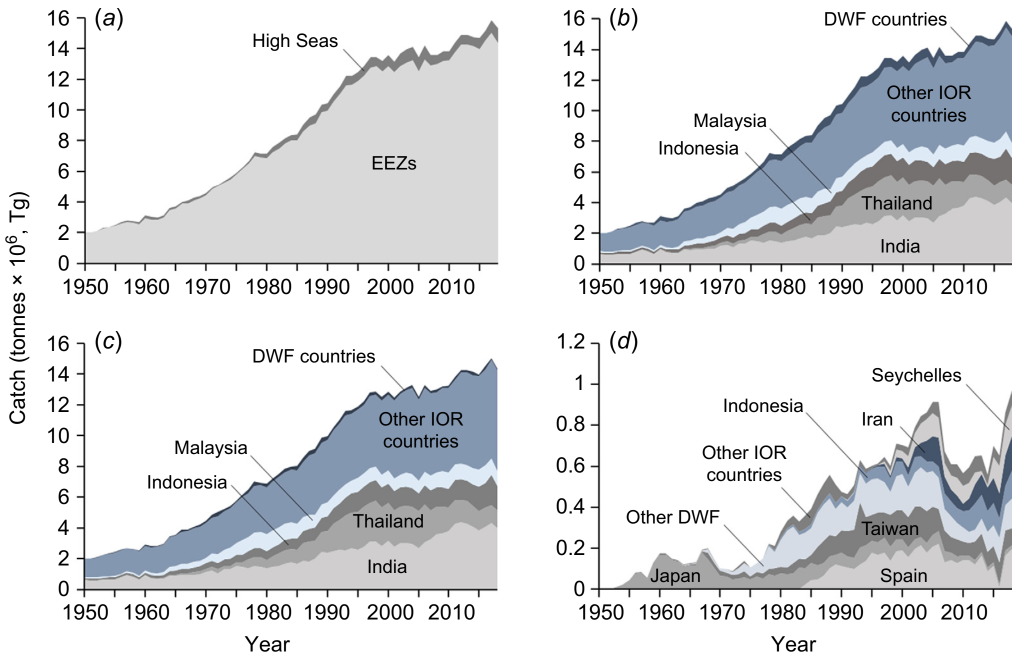

Fig. 5. Total reconstructed marine catches for the Indian Ocean, including the Red Sea and Persian Gulf, (*a*) by EEZ *v.* high-seas locations as derived by the spatial allocation of the *Sea Around Us* (Palomares *et al.* 2016; Zeller *et al.* 2016; Coulter *et al.* 2020), (*b*) by fishing country (flag state), separated into Indian Ocean rim countries (IOR) and distant-water fishing countries (DWF) from outside the Indian Ocean basin, (*c*) by fishing country for catches made within EEZs in the Indian Ocean basin, and (*d*) by fishing country for catches made in the high-seas areas in the Indian Ocean, separated into Indian Ocean rim countries (IOR) and distant-water fishing countries (DWF).

general industrial fleet development in this ocean basin, peaked in the late-1970s at close to 2.7 kg/kW-day, before declining steadily by 65% from peak levels to less than 1 kg/kW-day by 2010 (Fig. 7).

Discussion

In this synthesis, we have illustrated that the Indian Ocean, which has accounted for just 14% of global marine fisheries catches in recent years, is the only ocean basin with a continuing growth in catch volumes. Thus, this ocean contrasts sharply with the declining catch trends in the other two major ocean basins, the Pacific and Atlantic Oceans, and by extension also the global trend (Pauly and Zeller 2016). The increases in total reconstructed catches from the Indian Ocean basin, from $\sim 2.0 \times 10^6$ tonnes year^{-1} to nearly 16×10^6 tonnes year^{-1} by 2018 highlights the considerable importance of marine fisheries in this ocean basin, both for food security in the Indian Ocean rim countries as well as for global seafood markets. The differing trend in catches in the Indian Ocean from those elsewhere is thought to be due to the later onset of heavy industrial fishing in this region, compared with the Pacific and Atlantic oceans (see Fig. S1, S2; Pauly *et al.* 2005).

