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PERSPECTIVE

Bycatch in drift gillnet fisheries: A sink for Indian Ocean cetaceans

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Tweetable Abstract: Cetacean bycatch in Indian Ocean gillnets is an urgent, critical conservation problem that has received considerably less scientific and policy attention than other bycatch issues.

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Abstract

In 1992, the UN banned the use of large-scale pelagic driftnets on the high seas (UNGA Resolution 46/215). Three decades later, however, drift gillnets remain one of the primary fishing gears in the Indian Ocean, accounting for approximately 30% of tuna catches in this ocean. Recent estimates indicate that several million small cetaceans have been killed in Indian Ocean gillnets over the past few decades. National agencies and the regional fisheries management organization charged with managing tuna fisheries, the Indian Ocean Tuna Commission, have yet to effectively document the bycatch of small cetaceans in these fisheries. Here, we review current information on cetacean bycatch in Indian Ocean drift gillnets and propose potential solutions to this important conservation issue.

KEYWORDS
bycatch, cetaceans, driftnets, indian ocean, marine mammals, tuna fisheries

1 | INTRODUCTION

The incidental capture of nontarget species in fisheries ("bycatch") has been described in hundreds of technical documents and the peer-reviewed literature since the 1960s. Decades later, bycatch remains the primary threat to many species of marine megafauna and is driving several small cetacean species toward extinction (Brownell et al., 2019; Read et al., 2006). One of the most well-known case studies is the dolphin-set purse seine fishery for

yellowfin tuna (*Thunnus albacares*) in the Eastern Tropical Pacific (ETP), which caused the mortality of several million dolphins during the 20th century (Ballance et al., 2021; Hall, 1998). In this region, dolphin sightings indicated the presence of tuna schools due to a close ecological association between tuna and dolphins, so fishermen often set their purse seine nets on dolphins to catch tuna[1] (Ballance et al., 2021). Public outcry was one of the primary issues that led to the passage of the first legislation focused on marine mammals—the U.S. Marine Mammal Protection Act (MMPA) in 1972 (Ballance et al., 2021). Later developments to reduce this bycatch included the implementation of market measures, such as the "dolphin-safe" tuna label requirements, and a multilateral Agreement on the International Dolphin Conservation Program. Together, these management actions significantly reduced observed dolphin mortality and are often lauded as some of the most successful attempts to reduce bycatch—although this is a unique example as the fishery *intentionally* set purse seine nets on dolphins to capture tuna (Ballance et al., 2021).

Here, we highlight another cetacean bycatch issue that is comparable in scale to the ETP purse seine fishery in terms of dolphin mortality, but which has generated relatively little policy or scientific attention (Anderson et al., 2020). In the Indian Ocean, over 4 million cetaceans are estimated to have been killed in pelagic drift gillnets ("gillnets") targeting tuna and tuna-like species between 1950 and 2018, peaking at 100,000 cetaceans per year from 2004 to 2006 (Anderson et al., 2020). Despite scattered and incomplete data, the evidence suggests that cetacean bycatch levels in tuna gillnet fisheries may not be sustainable (Anderson et al., 2020; Kiszka et al., 2021). Our knowledge of bycatch, fishing effort, and even the catch of targeted species in Indian Ocean tuna gillnet fisheries is fragmented. In addition, there is very little information on the distribution, abundance, population structure, and demography of most cetacean species in the Indian Ocean, information necessary to assess the population-level impacts of bycatch. Here, we summarize available knowledge of bycatch, catch, and governance for the Indian Ocean tuna gillnet fisheries and then propose four action items to address this conservation issue.

2 | BACKGROUND

Indian Ocean tuna fisheries boast the second-largest tuna production in the world, contributing to approximately one-fifth of global production (International Seafood Sustainability Foundation, 2021). The Indian Ocean Tuna Commission (IOTC), one of five tuna regional fisheries management organizations, oversees these fisheries. The IOTC's 30 Commission Contracting Parties ("Members") conduct multilateral science and negotiate management measures for 16 tuna and tuna-like species in the region's fisheries,[2] as well as consider ecosystem and bycatch impacts of these fisheries.

2.1 | Regional governance

A suite of negotiated Conservation and Management Measures (CMMs) form the backbone of IOTC fisheries management.[3] These CMMs set the rulebook for target-species catch limits, reporting of bycatch occurrences, observer coverage, and other requirements (Table S1). A critical issue is that many IOTC measures do not apply to vessels (including those for which gillnets are the primary gear) less than 24 meters (m) in length overall (LOA) fishing in Exclusive Economic Zones (EEZs) (Table S1). Many of these same vessels are not subject to robust national reporting nor a requirement to use Automatic Identification Systems, rendering their fishing effort and catch poorly understood at the national level, too (WWF, 2020).

Classification of fishing vessels in the IOTC carries important implications for data reporting and observer coverage (Table S1). The IOTC categorizes vessels as "artisanal" if they are under 24 m LOA and fishing in EEZs (Resolution 19/04). The IOTC recently developed voluntary, finer-scale reporting options than previously available for gillnet vessels as "artisanal," "semi-industrial," or "industrial" based on the type of boat (i.e., motorized, non-motorized; inboard or outboard engine), boat size, and area of operation (IOTC, 2022a). This works toward gathering more information on gillnet vessels in the IOTC Area of Competence, but all publicly available data are still currently reported as either "artisanal" or "industrial" (IOTC, 2023; IOTC, 2022a).

Of direct relevance to cetaceans is Resolution 23/06, a measure that was adopted at the 2023 IOTC annual

[1] Note: While this is a multinational fishery, this particular method of setting on dolphins originated in the U.S.-flagged fleet (Gosliner, 1999).

[2] Note: For the purposes of this paper, we use the term "tuna fisheries" to refer to gillnet fisheries targeting the 16 tuna and tuna-like species (e.g., billfish and seerfish) managed by the IOTC. These managed species are: yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*), bigeye tuna (*Thunnus obesus*), Albacore tuna (*Thunnus alalunga*), Southern bluefin tuna (*Thunnus maccoyii*), longtail tuna (*Thunnus tonggol*), kawakawa (*Euthynnus affinis*), frigate tuna (*Auxis thazard*), bullet tuna (*Auxis rochei*), narrow barred Spanish mackerel (*Scomberomorus commerson*), Indo-Pacific king mackerel (*Scomberomorus guttatus*), blue marlin (*Makaira nigricans*), black marlin (*Makaira indica*), striped marlin (*Tetrapturus audax*), Indo-Pacific sailfish (*Istiophorus platypterus*), and swordfish (*Xiphias gladius*).

[3] All IOTC CMMs can be accessed via the current compendium of active CMMs: https://iotc.org/cmms.

meeting and provided an update on Resolution 13/04, previously adopted in 2013. This measure requires Members to report, through logbooks or observer coverage, details of any capture or entanglement of cetaceans to the relevant authority of the flag state and take all reasonable steps to ensure the safe release of any entangled cetaceans. However, the measure does not apply to artisanal fisheries operating in EEZs; there have been few reported interactions per this measure (IOTC, 2022c); and its efficacy in reducing cetacean interactions is not understood, although artisanal fisheries are encouraged to report any interactions with cetaceans to the relevant Member authority and immediately release the animal.

Other conservation measures have prompted formal objections from certain Members, which render them exempt from the requirements. For example, Pakistan objected to Resolution 17/07, which prohibits the use of driftnets longer than 2.5 km, in congruence with UN General Assembly Resolution 46/215, in the entire IOTC Area of Competence, including the high seas and EEZs. This objection means that Pakistan may continue to use large-scale driftnets within its EEZ. Another recent, interim conservation measure requires IOTC Members to set gillnets 2 m below the water surface by 2023 (Resolutions 21/01 and 19/01) to reduce small cetacean and other nontarget bycatch, among other requirements for yellowfin tuna catch limits. Recent studies have indicated that this measure may help to reduce the bycatch of some taxa in Pakistan (Kiszka et al., 2021), including small cetaceans, but some of the primary gillnetting nations—India, Indonesia, I.R. Iran, Oman, and others—objected to the measure, because of catch limits and other requirements related to yellowfin tuna harvest.