Industrial, large-scale fishing (Zeller *et al.* 2016), which has been prevalent in other ocean basins since the 1950s or even earlier (see Fig. S2), contributed only 57% of the catch in the Indian Ocean in 2018, compared with slightly over 75% in each of the Pacific and Atlantic ocean basins. However, despite the later onset in the Indian Ocean, heavy industrial fishing has already led to serious impacts on marine fish stocks; for example, excessive trawling has resulted in biomass declines in India (Sathianandan *et al.* 2021) and Pakistan (Raza *et al.* 2022). Industrial catches appear to have reached a plateau in the Indian Ocean since the late 1990s, suggesting that industrial fisheries may already have reached or exceeded sustainable catch limits. In addition, the growth and expansion of industrial fishing has resulted in serious environmental, socioeconomic and geopolitical challenges (Lobo *et al.* 2010; Scholtens *et al.* 2012; Kolding *et al.* 2014; Song *et al.* 2020).

Although satellite-based automatic identification system (AIS) measurements of fishing effort by foreign-flagged vessels may exceed domestic fleet AIS signals in some countries (Li *et al.* 2021), the comprehensively reconstructed data presented here suggest strongly that the vast majority of catches in the Indian Ocean are taken by Indian Ocean rim countries, and furthermore are taken within EEZ waters. Therefore, the future sustainability of fisheries in the Indian