2.2 | The tuna gillnet fishery

In the Indian Ocean, tuna gillnet fishing is widespread both on the high seas and in EEZs (IOTC, 2023). Between 2000 and 2020, the highest average gillnet catches (tons) were reported by I.R. Iran, India, Indonesia, Pakistan, and Sri Lanka (IOTC, 2023). Over half of IOTC Members fish with gillnets, but these five countries alone were responsible for approximately 85% of the total gillnet catches in the Indian Ocean since 2000 (IOTC, 2023).[4]

Gillnets are an attractive gear because their use does not require sophisticated equipment or bait, and they can, therefore, be operated relatively inexpensively. They are typically deployed overnight and are unselective—they entangle any large-bodied organism, such as whales, dolphins, sea turtles, large fish, and sharks. Gillnets are widely recognized as the most dangerous fishing gear for cetaceans (Brownell et al., 2019; Northridge et al., 2017; Roberson et al., 2022).

Pelagic gillnets catch over a third of the tuna harvest managed by the IOTC, and catches have been increasing (Anderson et al., 2020). This is unusual in two respects. First, gillnets are responsible for the greatest proportion of total catch of tuna in the Indian Ocean, unlike other regions where purse seines and longlines dominate tuna fisheries (Miyake et al., 2010). Second, most Indian Ocean tuna gillnet fisheries are considered "artisanal," although some of their characteristics, such as vessel length and inboard motorization, posit them toward the "semi-industrial" category (IOTC, 2022a). In 1992, the UN banned large-scale driftnets (over 2.5 km in length) on the high seas (Resolution 46/215). Gillnet use continues to increase in the IOTC area, but it is unlikely that artisanal or semi-industrial vessels would violate the ban given their vessel length and ability to carry gear of that length.

Furthermore, we have only a vague understanding of how many gillnet vessels operate in the Indian Ocean. In the past 5 years (2016–2020), only three countries (Indonesia, I.R. Iran, and Sri Lanka) have registered gillnet vessels with the IOTC—possibly because only vessels fishing on the high seas are required to be registered (IOTC, 2022b).

2.3 | Cetacean bycatch

Underreporting of cetacean bycatch is a pervasive problem in the Indian Ocean, particularly for gillnets. The IOTC database contains 143 records of cetacean bycatch between 1996 and 2022—but only from scientific observers onboard pelagic longline vessels (IOTC, 2022c). To date, no bycatch records for any species in gillnets have been reported to the IOTC (IOTC, 2022c), although such bycatches are common according to the available literature (e.g., Anderson et al., 2020; Kiszka et al., 2021). A recent ecological risk assessment concluded that gillnets pose the highest risk to cetaceans compared to longlines and purse seines, with multiple cetacean species at risk particularly in the Indian Ocean (Roberson et al., 2022).

While there are limited official bycatch records reported to the IOTC from fisheries using any gear and particularly gillnets, the existing scientific literature on cetacean bycatch in Indian Ocean tuna gillnet fisheries suggests that bycatch is very high (Anderson et al., 2020; Kiszka et al., 2021). Existing information largely stems from outdated national records based on port sampling or mitigation

[4] Note: The figures reported in this sentence are specifically for catch from "gillnets," "gillnet operated attached," and "offshore gillnets" as reported to the IOTC (IOTC, 2023). The IOTC recently updated gear classifications so Members can now report catch under driftnets, but it is currently unknown how many IOTC Members specifically employ driftnets.