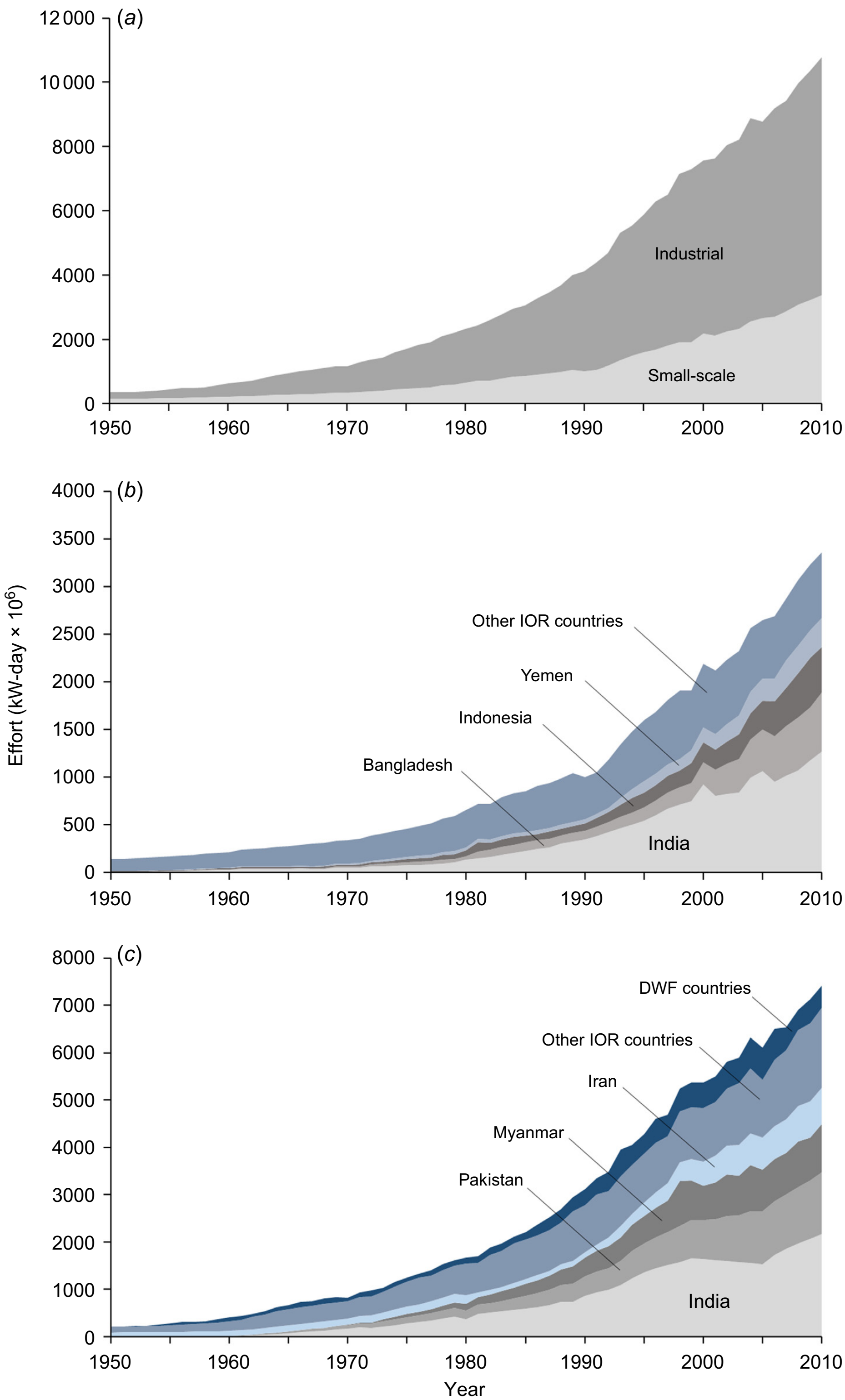

Fig. 6. Fishing effort expended in the Indian Ocean between 1950 and 2010, in kilowatt-days (Greer 2014; Greer *et al.* 2019), by (*a*) small-scale *v.* industrial (large-scale) fishing sector; (*b*) fishing country within the small-scale sector; and (*c*) fishing country within the large-scale (industrial) sector.

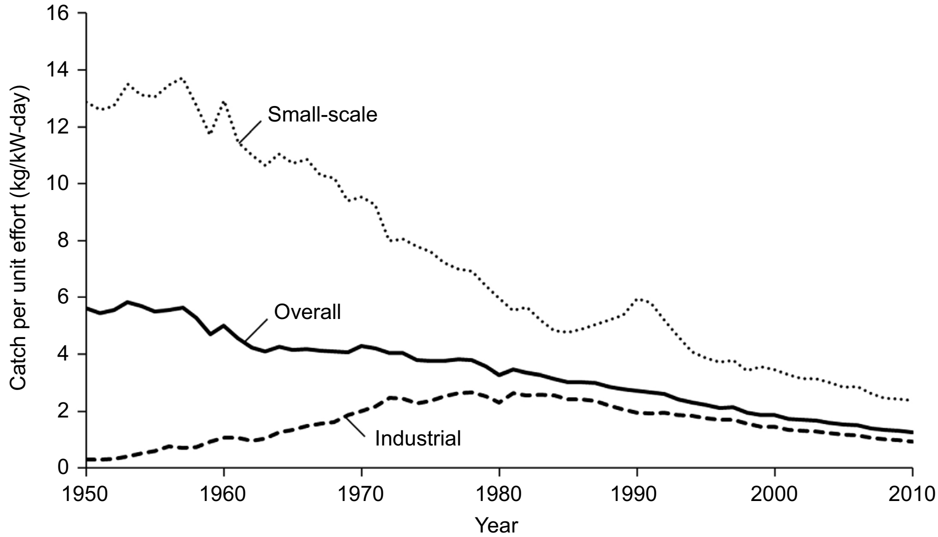

Fig. 7. Catch-per-unit-effort (CPUE) for 1950–2010 in the Indian Ocean basin as derived from reconstructed catches and independently estimated fishing effort by small-scale *v.* large-scale (industrial) fishing sectors.

Ocean is entirely in the hands of Indian Ocean rim governments, which legally have full fisheries jurisdiction over their EEZ waters. However, managing fisheries within national EEZs is a challenge for many Indian Ocean countries (OceanMind 2022; Rattle and Duncan-Jones 2022; White *et al.* 2022). Although there is a gradually increasing trend of high-seas catches for large pelagic species, high-seas fishing remains a very small (5% of Indian Ocean catches), if financially valuable, component (Gillett 2011; Lecomte *et al.* 2017; McKinney *et al.* 2020) of fisheries in the Indian Ocean.

As shown here, local fleets from Indian Ocean rim countries recently started contributing to the majority of the high-seas fisheries in the Indian Ocean. However, this may be partially or largely misleading, because of the reflagging of vessels with majority foreign beneficial ownership (Food and Agriculture Organization of the United Nations 2022). On the basis of officially reported catch data as presented by the FAO on behalf of countries, fleets from distant-water fishing countries seem to account for only a reasonably minor catch in the region and are generally focused on fishing for large pelagic species. Therefore, catches of large pelagic species such as tuna, billfishes and pelagic sharks within the IOTC area of responsibility are unlikely to represent a substantial component of regional or local food security for the Indian Ocean region. By contrast, much of this catch of large pelagic species is exported to developed, food-secure nations (Schiller *et al.* 2018). This is likely to include much of the growing contribution of large pelagic catches by fleets nominally flagged to Indian Ocean rim countries, with many of these vessels actually being reflagged vessels deemed to have majority foreign beneficial ownership (Food and Agriculture Organization of the United Nations 2022). Reflagging and private agreements can obscure and mask distant-water fishing patterns. This is exacerbated by bilateral fishing access agreements, such as between the Seychelles and Mauritius, which is heavily utilised by reflagged foreign fishing interests (Food and Agriculture Organization of the United Nations 2022). Although distant-water fishing fleets are thought to provide some value through local economic and employment opportunities, industrial tuna fisheries in much of the Indian Ocean tend to favour foreign interests, and have led to ongoing management and sustainability challenges for countries in the region, potentially at the expense of small-scale operators (Andriamahefazafy and Kull 2019; Andriamahefazafy *et al.* 2020). The focus within some Indian Ocean rim countries to pursue economic cash benefits by permitting, licensing or reflagging foreign industrial vessels or fishing companies with foreign beneficial ownership seems to be largely misguided (Le Manach *et al.* 2012, 2013; Carver 2019; Yozell and Shaver 2019; Olingo and Atieno 2021).

In many East African countries, industrial fisheries historically provided only a minor contribution towards catches and employment, compared with small-scale fisheries (van der Elst *et al.* 2005; van der Elst and Everett 2015; Moustahfid *et al.* 2019). However, there are clear signs that interest in foreign industrial fisheries has been expanding rapidly in some East African countries over the past decade (World Wide Fund for Nature 2012; Mallory 2013; Godfrey 2022; White *et al.* 2022). Such industrialisations should be treated very cautiously by host countries in the Indian Ocean, because they regularly and rapidly lead to detrimental conditions for coastal communities, truly domestic fisheries and a country's marine resources. This has been clearly demonstrated by the disastrous situation in West Africa over the past few decades (Belhabib *et al.* 2015, 2018, 2019; Doumbouya *et al.* 2017; Seto *et al.* 2017; Virdin *et al.* 2022).

Given the importance of small-scale fishing in the region, Indian Ocean rim countries should carefully reconsider any endeavours to increase or continue supporting and permitting industrial fishing in their waters, especially if driven by joint ventures, reflagging efforts or foreign beneficial ownership. A more cautious approach to industrial and foreign fishing by Indian Ocean rim countries is also warranted by the dearth of data and knowledge of actual levels of stock exploitation within their domestic waters, on which any perceived 'surplus' of available stocks as defined by UNCLOS, the UN Convention on the Law of the Sea (United Nations 1982; Food and Agriculture Organization of the United Nations 2022), needs to be based for potential industrial or foreign exploitation. This is clearly reflected by the substantial fractions of domestic catches that historically were unreported in some of these countries. For example, Somalia's domestic catches are thought to have been >90% higher than officially reported data suggest (Persson *et al.* 2015), and total domestic catches between 1950 and the mid-2000s in Mozambique were over six times higher than data reported by the FAO on behalf of Mozambique indicated (Jacquet *et al.* 2010). Industrial fisheries are driven by company profit maximisation through export focus, rather than domestic food security, employment and livelihood optimisation (Mansfield 2011; Arthur *et al.* 2022), and are heavily dependent on harmful, capacity-enhancing government subsidies (Sumaila *et al.* 2008, 2021; Harper *et al.* 2012; Schuhbauer *et al.* 2020), including in high-seas fisheries (Sala *et al.* 2018). This contrasts with carefully and well-managed small-scale fisheries with exclusively local ownership that also have the potential to lead to domestically retained export income while optimising local employment, livelihood and food security (Zeller and Pauly 2019).