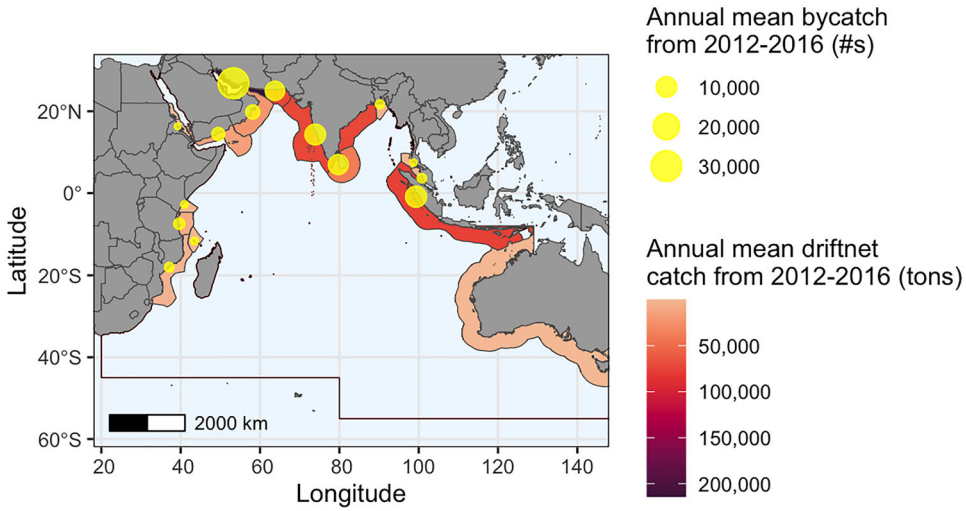

FIGURE 1 Annual mean gillnet target catches (tons) reported to the IOTC from 2012 to 2016 overlaid with annual mean estimated cetacean bycatch from 2012 to 2016 as reported in Anderson et al. (2020) for the IOTC Area of Competence. *Note*: Figure 1 depicts annual mean retained catches (t) from 2012 to 2016 for "gillnets," "gillnet operated attached," and "offshore gillnets" by IOTC Members reported in the IOTC nominal catch database as of April 11, 2023, overlaid with cetacean bycatch estimates reported in tab. 2 of Anderson et al. (2020). The figure depicts bycatch and catch in EEZs only, but fishing and bycatch occur outside EEZs, although spatial information is unavailable. FAO (2023) and Flanders (2019) provided the IOTC and EEZ shapefiles used in this image, respectively.

trials that have been extrapolated to regional bycatch estimates (e.g., Anderson et al., 2020). For example, Yousuf et al. (2009) estimated cetacean bycatch in gillnets in India to be around 9000 individuals between 2004 and 2005, and Kiszka et al. (2021) estimated bycatch in Pakistan gillnets set at the surface level to be around 8411 individuals per year. Please see Anderson et al. (2020), tab. 1, for additional estimates by country. The limited available information suggests countries with the highest cetacean bycatch are those with the highest gillnet tuna catches (Anderson et al., 2020; Figure 1). The estimates of 100,000 individuals killed per year (Anderson et al., 2020) were derived from small samples and limited information, and thus contain a considerable degree of uncertainty, but they are supported by other independent analyses (Kiszka et al., 2021).

We are unable to estimate the population-level impact of bycatch mortality due to the dearth of information on affected populations. The last major marine mammal survey of the entire Arabian Sea area was conducted in 1998, although the International Whaling Commission (IWC) is liaising with local networks to review available data on populations of Indian Ocean cetaceans (IWC, 2021). It is important to acknowledge that research is expanding in the Indian Ocean. As two examples, the Arabian Sea Humpback Whale Network (ASWN) is a consortium that conducts research on the Arabian Sea humpback whale population and other species through photo-identification, genetic sampling, and marine mammal stranding response (e.g., Minton et al., 2023). The Indian Ocean Network for Cetacean Research (IndoCet) brings together cetacean researchers in the southwest Indian Ocean, develops collaborative research initiatives ranging from extensive photo-identification to tagging projects, while also serving as a research repository (IndoCet, 2023).

Despite this, information on population structure and abundance estimates are lacking for almost all whales, dolphins, and porpoises in the northern Indian Ocean, where the highest concentration of gillnet use occurs.

3 | CURRENT PROGRESS

The Food and Agriculture Organization of the United Nations (FAO) developed a global set of voluntary marine mammal bycatch reduction guidelines in 2021 (FAO, 2021), providing a foundation to address cetacean bycatch in the Indian Ocean. The IOTC has been addressing bycatch through its Working Party on Ecosystems and Bycatch, with assistance from the IWC's Bycatch Mitigation Initiative (IWC BMI). In 2023, the IOTC endorsed an agreement for enhanced bycatch cooperation with the IWC to foster initiatives to reduce cetacean bycatch in Indian Ocean tuna fisheries (IOTC-IWC, 2021). In collaboration with the IWC Scientific Committee, the IWC Secretariat has launched an initiative to identify and document available information on the status of cetacean populations in the Indian Ocean. This effort is a critical part of assessing the impact of cetacean bycatch on these populations.

The United States recently implemented Import Provisions under the MMPA, requiring over 100 fishing nations,

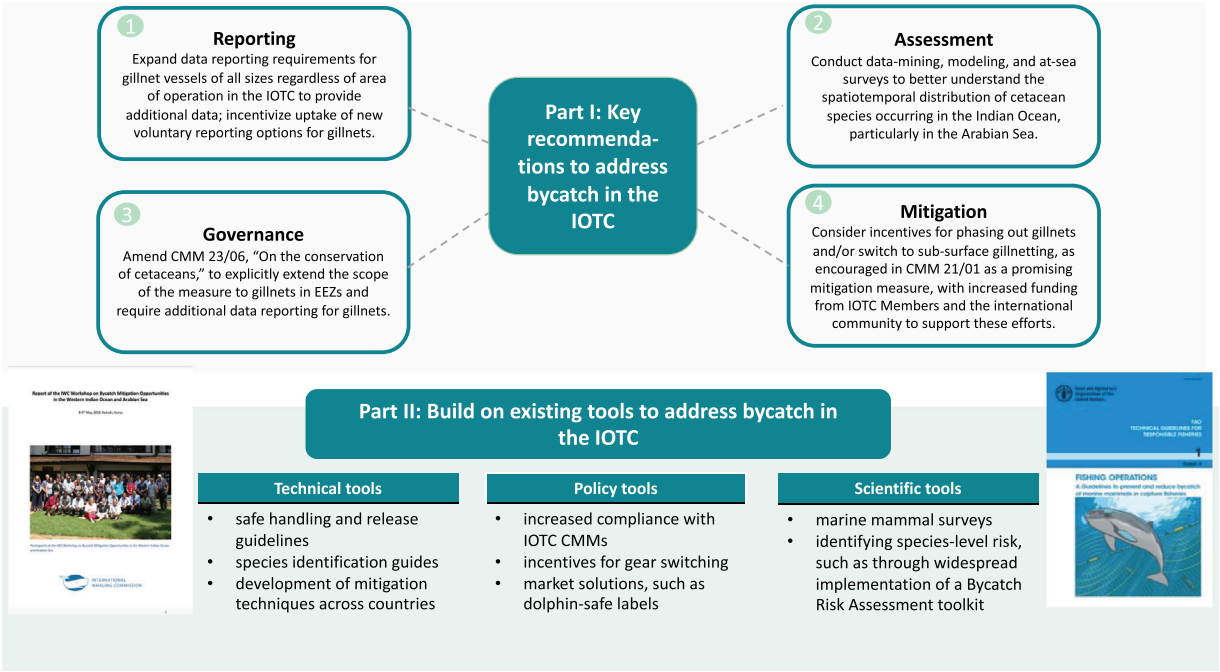

FIGURE 2 Recommended solutions and existing tools through the FAO and IOTC/IWC Bycatch Mitigation Initiative to address cetacean bycatch.

including most IOTC Members, to demonstrate that their marine mammal bycatch regulatory programs are "comparable in effectiveness" to those in the United States (81 FR 54389; Bering et al., 2022; Johnson et al., 2017; Williams et al., 2016). This Rule, which is expected to fully take effect by 2026, offers an additional, market-based incentive to develop bycatch mitigation policy at national levels, but it is unclear how countries with low levels of technical capacity will be able to meet these provisions (Bering et al., 2022). The full impacts of these Import Provisions on cetacean bycatch in gillnet fisheries in the Indian Ocean are yet to be determined.

3.1 | Recommendations

Several practical, low-cost solutions are available to reduce cetacean bycatch through gear modification or alternative deployment of existing gear. For example, subsurface gillnet trials have been successful at reducing cetacean bycatch in Pakistani gillnet fisheries without a large reduction in target species catch (Kiszka et al., 2021). Building on previous work (Figure 2), we make four specific recommendations to strengthen scientific knowledge and management:

1. **Reporting:** improve catch and bycatch reporting at the IOTC through two primary pathways: First, require registration and reporting of catch, bycatch, and fishing effort for gillnet vessels under 24 m in length fishing within EEZs via modifications to Resolutions 19/04 and 15/02. Second, encourage the voluntary reporting of more information (e.g., inboard or outboard engine; reporting driftnets distinctly from other types of gillnets) in gillnet fisheries to enhance understanding of gillnet fisheries in the IOTC, particularly under the new voluntary reporting scheme proposed by the IOTC Secretariat in November 2022 (IOTC, 2022a). Additionally, if more fleets transition into subsurface gillnetting, as successfully demonstrated in Pakistan, reporting specifications for gillnet set depth in Resolutions 15/01 and 15/02 will enhance assessment of the efficacy of this mitigation measure. As is currently done, the IOTC Secretariat should manage and analyze this information.
2. **Assessment:** increase knowledge of cetacean species' occurrence, distribution, and abundance to assess the impact of bycatch on these populations. Specifically, we recommend two pillars geared toward the research community: (a) conducting detailed studies on species-specific occurrence, distribution, and abundance; and (b) connecting and leveraging existing research throughout the region that has provided a strong platform for collaboration. Indeed, while information is lacking for most species in the region, there are multiple organizations conducting research, monitoring, and management in the Indian Ocean (e.g., IndoCet in the southwestern Indian Ocean; ASWN