The widespread penchant to prioritise economic cash benefits through foreign fishing access or reflagging (Aqorau 2009; Le Manach *et al.* 2013; Belhabib *et al.* 2015; Food and Agriculture Organization of the United Nations 2022) may not have been as prevalent historically in the Indian Ocean until more recently. Foreign fishing access generally started in the 1980s and 1990s in the south-western Indian Ocean, although some arrangements may have existed earlier (World Wide Fund for Nature 2012). Importantly, the dearth of information on the sustainability of fisheries resources and their underlying value within the region limits the capacity of countries to effectively constrain and control fishing, or ensure sustainable resource use by foreign fishing interests (van der Elst *et al.* 2009). It also risks contributing to IUU fishing (Merem *et al.* 2019; Okafor-Yarwood and Belhabib 2020). Concerns about the status of stocks in the Indian Ocean are supported by the nearly 80% decline in the CPUE over the past few decades, as observed in the present study. Furthermore, within numerous Indian Ocean rim countries, there have been independent reports of declining resources (e.g. Gladstone *et al.* 1999; Islam 2003; Silas *et al.* 2020). Similar situations are likely to exist in other Indian Ocean rim countries.

Under-reporting of total fish catches of between 30 and 50% is a global phenomenon (Pauly and Zeller 2016), and the fisheries of the Indian Ocean are little different, with at least 25% of the ocean basin-scale catch going unreported in recent years. Although the majority of industrial catch is currently assumed to be reported, small-scale catches are heavily under-represented in the official catch-data time-series, with nearly 80% of subsistence and ~20% of artisanal catches still going unreported. The estimates presented in this synthesis indicated that in recent years ~40% of total catches in the Indian Ocean region originate from small-scale fisheries, which is substantially higher than the global average of ~25% (Pauly and Zeller 2016). Thus, small-scale commercial and non-commercial fisheries remain far more important in the Indian Ocean region than in many other areas, and industrial fisheries and their numerous and often negative environmental and social side effects have not (yet?) pervaded and affected the Indian Ocean region as much as elsewhere. Many Indian Ocean rim countries face serious challenges with food security and rely heavily on fish for local food supply (Golden *et al.* 2016; von Grebmer *et al.* 2018; Taylor *et al.* 2019). Thus, local domestic and some regionally traded catches serve as a crucial source of food and nutritional security in the Indian Ocean region, as well as for poverty alleviation in some of the poorest coastal communities in the world (De Young 2006; van der Elst *et al.* 2009; Golden *et al.* 2016; Taylor *et al.* 2019). Therefore, well-managed, locally owned and operated small-scale fisheries are crucial for the Indian Ocean region in meeting current and future food security and livelihood requirements, as well as assisting with regional growth and development (Zeller and Pauly 2019). This is especially so given the general international trade-oriented nature of many industrial fisheries, which largely supply to highly food-secure, developed-country markets outside the Indian Ocean basin.

Unfortunately, the poor representation of small-scale fisheries in nationally collected and reported data signifies a major knowledge gap, and thereby contributes to the ongoing policy, management, economic and trade marginalisation of many small-scale fishers (Pauly 2006; Food and Agriculture Organization of the United Nations 2015; Schuhbauer *et al.* 2020). The fisheries challenges for specific regions in the Indian Ocean have also been examined in several regional studies, including for the Red Sea (Tesfamichael 2016; Tesfamichael and Pauly 2016), the Arabian–Persian Gulf (Al-Abdulrazzak and Pauly 2014*a*, 2014*b*; Al-Abdulrazzak *et al.* 2015), the Bay of Bengal (Harper *et al.* 2011; Kleisner and Pauly 2011), the Arabian Sea (Palomares *et al.* 2021*a*), East Africa (Zeller *et al.* 2020), as well as Southeast Asia (Lam and Pauly 2018). Furthermore, the nine large marine ecosystems (Sherman and Duda 1999) formally defined in the Indian Ocean were examined in the global UNEP report on large marine ecosystems (Pauly *et al.* 2008). Hopefully, the clear demonstration of the importance of small-scale fishing identified in the present synthesis and the numerous other studies indicated above can contribute to more environmentally and socially sustainable fisheries within the Indian Ocean region, with a priority focus on well-managed and well-supported small-scale fisheries rather than heavily subsidised industrial fisheries. This should include supporting small-scale fisheries that prioritise the use of passive, non-damaging gears (Zeller and Pauly 2019), and the elimination of capacity-enhancing subsidies, which contribute to overcapacity and overfishing (Sumaila *et al.* 2019, 2021). Such efforts to prioritise domestically owned small-scale fisheries may require concerted policy and management efforts to shift away from viewing foreign and industrial fishing as priority sources of income and economic growth, and requires prioritising the collection of actionable fisheries data and management improvements (van der Elst *et al.* 2009).