in the northern Indian Ocean and the Arabian Sea; WWF Pakistan leading mitigation trials in Pakistan), as well as marine biodiversity conservation more generally (Western Indian Ocean Marine Science Association). We encourage collaboration and information sharing among these groups—perhaps facilitated by the IOTC at a future Working Party on Ecosystems and Bycatch meeting—to share knowledge, identify priority information gaps, and develop future research directions.

3. **Governance and compliance:** revise the conservation measure adopted to address the bycatch of cetaceans in IOTC fisheries (Resolution 23/06) to include additional reporting for gillnets operating in EEZs, rather than just on the high seas, as well as requirements for safe handling and release (now voluntary). While changes made at the IOTC (2023) annual meeting of the Commission improved reporting requirements for all gear types among other additions, gillnets remain poorly documented particularly in EEZs. For both this recommendation related to Resolution 23/06, and for the first recommendation on improved reporting, improved compliance among Member states for all existing CMMs will strengthen governance and monitoring, too.
4. **Mitigation:** expand the use of mitigation methods across tuna gillnets in the Indian Ocean. Setting gillnets 2 m below the surface has proven to be an effective mitigation measure in Pakistan (Kiszka et al., 2021), but more research is needed to test the measure in other countries, trial other mitigation measures (e.g., trial the use of artificial lights as visual deterrents), and develop alternative gear adapted to local conditions to allow communities to phase out the use of gillnets in the Indian Ocean (e.g., transitioning to longline fisheries). Incentives and fisher engagement are vital parts of these trials and transitions to new mitigation measures, which could include monetary or in-kind compensation (as was done in the Pakistan mitigation trials), market incentives such as achieving seafood certifications such as Seafood Watch (albeit less likely in this context of tuna gillnet fisheries as compared to certifications for purse seine or longline-caught tuna catch in the Indian Ocean), investment in technology changes, and many others (e.g., Lent et al., 2022). This will require significant funding from Members and the international community to support mitigation trials and consideration of incentives.

4 | CONCLUSION

Cetacean bycatch in the Indian Ocean tuna gillnet fishery is very high and may not be sustainable for some species, particularly in the northern Indian Ocean (Anderson et al., 2020). Our ability to monitor and mitigate bycatch in the Indian Ocean is hampered by widespread data gaps and insufficient management measures, enforcement, and compliance (Anderson et al., 2020; Kiszka et al., 2021). Overall, cetacean bycatch remains understudied and poorly understood, particularly compared with fisheries in other oceans. The tuna-dolphin issue (Ballance et al., 2021) and other bycatch case studies—such as the progressive reduction of harbor porpoise bycatch in the U.S. New England sink gillnet fishery after implementation of mitigation measures such as acoustic alarms and time-area closures (Read, 2013)—demonstrate that practical measures to reduce cetacean bycatch can be implemented with the proper tools, policies, and political will. The collaborative work already undertaken by the IOTC and IWC has set a strong foundation and holds significant promise for the development of further actions to address this critical issue in the Indian Ocean.

AUTHOR CONTRIBUTIONS

Conceptualization: BE, AJR, and JJK. Visualization: BE. Writing—original draft: BE. Expertise and supervision: SB, RL, JJK, US, and LN. Writing—review and editing: SB, RL, JJK, US, LN, and AJR.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DISCLAIMER

These views represent the views of the authors and are not the official views of the IWC or the IOTC.

DATA AVAILABILITY STATEMENT

The paper generated no original data, but rather summarized data cited in Anderson et al. (2020), IOTC (2023),

Flanders Marine Institute (2019), and FAO (2023). Code for Figure 1 can be accessed online via: https://github.com/Bwe9403/IOTC_Elliottetal_2023paper.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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