Historically, there has been considerable uncertainty around fisheries statistics in the Indian Ocean region (Pauly *et al.* 2014; Pauly and Le Manach 2015; Pauly and Zeller 2016), contributing to low levels of stock assessments, other than for major tuna species (Moustahfid *et al.* 2019; Heidrich *et al.* 2022) and coral reef fish biomass assessments (e.g. McClanahan *et al.* 2016), and, hence, a poor state of knowledge of the biomass status and associated sustainability of stocks. Some data-limited stock assessments have been undertaken at the national level within the Indian Ocean region, for example, in India (Sathianandan *et al.* 2021) and Pakistan (Raza *et al.* 2022). Nevertheless, except for a number of high-level assessments conducted by the IOTC on a subset of IOTC-managed species (see Heidrich *et al.* 2022), comprehensive assessments of stocks in the Indian Ocean are mostly lacking. Despite the limited data available, national assessments have shown concerning results; for example, only 34% of assessed stocks in India were deemed to be sustainable (Sathianandan *et al.* 2021), and no quantification exists for the likely large number of exploited but unassessed stocks in the region. Furthermore, small-scale fisheries generally take place in coastal waters at relatively shallow depths (<200 m) and often target the same resources as industrial fisheries (Palomares and Pauly 2019). With ~90% of the global catch coming from continental shelves (Pauly *et al.* 2002), these areas may already be approaching or exceeding sustainable limits. However, limited data availability reduces the ability to undertake assessments, which is beginning to be addressed through new data-limited assessment methods (Froese *et al.* 2017, 2018, 2020) that are already providing novel insights (Palomares *et al.* 2020).

Aquaculture production of seafood is growing globally, and there is a strong interest by industry and many governments to expand such production facilities (Food and Agriculture Organization of the United Nations 2020). In the Western Indian Ocean, aquaculture is emerging as an important sector for development (Techera and Hassan 2021). However, countries in the Indian Ocean region would do well to recognise that most aquaculture operations are not a long-term viable alternative to well-managed fisheries for ensuring local food, nutritional and livelihood security (Sumaila *et al.* 2022). In many countries, unconstrained aquaculture growth has led to substantial impacts on marine ecosystems and wild fish stocks (Lebel *et al.* 2002; Ottinger *et al.* 2016), and without adequate management and control, aquaculture-driven demand can directly contribute to highly unsustainable fishing practices (Changing Markets Foundation 2019). The use of wild fish catches for fishmeal production can reduce local food supply, as ~90% of global catches that go to fishmeal production are food and even prime food-grade species (Cashion *et al.* 2017), which are often an important source of nutrients for coastal populations in developing countries (Tacon and Metian 2009; Konar *et al.* 2019). As such, very careful considerations should be given to supporting aquaculture development to prevent increasing pressure on wild fisheries resources that are vital to coastal populations (Sumaila *et al.* 2022).

Despite catches having grown since the 1950s, continued catch increases from the Indian Ocean region may not be sustainable, and all future endeavours need to also carefully consider the impacts of climate change (Moustahfid *et al.* 2019), with a particular food-security focus on the most vulnerable coastal communities and countries in the Indian Ocean (Taylor *et al.* 2019). This is already indicated by the slow-down in the rate of growth in catches since the late 1990s, especially for industrial fisheries, as clearly shown in the present contribution. Much of the increase in catches since the 1990s is the result of increasing small-scale, artisanal catches; however, many of the stocks and fishing grounds for the small-scale sector are likely to be already under intensive fishing pressure owing to the sectoral growth, the overlap with industrial fisheries and likely limited fishing grounds.

Overall, the findings of the present synthesis suggests that Indian Ocean rim countries should focus their fisheries policies on long-term domestic nutrient security, livelihood and stock sustainability and not on fisheries industrialisation or continuing economic fisheries growth targets. This requires constraining and curtailing industrial fleets, including elimination of harmful subsidies for large-scale fisheries, and supporting locally owned and operated small-scale fisheries, including for regional market access by within-ocean basin trade. Such a shift of emphasis will also require increased efforts being placed on the collection and use of small-scale fisheries-relevant data and analyses.

Supplementary material

Supplementary material is available online.

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